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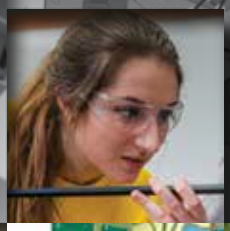
Solutions

VANDERBILT SCHOOL OF ENGINEERING
Nashville, Tennessee
JUNE 2020



ATTACKING COVID-19's many complex challenges

REPRODUCING SIMULATIONS to advance molecular modeling

4D PRINTING THERMITE for unusual welding sites

THE design ISSUE

This issue of Solutions is dedicated to the Class of 2020. Your undergraduate experience ended in an unexpected and unprecedented way. Your resilience carried you across the finish line to join the global community of Vanderbilt alumni, of which you will always be a part. Congratulations from the faculty, staff and alumni of the School of Engineering.

Front cover design by Tim Kovick of Corporate Design.

Back cover photo/John Russell/Vanderbilt

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Responding to COVID-19 challenges

Diverse projects highlight depth of talent and desire to make a difference

Engineers solve problems, and the novel coronavirus and the global pandemic it spawned present no shortage of complex ones. With intensity and innovation, the Vanderbilt engineering community—faculty, students, staff and alumni—has responded.

The projects span physical size, from designing an open-source mechanical ventilator to investigating individual proteins of the virus in search of vaccine targets. They span time, from making face shields and masks to protect front-line workers now to using mosquitoes to track and predict outbreaks in the future.

The work spans departments and sub-disciplines. It involves collaboration with clinicians, corporations and colleagues across campus, showcasing the breadth of 21st Century engineering.

Vanderbilt engineers are involved in at least 20 separate COVID-19-related projects. **Take a look at a few of them.**

Durable masks

For more than eight weeks, two 3D printers at the Vanderbilt Biophotonics Center ran around-the-clock, printing protective masks rather than prototyping components for custom optical instruments. While access to campus was restricted, researchers programmed the printers remotely. Bryan Millis, a research assistant professor in the biophotonics center, collected the printed masks and reloaded printer filament when he checked on the equipment every few days. Their design allows a paper surgical mask to be cut up into six pieces to be used as inserts in the printed masks. Millis and colleagues used a model developed and tested by a clinic in Montana earlier this year. The Montana Mask is a community model; creators made the specifications freely available to help fill the gap in personal protective equipment. The team printed more than five dozen masks for local non-profit groups as well as biophotonics center researchers.

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Protein folding

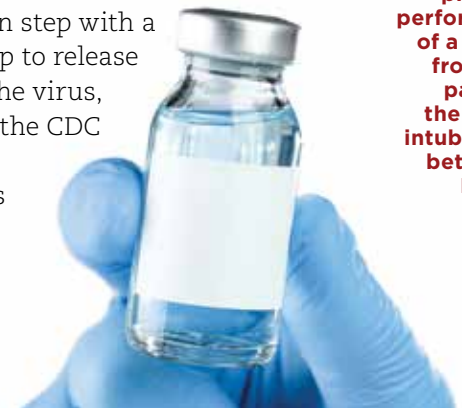
The Biophotonics Center joined the largest distributed supercomputing project in the world. "Folding" refers to how proteins assemble themselves into particular shapes to do their work. Folding@Home uses the power of more than 1 million individual computers to run molecular dynamics simulations and identify potential binding sites for drugs and antibodies. Now it's targeting SARS-CoV-2. VBC has high-power workstations typically used for analyzing large data sets; with researchers off campus for 10 weeks, that computational power was used by Folding@Home. Even now the program runs in the background.

Patient support

E. Bronson Ingram Distinguished Professor of Engineering Janos Sztipanovits is at work on a customizable and adaptable smart phone application that supports patients at home with mild COVID-19 symptoms. Key services GUARD would monitor include the appearance of emergency signs, sending patient specific guidance and reminders, managing the treatment of symptoms, and advising the patient when to end home isolation or request hospitalization. The work builds on the results of earlier efforts and can be rapidly implemented.

Quick test

A team of biomedical engineers that developed quick diagnostic tests for malaria and tuberculosis elegantly pivoted to the virus causing COVID-19. In an unpublished study of 200 residual samples from VUMC patients the technique detected the RNA of the virus in more than 95 percent of the positive samples and correctly identified 100 percent of the negative samples, said Nicholas Adams, research assistant professor of biomedical engineering. A manuscript detailing findings in the small study is under review and expected to be published soon. The team, led by Professor of Biomedical Engineering Frederick Haselton, focuses on developing diagnostic and other health care technologies for patients and physicians in low-resource settings. In other studies, it has successfully detected tuberculosis in urine, malaria in blood and flu in viral transport medium. "Based on the observation that our flu test worked without RNA extraction using similar enzymes and ingredients, we replaced the cumbersome RNA extraction step with a simple heat step to release the RNA from the virus, using the rest of the CDC test workflow, and showed that it works very well without it," Adams said.



A four-sided fabricated enclosure protects doctors and nurses performing endotracheal intubation of a patient, helping shield them from droplets expelled by the patient with COVID-19. Like the open-source ventilator, the intubation box was a collaboration between VUMC and Vanderbilt Institute for Surgery and Engineering.

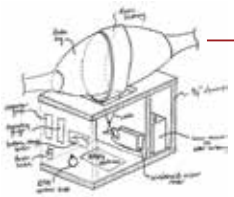
Anatomy of innovation

From a napkin sketch to 100 ventilators in 5 weeks.

Great ideas may flash all at once, in the middle of the night or while driving a car. Often, though, innovation works like this:

Duke Herrell, a professor of urologic surgery at Vanderbilt University Medical Center called Robert Webster, a frequent collaborator and Richard A. Schroeder Professor of Mechanical Engineering, as COVID-19 pandemic cases in the U.S. began to skyrocket. Health care providers faced shortages of ventilators. Patients with serious cases of the disease needed help to breathe, and the global shortage already was clear.

Webster called Eric Barth, who suggested talking with Kevin Galloway, Vanderbilt Director of Making. Barth and Galloway also are mechanical engineers. The goal was to design and build an open-source ventilator out of readily available materials, such as plywood, drawer glides and windshield wiper motors. That was March 21, 2020.



MAR 21
Idea sketched onto a napkin

MAR 22
First prototype assembled, team expands to include several graduate students

MAR 23
Second prototype assembled, more physicians and graduate students join the team

MAR 24-27
Sensors and controls implemented, testing conducted with respiratory training mannequin, Nissan USA donates five windshield wiper motors

MAR 28
Version 3 prototype finished

MAR 29
George P. Johnson, Inc., volunteers to assist with fabricating plywood pieces, FDA approval efforts initiated

MAR 30-APR 3
Second copy of V3 design fabricated, long-term running tests initiated, clinical discussions continue, first animal study conducted, Nissan donates 100 wiper motors, Make Nashville joins the team as a fabrication facility

APR 4-8
Breathing-assist tested and integrated, alarms and mechanical safety features integrated, four-hour animal study succeeds with no complications or adverse events

APR 9-12
Fabrication commences on 100 units

APR 17-19
First fully integrated V4.0 units assembled with on-board controls and improved safety features at Make Nashville.

APR 22
A fully integrated 4.0 system with on-board control has been running for 96 hours straight with no issues

APR 23
Emergency Use Authorization application submitted to the FDA

The team has received inquiries from across the globe, particularly from physicians in resource-strained countries.

Design and system specifications, as well as a GitHub repository with the full firmware code, for the Commodore Open-source Ventilator, or COV, are available at **https://vandyvents.com**

Disease prediction

A specialized drone spots its target, swoops down and grabs it. The drone is after mosquitos because a sated mosquito has much to tell us, including what it bit and what pathogens the host carries. The goal is to analyze viruses and microbes to identify disease threats early. It is estimated that 60-75 percent of emerging infectious diseases are caused by pathogens that jump from animals to people. Combining robotics, genomics and big data collection was the idea of computer scientist Ethan Jackson, Ph.D.'07, who is Senior Director and Principal Researcher at Microsoft Healthcare. Jackson directs Microsoft Premonition, which conducted successful proof-of-concept tests in West Africa, the Caribbean and Texas through an industry-academia collaboration. The Vanderbilt Institute for Software Integrated Systems led the academic track, and Microsoft is ramping up for a large-scale pilot that also will involve industry and academic partners.

Making face shields in an auto industry plant and living rooms

After a med school resident asked Katy Riojas how the School of Engineering could help with shortages of personal protective equipment, Riojas spent a week looking at designs and efforts elsewhere. She found a design that used everyday materials including adhesive foam weather-stripping, elastic bands, and transparency sheets or binder covers. The shields could be made at home in about a minute apiece. Within another week Riojas, a mechanical engineering Ph.D. student, and a crew of volunteers had made 1,000 face shields. "Vanderbilt is unique in that engineering faculty and students and clinicians are very intertwined, and there's a lot of feedback in both directions, which makes innovation really fun," she said.

At the same time, a different production line was taking shape across the state. Britt Autry, BE'92, and other engineers at DENSO Manufacturing Tennessee, Inc., brainstormed how the company could pivot from auto parts to personal protective equipment for hospitals in need. Within a day, they had their initial prototype and spent a week working through seven design iterations with input from nurses at the nearby Blount Memorial Hospital in Maryville, Tennessee. DENSO had requests from regional hospitals for more than 50,000 shields–all the company donated.

Meeting the challenge

The 2020 spring semester has proven to be one of the most challenging in Vanderbilt's history. The university in March made the wise decision to suspend on-campus operations, which are complex under normal circumstances. For research labs, this proved exceptionally challenging. How do we continue to perform at a high level without being in our labs or working face-to-face with our colleagues, collaborators, and students? Could we continue to advance our work without the usual creative collisions that make teaching and research so valuable? In short, yes! Teaching, mentoring and those all-important collisions of ideas still happened.

Now, our city is beginning to return to work, and our researchers and graduate students are ramping up research activity on campus. The prevailing theme is safety. As the professional engineer's code of ethics states, the safety of our public is paramount. The city of Nashville and the university have complementary plans for phased reopening. The university's plan is tailored to Vanderbilt's unique density, operations and other considerations as a residential, research and educational institution. The first phase of the Return to Campus Plan began Monday, May 18, for on-campus research activities that cannot be conducted remotely. Provided everything goes well, subsequent phases will occur in a carefully planned way.

From COVID to copper to crowdfunding

Three students in Class of 2020 launch company to make antimicrobial phone cases

Not long after thinking copper-based cell phone cases could help protect users from COVID-19, a trio of recent Vanderbilt graduates was in business—even if that wasn't the original plan.

Their crowd-sourced Indiegogo campaign exceeded its goal by 50 percent, collecting about $15,500. Aeris, Inc., the company they formed, had agreements with overseas suppliers for materials and a California company to assemble the cases. An intellectual property attorney was preparing a preliminary U.S. patent application for the team's new process of applying copper. Potential sources of more traditional startup investment, including people in the copper industry, wanted to talk.

"There was far more interest than we were expecting and a real opportunity to turn this into a business," said Isaac Lichter, BS'20, an engineering science major.

Aeris, a Latin word for copper, started as something to do while two of the three founders quarantined at home with mild cases of COVID-19 in spring 2020. Research led them to the antimicrobial properties of copper, and they brainstormed. With cases of COVID-19 escalating and news reports of health care workers sanitizing their phones multiple times a day, a truly "virus-killing" device case seemed a no-brainer, Lichter said.

They used the garage at their off-campus home to begin prototyping. The first iteration involved electroplating solid copper, which was quickly deemed impractical. Copper oxidizes quickly, can block radio and wireless signals, and alone is not durable enough for mobile phone protection. The final product uses an alloy with 70 percent copper and a separate thin layer that creates a barrier between the phone and the alloy.

By mid-May Aeris Copper had orders for 400 units, not including 250 to be donated to health care workers at Vanderbilt University Medical Center. Lichter handles the production, sourcing, manufacturing, design and other engineering aspects of the process. Andrew Medland, BA'20 who majored in medicine, health and society, is head of operations, philanthropy, social media and other marketing channels. Nick O'Brien, BA'20, an economics major, is in charge of public relations, finances, website design and all things digital.

The first orders are expected to ship in early June. Help from the Vanderbilt alumni network made it possible to jump from idea to delivery in about three months. Such connections not only saved vital time but also helped avoid some up-front costs.

"I've been shocked how willing people are to help us and believe in us," Lichter said. "I wish I had realized sooner the weight that the alumni network carries."

Robotics Team digs the Moon

As excavators go, 1 meter long and ½-meter wide and high is not that large. Adding controls to operate it remotely, wheels to take it to and from a dig site and a bucket to dig at least 30 centimeters beneath a simulated lunar service makes it feel even smaller.

Hello, design constraints. Specs for NASA's RMC: Lunabotics 2020 reduced the maximum size of the robotic digger by one third in all directions from the prior year. The Vanderbilt Robotics Team was undeterred, entering the national contest for the third year. The organization is in its fourth year.

About 40 engineering undergraduates met three times a week to design, build and program the robot.

Andrew Mathias, a rising senior in electrical engineering, downsized the control box after researching and finding better connectors. Sophia Viner and Katherine Yuhe, rising sophomore and junior mechanical engineering majors, respectively, were among those who got hands-on machining experience. Fifteen students handled programming. And keeping everyone on task fell to Stephanie Schroth, a rising senior in mechanical engineering and president of Vanderbilt Robotics. In doing so, Schroth realized how much she enjoyed project management.

The team stopped only after NASA scrapped the mission in March 2020, citing concerns about transmission of COVID-19. But the work was far from wasted.

Everything is documented, so the next team, which will include some members for a third year, does not start from scratch.

Top: Sophia Viner, left, and Katherine Yuhe, right, machine components for the Robotics Team's moon digger.
Left: The Vanderbilt entry in the 2019 NASA challenge was designed to take samples from the surface of Mars.
Bottom foreground: Jonathan Dwiyono, a rising BME sophomore, works on the electronics.
Photos: Anne Rayner/Vanderbilt

Student input gives Fleming Yard new form and function

Good design starts with questions.

What do you think are the biggest problems regarding waste facing the campus? Where do you spend most of your non-class time on campus? If you were to study outside, what kind of place would attract you? What would you like to do in Vanderbilt's outdoor spaces that is difficult or impossible?

Civil engineering undergraduates posed these and other questions to student peers as they gathered information for a redesign of Fleming Yard. Few even knew what and where Fleming Yard was.

They do now.

Fleming Yard, located between Alumni Lawn and Sarratt Student Center, has had an impressive upgrade.

Common themes emerged through the student interviews—accessible spaces suitable for studying, eating, observing and performing, functionality for events at night as well as during the day, and some protection from the weather.

The Vanderbilt Division of Administration had partnered with Lori Troxel, professor of the practice of civil and environmental engineering, to include students in the planning process for creating and maintaining sustainable, accessible and park-like environments across campus. The deeper look at Fleming Yard came during Troxel's 2018 class on sustainable design and became the DIVE (Design as an Immersive Vanderbilt Experience) project for class members.

The updated space was rededicated in November 2019.

"Now, many students say it is their favorite place on campus," Troxel said. "Our students studied energy, storm water and waste solutions to optimize the sustainability and accessibility of the space," Troxel said. "Their energetic work drove tangible solutions that most of them would be able to see and use."

The park-like setting features recycled plastic decking and furniture, accessible pathways and routes, a hydration station for filling reusable water bottles, LED lighting, speakers for outdoor events and a fountain sculpture supplied by a storm water capture and filtration system.

Jerom Theunissen, BE'18, was among the students who worked on the project.

"With our proposal, we wanted to check all these boxes, by includ-

The updated Fleming Yard gives students seating options, a raised walkway and a working example of storm water capture.
Top left: The arched water feature, which reuses storm water, repeats the shape of windows and doors of new campus residence halls.
Top right: Acting Chancellor and Provost Susan Wente shares the history of Fleming Yard and its revamp at the dedication event in November 2019. Photos: Joe Howell/Vanderbilt

ing a stormwater centerpiece, stage area, study area, eating area, diverse seating types, and canopy and string lights," he said.

Fleming Yard was named for Samuel Milton Fleming, BA'28, who served on the Vanderbilt University Board of Trust from 1952 to 1981, including as chairman from 1975 to 1981. Fleming Yard was created in 1988 through a gift from his daughter, Emerita Trustee Joanne Fleming Hayes, BA'68, who served on the Board of Trust from 1997 to 2015. The outdoor space's current revitalization also was supported by Hayes, who attended the re-dedication ceremony.

Theunissen, who works at Easterseals in Chicago on the National Center for Mobility Management project, couldn't attend the ceremony but saw the transformation when he visited campus in December 2019.

"I was pleased to find many of the elements we recommended in the design incorporated," he said. "It was a fantastic opportunity being able to transform a space on campus that will be used by students, faculty and staff for years to come."

Software suite expedites reproducible computer simulations

Science moves forward when researchers verify their and others' results.

"Reproducibility in scientific research is a prominent issue, and molecular simulations, which play an important role in many subfields of science and engineering, pose particular computational challenges," said Peter Cummings, associate dean for research and John R. Hall Professor of Chemical Engineering.

To address the challenges, Cummings, Clare McCabe and their colleagues in the Multiscale Modeling and Simulation group and computer scientists, particularly Akos Ledeczi, in Vanderbilt's Institute for Software Integrated Systems, developed a robust suite of open-source software tools. The Molecular Simulation and Design Framework (MoSDeF) expedites reproducible computer simulations.

Reproducibility is an essential part of the scientific method. But a crisis of reproducibility, and hence confidence, gained currency over the last decade as disappointing results emerged from large-scale projects to reproduce studies in some medical and science fields.

Peter Cummings

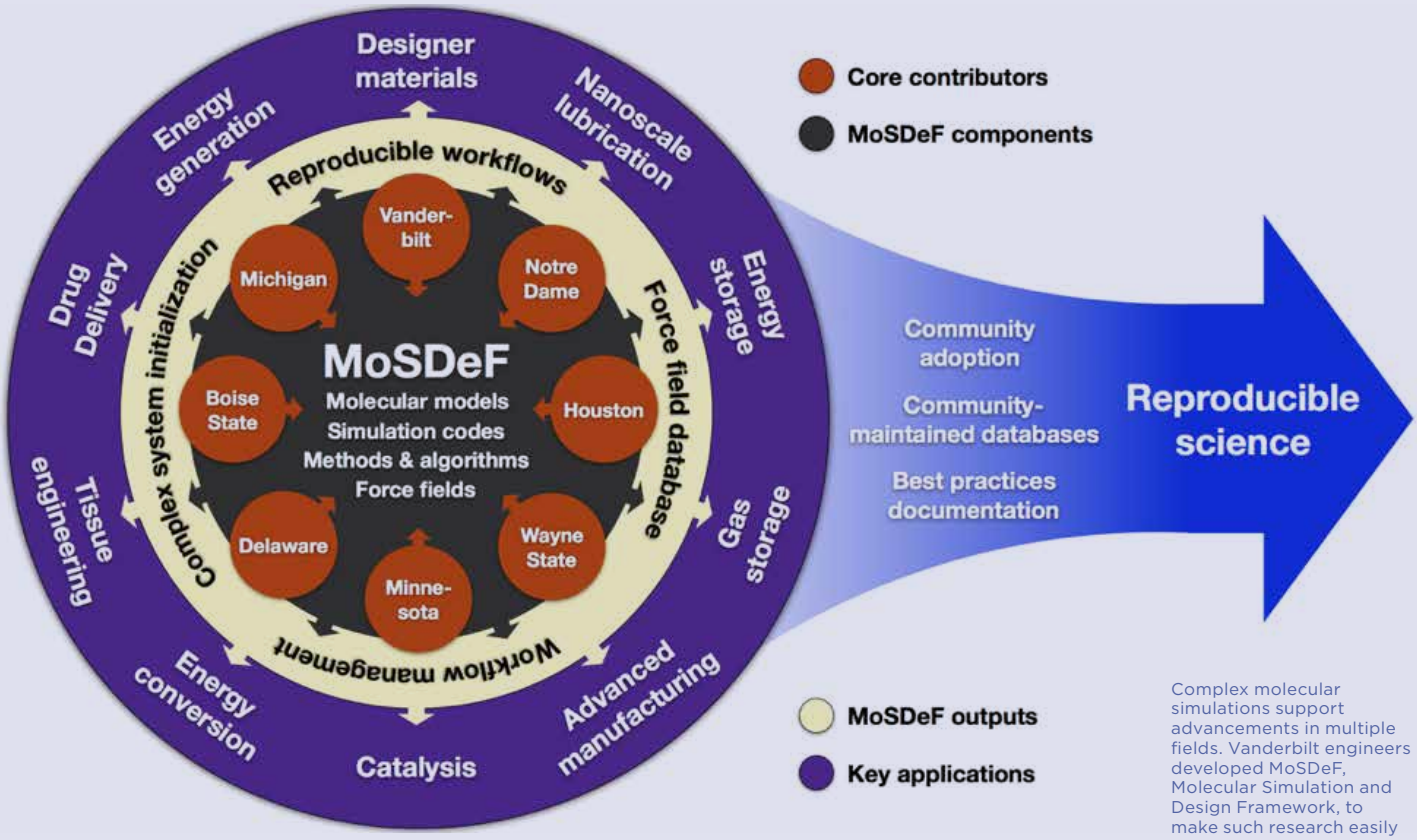
The ability to close the reproducibility gap has important stakeholders and widespread interest. A $3 million NSF grant has provided support for the Cummings, McCabe and Ledeczi research groups from Vanderbilt, the universities of Michigan, Notre Dame, Delaware, Houston and Minnesota, along with Boise and Wayne state universities, to further improve MoSDeF.

Already, the toolkit has been used in published results and ongoing research projects, with an impressive 30,000-plus downloads from the Anaconda Cloud software distribution site.

In some fields, the ability to reproduce an experiment and obtain the same results is inherently more difficult—not because the science is unsound but because the details provided in a peer-reviewed publication aren't enough to recreate the conditions.

The challenges are especially acute in simulating soft matter systems, defined as anything easily deformed at room temperature, such as liquids, polymers, foams, gels and most biological materials. Performing a molecular simulation of such a system involves multiple steps traditionally done one at a time by researchers in a bespoke fashion.

The complexity of soft matter simulations, with hundreds of variables that must be assigned values as the simulation is set up and run, is the source of error and irreproducibility. Distrust of peer-reviewed molecular simulation results is sufficiently high that many groups will repeat a published study to confirm them, tying up computational resources and researcher time.



Complex molecular simulations support advancements in multiple fields. Vanderbilt engineers developed MoSDeF, Molecular Simulation and Design Framework, to make such research easily reproducible. The is open-source software suite is available at mosdef.org.

"I am pretty sure every researcher in our field has had the experience of going down the rabbit hole of trying to confirm a previously published study, only to find in the end that one of these hundreds of unpublished variables was assigned incorrectly," said Cummings, a globally recognized leader in molecular theory and simulation.

MoSDeF dramatically reduces this problem by automating as many steps as possible.

Consider one key aspect of a molecular simulation: the forcefield, which is a mathematical model for how molecules interact with each other. For a complex molecule, the forcefield can easily have 100 parameters. If a system is a mixture of four or five such molecules, the number of parameters skyrockets. These parameters are made available when the forcefield is first published, but often the original publication will have typographical errors or mistakes in units that are corrected in subsequent papers, or the parameters are further optimized.

One component of MoSDeF provides validated parameters and applies force fields automatically.

"I like to think of an analogy to manufacturing," Cummings said. "If an artisan potter makes coffee mugs, each will be slightly different. But in an automated manufacturing environment, they will be replicas of each other. Additionally, if someone sets up the same factory with the same equipment in another location, the same coffee mugs will be produced—that is the essence of reproducibility."

To have a broad impact, all modules and workflows developed for MoSDeF build on the scientific Python stack to enable transparency and ease entry for new users. The Python packages simplify the creation, atom-typing and simulation of complex molecular models.

"By using freely available tools designed for collaborative code development, such as GitHub and Slack, we are creating a community-developed effort," said McCabe, Cornelius Vanderbilt Professor of Engineering.

For more information, visit mosdef.org.

MoSDeF is supported by the National Science Foundation under Grant No. 18358741, 1047828 and 1535150.

7 Questions with Eleni Pappas,

BE'08, Principal at Traffic Engineers, Inc.

Eleni Pappas loves long walks and one of her big goals is to make Houston a truly walkable city. As a Principal at Traffic Engineers Inc., a Houston firm that serves community and private industry, she is in a position to help pave the way. Eleni's skills include multimodal transportation planning, roadway schematic design, bikeway design, sidewalk design, traffic calming options, traffic studies, transit operations, crash data analysis and GIS. She is adept at communicating transportation information to a broad set of stakeholders using advanced mapping techniques. Eleni, vice chair of the school's Board of Visitors, earned a bachelor's degree in civil engineering from Vanderbilt in 2008. She went on to earn an M.S. in Civil Engineering (transportation) from University of Texas at Austin. In 2019 she completed an MBA at Rice University. She is a lifelong Houston resident.

1 What skills and experiences at Vanderbilt do you think most contributed to your career development?

The engineering program is structured to create really well-rounded engineers. It has strong communication components, including being required to write and present. My senior design project was re-timing five signals on West End Avenue in front of the Vanderbilt campus. It was great and very realistic. We not only did the work, working with the consultant who was coaching us, but also meet with city of Nashville officials to talk about our recommendations. Our professor filmed us during presentation practice sessions as a way to improve our skills. I hated it, but it was really great practice for the work I do today. Communication skills ended up being what I use all the time, meeting with clients, prospective clients and addressing community meetings.

2 We know design is a complex process and hardly linear. What are some recurring design questions you and your team face that require the most focus and discipline?

From large-scale regional studies to a specific intersection, it is all about the streets. We constantly have to think through the questions about the right street design for the community. It is not cookie-cutter. It is not one size fits all. Traditionally, traffic engineers are great at solving the question, "How do we move more cars?" But we have to start asking different questions, like "How do we move more people?" Rephrasing the question can allow us to design great streets that support our communities and become economic drivers for our cities.

3 What has been your biggest engineering challenge?

Making streets safer. On a broader scale, 40,000 people a year die on city streets, which is up from 30,000 a decade ago. Those are needless deaths. Looking at safety data is part of my job. I review crash reports and see how much of the fatalities were preventable. How do we design our streets to be safer? How to we protect the most vulnerable roadway users: those that walk and bike? How do we make that possible? We can answer these questions.

Vision Zero is an international initiative to design safer streets to bring total traffic fatalities to zero. It changes how you think about design. Houston is among the participating cities, and in my role I can make an impact on how people move safely around their city.

4 How do you start the workday?

I am not a morning person. Ideally, I have my morning coffee and make my list for the day. I use a legal pad and each day gets a new page. Sitting down and thinking about the day before starting it, for me, is much more calming than diving in.

5 What are you curious about?

Everything! I have colleagues who read transportation books in their free time. When I have free time I read everything else: maps, World War I history, Russia, food, how we eat. I love reading books about a single food item—butter, the potato, banana, the lobster. Lately, with pandemic-related social distancing, I am using Audible a lot more on walks but also tackling books already in the house that I've never had a chance to get to.

> Autonomous cars are not going to save the world. What is going to save the world is good planning for people.
>
> **Eleni Pappas, BE'08**

6 What are the biggest differences in the field now compared to when you graduated? What makes this an exciting time to be in traffic engineering?

Our cities are so important, and I've seen the standards of Houston and other cities evolve and change. It is well known that on wide streets drivers go faster; on more narrow streets they go slower. Why are city streets designed like freeways? They shouldn't be. There are more robust discussions about designing streets in a holistic way, making travel lanes 10 feet wide rather than 12, focusing more on health, safety and mobility. People are really thinking through the question, "What is the right way to design for each of our communities?" The focus should be on creating the best experience for people.

When people think about transportation engineering today they want to know about autonomous vehicles. I think autonomous vehicles are great and the technology fascinating. For the freight industry and mass transit, the technology can be a big asset by reducing the people-hours required to operate vehicles. We already see the technology in cars today, and it can make driving safer and help achieve Vision Zero goals. But likely we will still see single-occupancy cars (or cars with no person) and an increase in traffic volumes on our streets with more vehicles circulating.

Autonomous cars are not going to save the world. What is going to save the world is good planning for people.

And now, in these times, when we are staying home to be safe, travel patterns have completely changed and are likely to continue to evolve as the way we work changes to accommodate social distancing. Will the old ways of building interstates and roadway for four hours of peak commuting each day still make sense?

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

At 21, I was still at Vanderbilt. Vanderbilt is a beautiful campus, a place where you can walk alongside beautiful trees and be outside all the time. Once you go into the "real world" you realize how that becomes much harder. I'd tell my younger self: "What you have is really great. Find a way to make it part of your routine now." And take an accounting class if you can.

Printing a portable heat source

Underwater welding is one of the more dangerous occupations on the planet. Welding off-planet, in space, has its own perils, as does welding in a combat zone.

A recent mechanical engineering doctoral graduate has created a material that could minimize both the equipment needed and operator hazards. The material—a safe, stable, thermite paste—can serve as a portable, programmable heat source for use in extreme conditions. The paste is 3D-printed and deposited in patterns called reactive material architectures that can be controlled and directed.

"I think it has a lot of potential," said Kelsay Neely, BE'15, Ph.D.'20. "You just print it, put it on the joint and light it."

She has successfully used the printed paste to heat solder to fuse aluminum, and, more recently, copper lap joints.

The paste is about the consistency of peanut butter. The recipe starts with a well-mixed blend of iron oxide, aluminum powder and gypsum powder. Addition of water activates the gypsum powder as a binder; the paste begins to cure immediately. Addition of tartaric acid to the water before mixing can slow down curing, but even then, working time is limited to less than 45 minutes or the paste becomes too thick and sticky to print, Neely said.

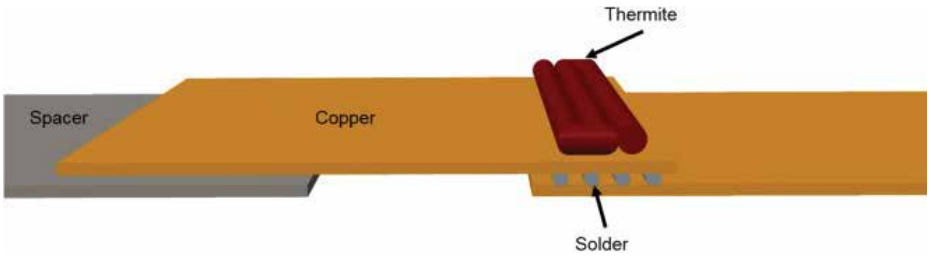
Her thermite paste is safe to create, print and transport.

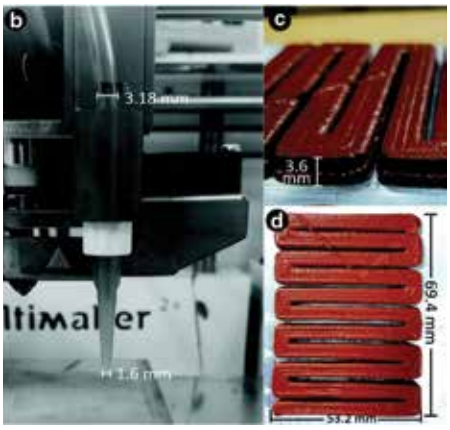
"If anything, I have an overdeveloped sense of safety," Neely said.

Other researchers have developed printed reactive material that can be controlled at the nanoscale but only small amounts of it can be deposited, limiting how much energy can be used. At the macroscale, at least ½ millimeter, another approach uses fluoropolymer-based reactive materials but requires special techniques to synthesize the polymer and refine the filament so the material doesn't ignite unintentionally.

In her work Neely, a mechanical engineering major at Vanderbilt, has combined two interests—3D printing, or in this case, 4D printing—and energetic materials. The extra dimension is time; a 4D material transforms over time, reacting to an environmental stimulus such as humidity or temperature and changing form. She credits Alvin Strauss, professor of mechanical engineering, and Kevin Galloway, research associate professor of mechanical engineering and Vanderbilt's director of making, her Ph.D. advisers, for green-lighting the idea.

Their study with copper lap joints was published in the April 2020 issue of *Manufacturing Letters*. The aluminum study which included foundational work, was published in August 2019 in *3D Printing and Additive Manufacturing*. The work has been supported by The U.S. Naval Sea Systems Command NAVSEA through the Naval Engineering Education Consortium NEEC Grant #N00174-19-1-0020 and the NASA Tennessee Space Grant Consortium.





Kelsay Neely's 3D-printed thermite can fuse metals. Above: Thermite paste is printed atop one strip of copper. When ignited, it heats the solder, welding the copper strips together.
Right: The thermite paste is printed in different shapes to control how and where it burns.

Doorport, started by EE alum, sold to "prop tech" industry player

The phrase "touchless transaction" was not in the public discourse when Ben Taylor launched Doorport in 2016.

It is now. PointCentral, part of Alarm.com, bought Doorport in March 2020. Taylor, BE'15, is director of smart access solutions at PointCentral, managing integration of Doorport's products into the larger company's platform.

"COVID-19 has accelerated all of this technology," said Taylor, who majored in electrical engineering. "Smart and contactless—not having to touch something is a big selling point now."

Negotiations for Doorport's acquisition began well before the COVID pandemic, but the timing was serendipitous. Frustration was mounting over repeat delivery attempts and unattended packages among all stakeholders: consumers, property owners and delivery drivers.

"Property managers and residents alike want a seamless curb-to-couch solution that conveniently and securely manages front door access for guests as well as service and package delivery," Sean Miller, president of PointCentral, said in a statement announcing the acquisition.

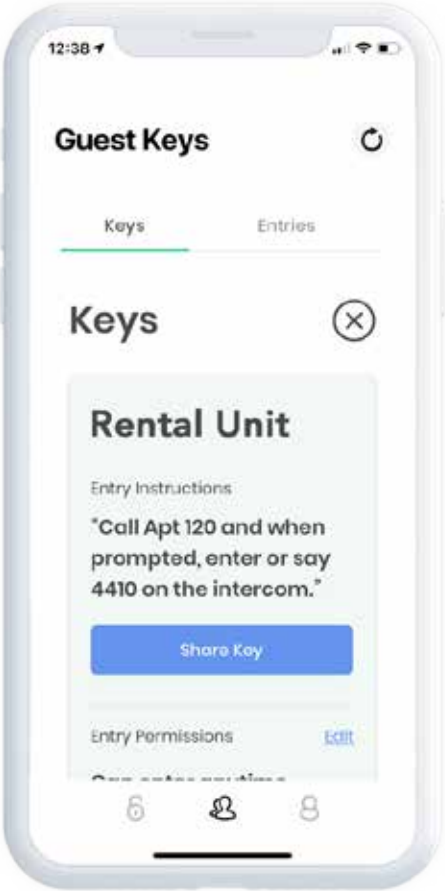
Doorport had developed hardware and software products: an aftermarket intercom add-on for residents to admit guests, including delivery people, from wherever they were, and a software-only product that let anyone upgrade their building access simply by replacing their intercom listing's phone number. Apartment managers and residents could easily and independently create "keys" with instructions for expected deliveries, whether from FedEx, GrubHub, the Thai place down the street or a favorite retailer.

The company was in a 2019 cohort at Y Combinator, a prestigious Silicon Valley accelerator, and featured in *Tech Crunch* and *The New York Times*. Investors included MetaPop, Kairos and Sinai Ventures.

Taylor, who grew up in the Nashville area, shared his journey with students and faculty in October 2019 as part of The Chambers Family Entrepreneurial Lectureship series, which is endowed by the Chambers Medical Foundation. During Taylor's first year at Vanderbilt, someone found a broken iPhone and gave it to him because Taylor's interest in taking things apart was no secret. He watched a YouTube video, replaced the screen, fired up the device, located the owner and returned the phone.

Taylor was in business.

"Amazing opportunities are out there," he said.



Doorport users create keys with instructions for deliveries. The company was acquired by Alarm.com in March 2020.

Modular battery system stores solar power, provides backup power

Anguilla is a small island nation, east of Puerto Rico and north of Saint Martin, with about 16,000 residents. Its land comprises fewer than 35 square miles, and a single utility company serves the country, which several years ago began turning to renewables to build resilience and stability into its power system.

As an island nation largely reliant on diesel generation, energy prices were sky-high, and concern about resilience increased with the intensity of each annual hurricane season. Then, in 2017, Hurricane Irma devastated Anguilla's infrastructure, and the government wanted ways to strengthen critical facilities.

All of which made Anguilla an ideal pilot location for Gridspan Energy, a flexible mobile battery system for solar power storage as well as backup power developed by a School of Engineering alumnus.

Founder and CEO Alec Macklis, BE'16, said Gridspan commissioned the Anguilla project at the end of last year and is looking for additional pilot partners in the eastern Caribbean and western Africa.

Anguilla hosted the first pilot of Gridspan, a flexible mobile battery system for power storage developed by Alec Macklis, BE'16.

Gridspan's technical advancements are in the design, deployment and integration of its mobile energy storage system. The business model is innovative as well, offering customers a monthly leasing arrangement for energy storage. The goal is to give island nations and other regions with grid-weak systems, which often rely on expensive, carbon-heavy diesel for power, an affordable and accessible option for energy storage; a critical part of any reliable solar power system.

"We found customer cost structure and system installation were the two most significant barriers to energy storage deployment," said Macklis who majored in civil engineering. "This model encourages adoption by providing savings and removing the need for customers to purchase and maintain their own systems."

To build a system, Gridspan buys lithium-iron-phosphate batteries and links them in arrays that fit within a shipping container. As a mobile and modular energy system, it can be carried on ships or trucks. In the Anguilla pilot, the unit was

Gridspan's modular battery assembly is housed in an air-conditioned shipping container. The container is easy to relocate and can be shipped, trucked or transported by train.

shipped, set up at the government headquarters and moved to two other sites to show versatility and ease of use. It can store power from any source for later use and powers critical facilities during blackouts and other grid interruptions.

Designed to "plug and play," the system does not require an advanced electrician and can be connected in 15 minutes. "It is all integrated and air-conditioned and the whole 'box' is protected against the elements, including salt damage," Macklis said.

He first developed and investigated the techno-economic feasibility of novel mobile energy storage applications at Imperial College London, where he completed a master's degree in sustainable energy systems in 2017. In 2018, Macklis worked with Hiba Baroud, Vanderbilt assistant professor of civil and environmental engineering, to secure a $50,000 NSF I-Corps grant and dig deeper into the potential market.

Also, in 2018, Gridspan was one of four companies selected for the first Greentown Labs Bold Ideas Challenge, a six-month accelerator in partnership with Schneider Electric. Macklis was featured as a 2019 Changemaker at the International Student Energy Summit in London in September 2019.

For communities where tropical weather routinely causes blackouts and scheduled "brown-outs", these systems help manage peak loads and can make a big impact, he said.

"The storage solutions can be dispatched as needed, so communities can prepare for natural disasters, the ebb and flow of tourist season or other fluctuations in electricity needs," Macklis said.

> "This model encourages adoption by providing savings and removing the need for customers to purchase and maintain their own systems."
>
> **Alec Macklis, BE'16, Founder and CEO, Gridspan**

Illuminating science one T-shirt at a time

Necessity as much as aesthetics drove Wilson Adams' interest in graphic design. He wanted to go beyond predictable two-dimensional charts with labels to illustrate his research.

Adams, a Ph.D. candidate in biomedical engineering, taught himself how to create 3D images and iterated further, adding more complex representations such as light dispersion and diffraction. He discovered he enjoyed toying around with designs and realized they could do more than punch up presentations and journal articles. Good design could engage more scientists and, better still, reach out to non-scientists.

Though starting a company was not part of his graduate school agenda, in February 2020 Adams did just that. He named the venture Fluorcyte — combining fluor, as in fluorescent, and cyte, another word for cell — and launched an outlet for science-inspired graphic design that combines his interests in microscopy, open-source science and STEAM education.

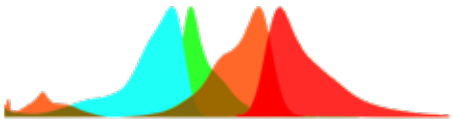
Fluorcyte.com showcases fluorophores, which are fluorescent molecules that can re-emit light upon excitation, on T-shirts, mugs and stickers. Science-loving shoppers can choose from spectral images, multiphoton-inspired designs and crowd-sourced limited editions.

Many science-themed t-shirts feature images and puns that appeal only to those in the know. Adams didn't want to take that route. "These are not meant to be super nerdy," he said. "There is a huge area of science that is visually appealing in its own right."

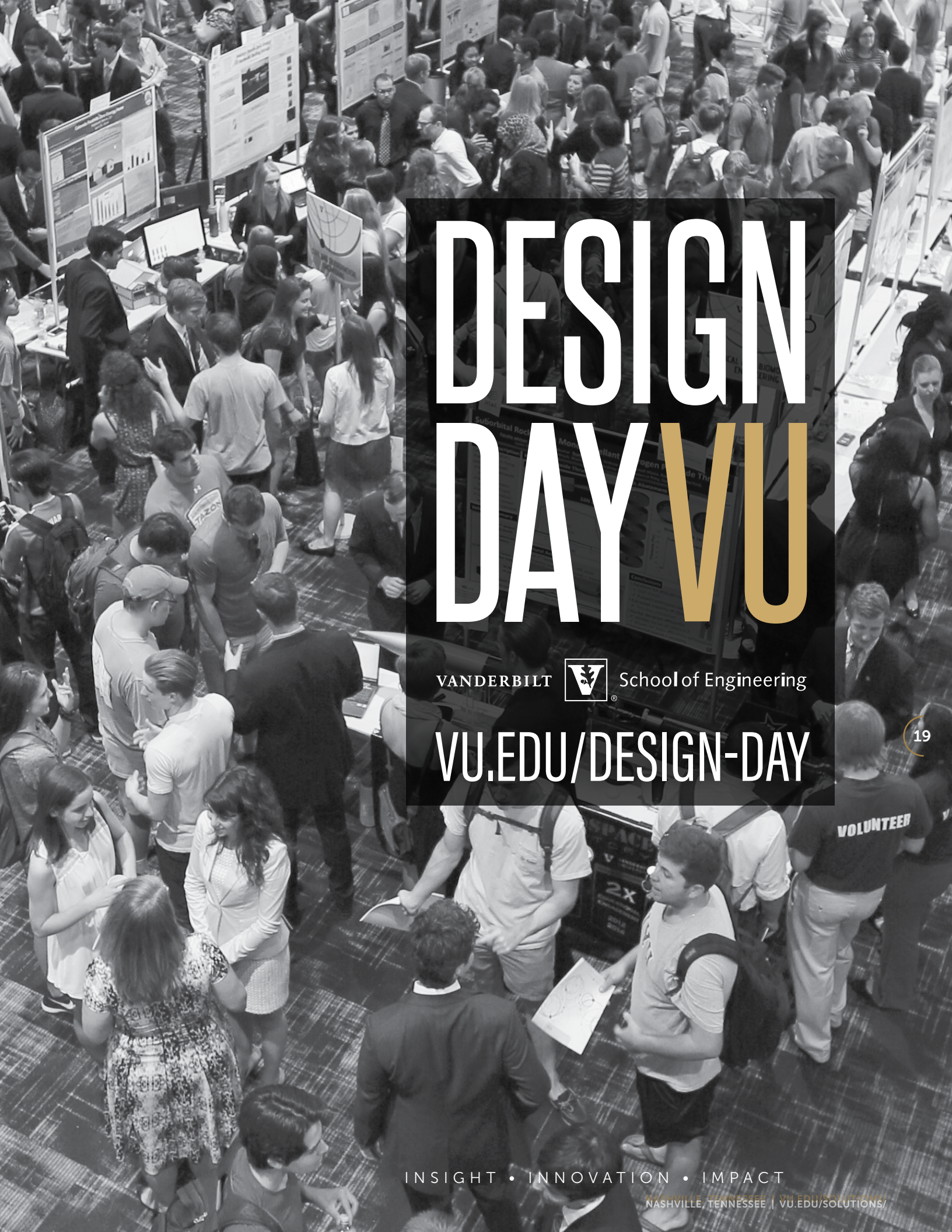
Part of his mission is to support open-source science platforms, including FPbase.org, that have helped him in his advanced microscopy and neuroscience research. FPbase is an open-source database of fluorescent proteins, molecules and tools for optimizing experimental needs to measure fluorescence that Adams says he uses nearly every day.

A portion of the sales from a line of FPbase-branded products and the Spectral collection will go to help with maintenance and development costs.

"I want to give credit where credit is due," Adams said.



A BME Ph.D. candidate launches https://fluorcyte.com with images of fluorescent molecules for t-shirts and other products. Wilson Adams wants to raise interest in microscopy, STEM and open-source science.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2020 Senior Design Winners

THOMAS G. ARNOLD PRIZES

The Thomas G. Arnold Prizes for Biomedical Engineering Systems Design and Research are shared by **Tejas Subramanian,** Acton, Massachusetts; (research), and for design (Project: Smart IV tubing clamp for the NICU), **Jorie Budzikowski,** Wheaton, Illinois; **Stephanie Molitor,** Erie, Colorado; **Madelyn Schmall,** Chanhassen, Minnesota; **Kathryn Ufford,** Bloomfield Hills, Michigan; and **Rachel Welscott,** Clearwater, Florida.

CIVIL ENGINEERING DESIGN AWARD

The Civil Engineering Design Award goes to **Caroline Janssen,** Montgomery, Ohio; **Will Hellman,** Louisville, Kentucky; **Miranda Mangahas,** Clifton, Virginia; **Nathan Miller,** Indianapolis, Indiana; and **Cole Siegenfeld,** Melville, New York; for their senior design project of a pedestrian bridge across a river in Honduras.

MECHANICAL ENGINEERING DESIGN AWARD

The Mechanical Engineering Design Award is shared by two teams: The Design, Fabrication and Control of an Autonomous Robotic Painting System Team and the Mechatronic Design of a Multi-Axis Motorized Stereoscope System Team. The painting systems team members are **Braden Barnett,** Encino, California; **John Goeke,** Racine, Wisconsin; **Sam Gottlieb,** Grand Blanc, Michigan; **Emmet Haden,** Charlottesville, Virginia; **Swapnil Pande,** Chantilly, Virginia; and **Charles Tusa,** Austin, Texas. The stereoscope system team members are **Osama Assal,** Hoboken, New Jersey; **Mark McKee,** Greenville, Tennessee; **Tristan Miranda,** Mission Viejo, California; **Zach Taylor,** Acworth, Georgia; and **Connor Woodall,** Madison, Wisconsin.

WALTER C. CRILEY PRIZE

The Walter C. Criley Prize in electrical engineering and computer is awarded to **Rosalia Brooks,** Clarksville, Tennessee; **Eleanor Burch,** Simpsonville, South Carolina; **Madeline Sgro,** Orange Park, Florida (Project: Internal Positioning System using Bluetooth beacons). The prize also is awarded to **John Goeke,** Racine, Wisconsin; and **Samuel Gottlieb,** Grand Blanc, Michigan; for their work on the robotic painting team in mechanical engineering.

KENNETH A. DEBELACK AWARD FOR EXCELLENCE IN DESIGN

Winners of the Kenneth A. Debelak Award for Excellence in Design in chemical and biomolecular engineering are **Allison Daney,** Naples, Florida; **Brooke Daney,** Naples, Florida; **Kara Giacose,** Wyckoff, New Jersey; and **Claire Vossler,** Studio City, California (Project: Multi-product Brewing).

Preface

On behalf of the School of Engineering, I would like to share the more than 50 engineering and computer science capstone design projects for 2020. We had capstone projects completed in partnership with sponsors including Nissan North America, NASA Marshall Space Flight Center, VUMC, Peabody, Booz Allen Hamilton, Cumberland River Compact, Nashville Civic Design Center, Merck, Inventiv Tools, DENSO Manufacturing Tennessee, 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. Of course, none of the teams, sponsors, or the many other people involved knew last August how much the real world would change before these projects were completed. All these students, guides, sponsors, and mentors will remember the adaptability, perseverance, and hard work it took to continue collaborating from all corners of the globe.

Students learned about professionalism, teamwork, entrepreneurship, and, above all this year, resilience. As their projects take form, student teams interact with their industry and faculty advisers, hold meetings (perhaps more of them remotely this year), write formal documentation and present their work. By the end of the academic year, the teams produce design processes, systems, prototypes, simulations, or virtual demonstrations.

This book is one tangible representation of Design Day, which has always been a celebration of all the lessons learned over four years of undergraduate engineering education. As you read this book, know those lessons were learned and demonstrated throughout all these projects.

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 closely 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 want to learn more, please contact me.

Be resilient, persevere, and work hard to make each other's world a little better each day. We are grateful for your support and guidance of our next generation of engineers and scientists.

With gratitude,

Thomas J. Withrow
Assistant Dean for Design
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Contents

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BIOMEDICAL ENGINEERING

Device for detection and alert of tremors

Complex motor stereotypies are characterized by episodes of unconscious repetitive movement of the head, hands or arms. Usually, these episodes can be stopped using auditory or tactile stimulation. While these tremors are not fatal, this condition has real consequences of social stigma and isolation. Alternative methods of treatment include behavioral therapy and anti-psychotic medications, but these have proven to have little effect and can be expensive. Our goal is to develop a detection and alert device to mitigate the frequency of episodes. The device has two components: a headband component for tremor detection and a vibrating wristband component to alert the user of an oncoming tremor. The device is discreet, cost effective, and able to recognize a pattern of motion. It can detect and alert an individual of a stereotypy event in 5 seconds and record the duration, intensity and frequency of those events, providing useful data.

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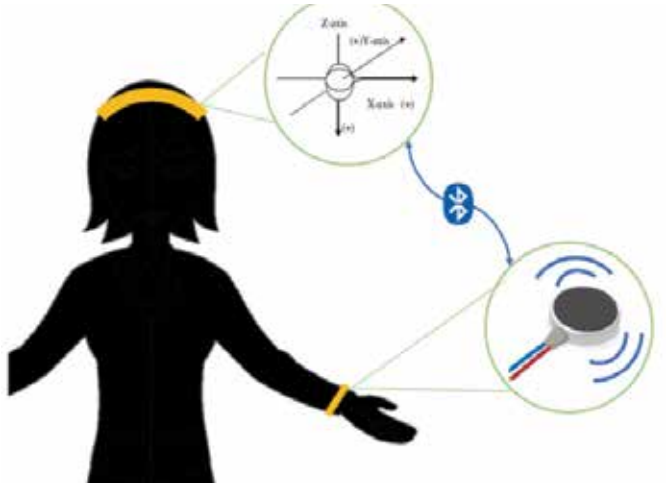

The stereotypy-tracking device consists of headband and wristband components. An inertial measurement unit in the headband detects a tremor by comparing incoming signals with a pre-recorded tremor signal. The wristband component receives a message via Bluetooth that causes it to vibrate, using tactile stimuli to alert the patient.

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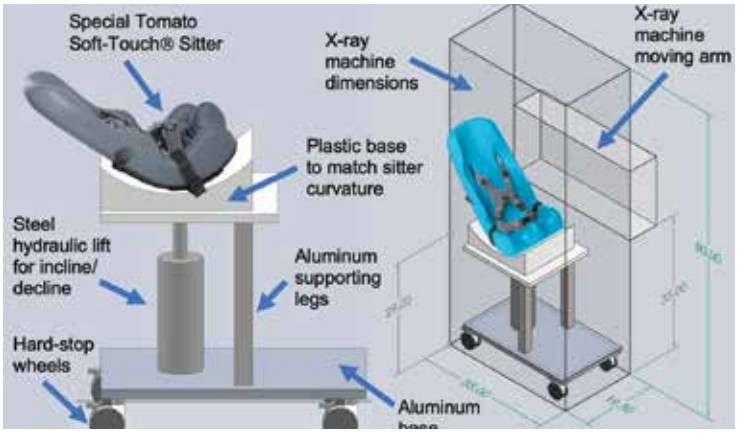
BIOMEDICAL ENGINEERING

Positioning system for pediatric videofluoroscopic swallow studies

At Vanderbilt Children's Hospital, videofluoroscopic swallow studies are performed regularly to identify a patient's specific risks while swallowing. Studies are performed by taking X-rays in real time while the patient swallows liquids/foods mixed with barium. The current positioning system used for these studies is both unstable and incompatible with the surrounding medical equipment. Specifically, the current design cannot accommodate children in the age range of 5 to 15. Our team designed a seating system that can support a patient up to 200 pounds and incorporates characteristics that facilitate the work of the clinicians. The chair is designed with a robust aluminum frame for support and incorporates a hydraulic lift to recline the chair while the patient is seated. Most importantly, the chair will fit within the parameters of the X-ray machine as most current seating systems do not fit or fail to place the child in the X-ray field of view.



The chair fits the narrow X-ray machine dimensions and includes an aluminum base, hard-stop wheels, a steel hydraulic lift for incline/decline, aluminum supporting legs, and a plastic base designed to match the curvature of all three Special Tomato Soft-Touch Sitters.

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BIOMEDICAL ENGINEERING

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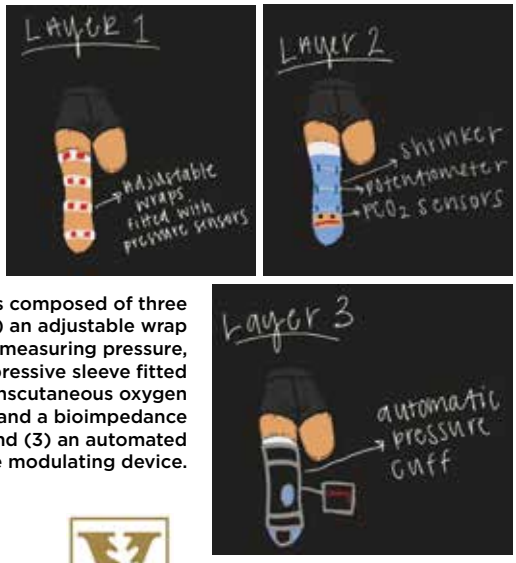
Smart shrinker: improving wound healing in lower limb amputees

Peripheral artery disease affects more than 8.5 million people in the United States alone. If left untreated, severe lack of blood flow to tissue can lead to ischemia and eventually amputation. This amputation causes edema (fluid accumulation), which increases the time needed for the wound to heal enough for a prosthetic to fit. The objective of this project is to significantly improve treatment of edema in lower leg amputees. Using pressure sleeves and Ace wraps to the limb stump does not account for the careful pressure balance required for treating edema. Accurate edema control requires a balance of applying just the right amount of pressure to the limb stump to increase blood perfusion to the wound without causing tissue necrosis and delayed healing. We designed a smart external limb sleeve that automatically applies or reduces compression based on limb volume and skin perfusion sensor readings. This novel medical device can actively control edema in the leg and ensure adequate wound healing immediately after lower leg amputation.



The device is composed of three layers: (1) an adjustable wrap capable of measuring pressure, (2) a compressive sleeve fitted with transcutaneous oxygen sensors and a bioimpedance board, and (3) an automated pressure modulating device.

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Hanger CLINIC
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BIOMEDICAL ENGINEERING

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Pediatric bone clamp based on 3D MRI/CT elbow models

The second most common pediatric elbow fracture involves the lateral condyle of the distal humerus. For fracture surgery, a bone clamp is often very helpful to maintain the reduction as internal fixation is placed. Currently, no ideal bone reduction forcep has been designed specifically for pediatric lateral condyle fractures. Our goal is two-fold: develop a bone reduction forcep to fit the unique osseous anatomy of the lateral condyle of pediatric patients between ages 2-18, and design the forcep body to have a 90-degree angle to facilitate rotation of the arm for a lateral fluoroscopic view during the procedure. The team designed a bone clamp based on 3D models built from MRI scans of pediatric elbows. The pointed tines of the forcep are angulated in different directions: one tine grasps a 2-mm pin placed in the middle of the distal humerus, while the other tine holds the fractured fragment in the correct position for pin fixation. An appropriately scaled ratcheting mechanism eliminates the need for different-sized clamps to accommodate age ranges. This surgical device is the first of its kind to address the challenges of pediatric lateral condyle fracture repair.

The bone reduction forcep boasts asymmetrical tines: one for grasping an externally fixed pin and the other for stabilizing the fractured lateral condyle fragment of the distal humerus.

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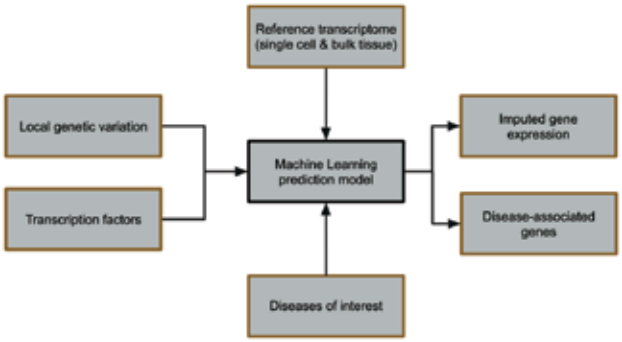
BIOMEDICAL ENGINEERING

Machine learning framework for data integration in genomics and precision medicine

Our project optimizes existing machine learning methods to integrate high-dimensional genomic and transcriptomic data sets to better model and predict disease. The optimized prediction model incorporates both local genetic variation and transcription factors as an input to improve its estimation of gene expression and identification of disease-associated genes. The team performed several quality control analyses to identify the minimum set of relevant transcription factors to improve the model's performance. These analyses included identification of highly variable genes, construction of gene communities using the Leiden algorithm, estimation of RNA velocity, and others. After identifying a set of relevant transcription factors, the prediction model's performance will be illustrated by applying it to hematological disease studies. The team relied on ACCRE, Vanderbilt's high-performance computing cluster, to carry out computational methods, and we accessed electronic health data from Vanderbilt's biobank, BioVU. We expect our method to identify novel genes implicated in the etiology of hematological disorders.



Adding transcription factors (i.e. a biologically meaningful selection of global genetic variation) as an input is expected to improve the model's estimation of gene expression and identification of disease-associated genes.

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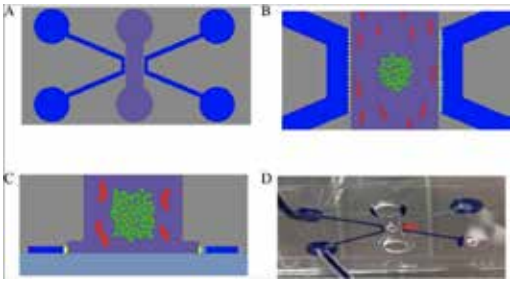
BIOMEDICAL ENGINEERING

Microfluidic bioreactor for testing chemotherapeutics on an organoid co-culture system

The tumor-immune microenvironment plays an essential role in cancer growth and metastasis. However, current approaches to preclinical cancer research have significant disadvantages in replicating the complexity of the tumor-immune microenvironment. A preclinical model is needed that more accurately capitulates the three-dimensional human physiological system. A microfluidic bioreactor allows for controlled perfusion of a three-dimensional extracellular matrix, high-throughput experimentation and specific regulation of variables. It mimics the complexity and specificity of human systems and presents the opportunity to study the three-dimensional tumor-immune microenvironment. The device consists of two side channels for flow of media, cells, and drug(s) as well as a center channel that holds the tumor organoid and extracellular matrix. The system utilizes a syringe pump to achieve steady, laminar flow for long-term study. The team aims to implement a standardized, effective method for cell delivery to the center of the device and a stable microenvironment that includes a semipermeable endothelial monolayer through which leukocytes, media, and drug(s) may pass. This project establishes a system with the potential to transform approaches to cancer treatment by permitting high-throughput, patient-specific drug viability testing.



The microfluidic "Road Kill" bioreactor includes two inlet side channels and one center channel. A row of microposts, on which an endothelial cell monolayer grows, separates the side and center channels on both sides. The side channels allow flow of immune cells, media and investigational drug(s) or drug combinations, while the center channel holds extracellular matrix. A patient-derived tumor organoid is loaded into the center channel through a top port to stimulate the seed-soil interactions within the tumor-immune microenvironment.

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BIOMEDICAL ENGINEERING

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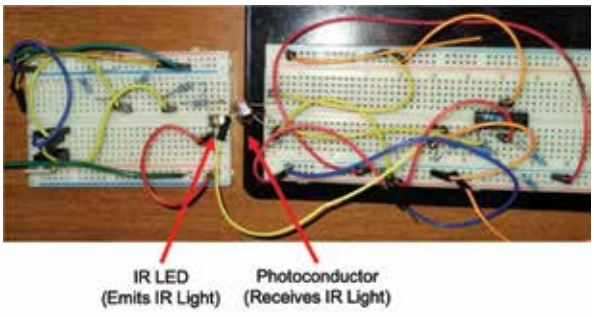
NICOLAS: non-invasive continuous optical lactic acid sensor

The non-invasive continuous optical lactic acid sensor is a smart sensing modality developed for continuous, noninvasive blood lactate level monitoring in clinical settings. It will be a significant improvement over the current clinical standard of intermittent blood draws for sampling. Our device samples lactate levels continuously and noninvasively and is less resource-intensive. Our sensor uses near infrared spectroscopy (NIRS) and ratiometric analyses to detect fluctuations in blood lactate relative to an established baseline. It will alert healthcare professionals to rapid spikes that may occur due to sepsis, organ failure or hemorrhage. Using blood lactate level as an early indicator of severe complications, NICOLAS allows for earlier intervention, which could result in improved patient outcomes.



The circuit shows the IR LED-photoconductor system that is the basis for NICOLAS. Using this circuit, we will be able to determine optically the concentration of lactate in a patient's blood.

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BIOMEDICAL ENGINEERING

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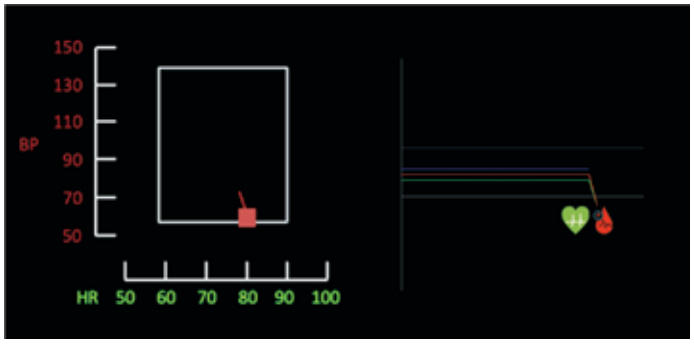
Multisensory medical alarms

An excessive number of disruptive, uninformative false alarms in hospital ICUs causes alarm fatigue in clinicians and can negatively impact patient recovery. Alarm fatigue is the desensitization to alerts, which can lead to missed alarms and compromised patient safety. Our team developed a wearable medical device with an intuitive visual icon display that keeps a doctor informed of patient vital sign trends before an alarm threshold is met. The goal is to decrease the number of audible alarms and increase awareness of changes in oxygen saturation, heart rate, and blood pressure. We compared two novel visual displays and measured the accuracy and response time of participants in monitoring patient vital signs. The advantage of a wearable device is that it is within a doctor's line of site and reports information on trends of patient vital signs in the recent past. The aim is to significantly decrease response time and promote faster recognition of vital signs, allowing healthcare workers to respond more appropriately.



Our study compared the effectiveness of a configural visual display (left) and a visual icon display (right) in communicating dangerous trends in patient vital signs before they hit an alarm threshold as well as the benefits of the visual icon display integrated onto a wearable device.

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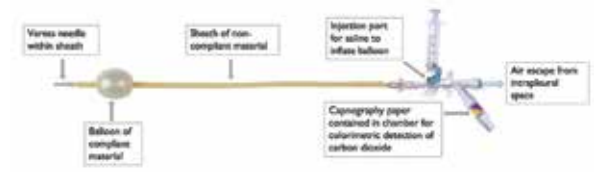
BIOMEDICAL ENGINEERING

Novel needle decompression system for tension pneumothorax

Tension pneumothorax is a condition where the air in the peritoneal space escapes into the interpleural space resulting in increased pressure on the lung and eventual collapse.

As the lungs' outerplural membrane expands, it pushes on the heart and causes a systemic decrease in blood pressure. It is a deadly complication that normally arises post trauma and has few effective treatment options. The premier treatment, needle decompression, lacks the ability to detect success, and it can destabilized during transit, which can result in fatal complications. To address those problems, our design is a novel needle decompression system that uses a balloon catheter to stabilize the needle, a capnography device to detect the high carbon-dioxide levels characteristic of air in the pleural space, and a veress needle for physical feedback for emergency responders to feel entrance to the pleural space. This device builds upon a previous iteration while maintaining the classic "feel" of standard systems. The team hopes to scale down the prototype to standard decompression system size and test on mannequins, animal models and cadavers.



The needle decompression system includes CO2 capnography for visual placement detection, a veress needle for physical feedback of placement detection, and a balloon catheter for stability during transit.

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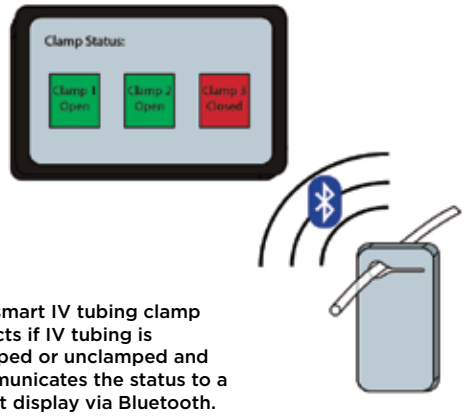
BIOMEDICAL ENGINEERING

Smart IV tubing clamp for the NICU

This smart clamp fulfills a need in the NICU for automatic detection of the status of IV tubing clamps, as the current systems are not sensitive enough at the low drip rates used to detect accidental occlusions. The design consists of a physical clamp to occlude medication flow when intended, as well as a "smart" electronic circuit that detects if the IV tubing is in the open or closed state. When the tubing is clamped, the tube triggers a digital switch, changing the voltage input to a battery-powered microcontroller within the clamp housing. If the tubing is in the clamped state, an LED on the clamp will light up and the status will be updated on a tablet display. This is an improvement over the current design because the clamp status is detected automatically. We anticipate this design will shorten protocols, reduce medical provider error, and improve the delivery of high-risk medications in the NICU.



The smart IV tubing clamp detects if IV tubing is clamped or unclamped and communicates the status to a tablet display via Bluetooth.

Monroe Carell Jr. Children's Hospital at Vanderbilt

BIOMEDICAL ENGINEERING

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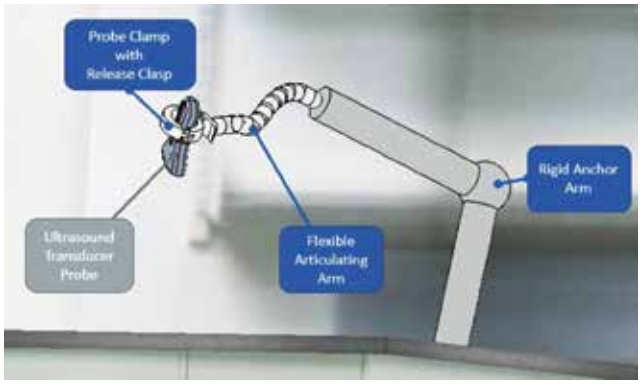
Mechanical articulating ultrasound probe arm

Ultrasound guidance is popular in a range of surgical procedures to localize anatomical structures in real time. The goal of our project is to develop a device that enhances ultrasound probe actuation for hands-free operation and improves imaging quality. Our design is a completely mechanical, non-electrical solution that can be easily adjusted during procedures. A rigid arm clamps securely to bed rails and can be adjusted with three degrees of freedom before being locked into place. A flexible arm connects to the rigid section and is comprised of links. This portion locks securely in place when desired and can adjust with two millimeters of precision. The rigid arm provides initial large-scale ultrasound probe movement while the flexible arm provides small-scale adjustments during the procedure. The final component is a clamp that can hold a variety of ultrasound probes securely to the repositionable section. This design will help improve imaging and procedural accuracy and decrease the need for additional surgical personnel.



3D model of the ultrasound probe arm designed in AutoDesk Fusion 360™. The arm has three main components: a rigid arm, a flexible articulating arm, and a grip. The rigid arm is used to anchor the device and provide rough positioning. The flexible arm provides more fine-tuned positioning with the aid of a release clasp.

VANDERBILT UNIVERSITY MEDICAL CENTER

BIOMEDICAL ENGINEERING

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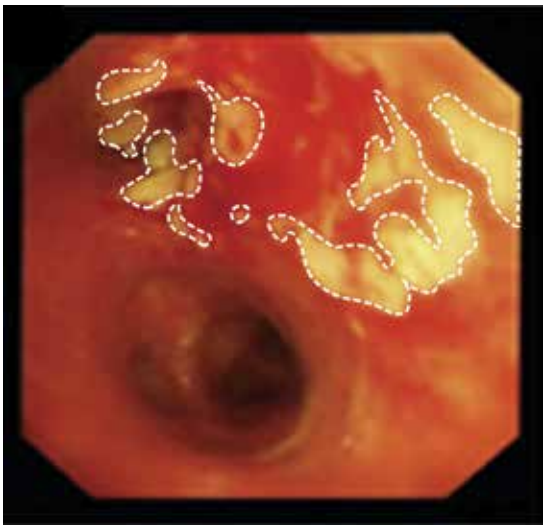
Low-resource bronchoscope

There is significant demand for healthcare services in low-income countries where respiratory diseases such as tuberculosis remain huge challenges. Currently, sputum sample tests are used to diagnose TB in low-income areas. However, TB patients are frequently unable to produce sputum of sufficient volume or quality. Bronchoscopy can be used to extract sputum at the suspected source of infection, significantly increasing both specificity and sensitivity. Unfortunately, bronchoscopy is difficult to perform in low-income areas due to high cost and difficulty of operation. We aim to develop a low-resource bronchoscope that is cost effective and easy to use by non-professionals to aid in point-of-care diagnostics. Our instrument consists of a reusable probe body, a single-use sheath to avoid reprocessing costs, an intuitive control scheme and companion application for real-time video display, and image processing to further aid clinical decision making.



Example of a proposed output image with a real-time feature recognition of inflamed tissue relayed from the bronchoscope and displayed using a companion device.

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CHEMICAL AND BIOMOLECULAR ENGINEERING

Design of a microbrewery for diverse product manufacturing

The last ten years have seen a sharp uptick in the number of craft breweries in the United States along with an increase in both the volume and dollar shares of the craft brewing category of the beer market. Our group targeted this growing market by designing and evaluating the economic viability of a new craft brewery. We designed a large-scale craft brewery—Crispy Hoppin' Brewing Enterprise—to produce 100,000 barrels per year of 13 different beers. The brewery produces five varieties year-round, as well as four seasonal and four limited edition brews. In addition to reaching this volume production, we designed our brewery to be environmentally friendly and energy efficient. We wrote original recipes for each of the beers, performed a detailed economic study on both raw material and equipment costs, and determined the specifics of building or contracting a facility. Throughout the design process, we attempted home brewing and met with Nashville craft brewery owners and brewmasters to learn about their operations.

An example of typical brewing equipment used to produce craft beer.

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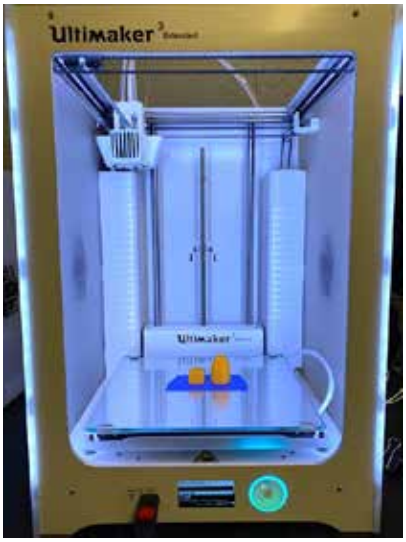
CHEMICAL AND BIOMOLECULAR ENGINEERING

3D printing in chemical engineering applications

Every year, more than 30,000 adults and children are brought to emergency rooms for losing one or more fingers. Currently, there are hundreds of prosthetic designs that rely on 3D printing. However, a cheap design with interchangeable parts that meets the needs of everyday life does not yet exist. Our project compiled documentation for printing and extruding various polymers, developed custom polymer blends as needed, and designed a modular, novel 3D-printed prosthetic finger that meets the needs of any user. This platform for our design allows rapid production of fitted and functional prosthetic fingers. Some of the needs we addressed include the ability to effectively use touch screens, throw a football consistently, and dexterity in piano playing. Polymer blends were created using the extrusion system and tested in 3D printers.



Rapid prototyping with 3D printers is a key capability in custom made prosthetics. This leads to a more accessible prosthetics due to lower costs and shorter time to optimization.

CHEMICAL AND BIOMOLECULAR ENGINEERING

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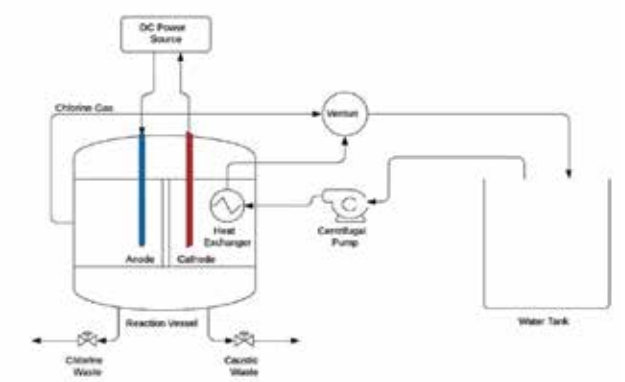
Development of a lab-scale chlor-alkali process

The chlor-alkali process is a very important process that creates two common chemical building blocks—free chlorine and caustic soda. Our project focuses on chlorine production with the intent of disinfecting water for drinking. We modeled the kinetics of the process under different conditions in order to reduce the required power for effective ion separation. Additionally, modification of the reactor to run the process in a semi-continuous method could yield greater amounts of chlorine for disinfecting during a given time period by reducing reactor turnover time. After experimentally determining the parameters of our reactor, we can run the reactor closer to ideal operation in the field and allow for theoretical scale-up by using significant calculated values such as current density and polarization voltage. The data provided by this project will help provide accessible and clean drinking water to disadvantaged communities all around the world.



The lab-scale chlor-alkali process uses saltwater and a semipermeable membrane to electrochemically clean water via production of chlorine.

CHEMICAL AND BIOMOLECULAR ENGINEERING

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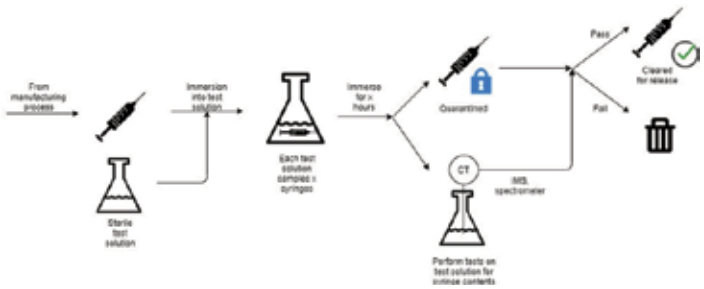
CCIT for alum and non-alum containing pre-filled syringes

Container closure integrity testing (CCIT) is a crucial quality-control test for drug products. CCIT evaluates the ability of a drug container to protect its contents against external contamination and is required by regulatory agencies. Vacuum decay testing is the current industry standard that is a proven method for many vaccines in vial form. However, the pharmaceutical industry is trending toward single-use pre-filled vaccines, which is incompatible with vacuum decay testing. Therefore, it was desirable to design a novel CCIT method for these products. The primary project objective was to determine and develop a CCIT method that is suitable for pre-filled vaccines, which may contain alum, a common additive. Other objectives included a regulatory overview, design feasibility testing, risk assessment and cost evaluations in order to propose a viable CCIT method. The team developed two novel methods, thermal defect imaging and external solution sampling, that can solve the problem in a low-cost, high-throughput manner. The team conducted proof-of-concept experiments to establish the risk and feasibility of the proposed methods. After determining a suitable method, the team performed a comprehensive cost analysis and provided an official recommendation for a proposed CCIT method.



Schematic of external solution sampling. The vaccine is placed in a test solution to determine if any vaccine content leaks into the solution, which would indicate compromised sterility. The solution can be analyzed by various methods, such as ion mobility spectrometry or UV-Vis spectroscopy.

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CHEMICAL AND BIOMOLECULAR ENGINEERING

Heat integration design of a PVC plant

Chemical plants spend significant revenue every year on utilities, typically for production of steam and cooling water. These utilities are used to heat or cool streams to desired temperatures for operation. However, many plant designs neglect the heating and cooling ability of already existing streams, which can be integrated. By integrating existing sources of energy, the facility can continuously save on operating costs while simultaneously lowering its water and energy usage. Using heat integration network technology, our team designed a network of heat exchangers to minimize utility costs at one of several plants within a pre-existing polyvinyl chloride (PVC) synthesis facility. This design accounts for the economic benefit of integrating streams while also considering possible new safety complications.

Aerial view of a chemical production facility. Our team aimed to optimize a polyvinyl chloride synthesis facility to minimize its utility expenses.

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Chemical Engineering Design Advisory Board

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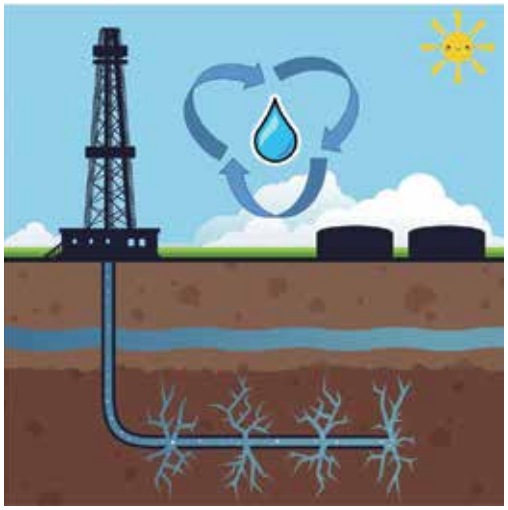
CHEMICAL AND BIOMOLECULAR ENGINEERING

Mobile wastewater treatment system for hydraulic fracturing waste

Hydraulic fracturing, or "fracking," continues to grow as a method to extract natural gas from shale formations. Millions of gallons of water, along with sand and injection fluid additives, are injected into the ground to generate fissures to release the natural gas. After the initial injection, around 20% of the original fluid returns to the surface over the course of two weeks as flowback water. The primary goal of this project is to reduce the water burden of the hydraulic fracturing process by cleaning flowback water for re-use. Our team aims to design a system to treat around 15% of the original volume of water injected after it returns to the surface by removing toxic chemicals, dissolved salts, and radioactive compounds from flowback water. Water will be treated in three phases: a primary phase to remove organic components and oil, a secondary phase to remove metal cations, and a tertiary phase to remove dissolved solids. The treated water can be recombined with fresh fracking fluid to be re-injected into a new well.



To reduce the water burden of hydraulic fracturing, wastewater will be treated after it returns to the surface for reuse as injection fluid.

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CHEMICAL AND BIOMOLECULAR ENGINEERING

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Batteries to meet Vanderbilt University's renewable energy goals

During the day, batteries store power generated by solar panels; at night, they discharge that power back to the electrical grid.

Climate change has pushed many organizations to begin implementing renewable energy technologies. Accordingly, Vanderbilt University recently announced its goal to achieve carbon neutrality by 2050 [FutureVU] and is planning to install solar panels on campus. However, many renewable energy sources, such as solar and wind, are intermittent, meaning that energy production can be unreliable. This factor severely limits renewable energy's integration with the electric grid. One solution is developing large-capacity batteries so that excess energy renewables generated during active periods can be stored for later use. Currently, lithium-ion batteries are commercially available but they face poor lifetimes and are difficult to implement on a large scale. Redox flow batteries (RFBs), on the other hand, are an emerging technology that can mitigate these concerns and be easily controlled for various energy and power requirements. Our project is an academic study to determine how to implement redox flow batteries for energy storage as part of the FutureVU initiative. We designed and modeled a system of vanadium-based RFBs to store energy generated by rooftop solar panels. Additionally, our team conducted performance, cost, and safety analyses to optimize our design before providing recommendations to Vanderbilt administration and faculty members.

CHEMICAL AND BIOMOLECULAR ENGINEERING

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Industrial applications of virtual reality in chemical engineering

Oculus Rift S user portrayed in a functional simulated oil refinery environment created in Unity.

This team seeks to apply the groundbreaking technology of virtual reality to chemical engineering education and training with situational process safety modules. Functional environments were created in the Unity development platform alongside Oculus hardware and software to simulate realistic scenes in which the user must seek out, analyze, and act upon a hazard, immediate risk, or lapse of process safety. These modules aspire to create hands-on learning experiences for the Vanderbilt chemical engineering department where previously discussed safety topics can be simulated in live action. The modules follow a linear progression: the user must use knowledge from previous stages to solve or prevent hazards in future stages. Within each stage, the team implements custom packages and assets in Unity to simulate technical laboratory equipment such as pipe and valve systems, fluid pumps, chemical reactors, distillation columns and filtration systems. This equipment will be incorporated into the virtual reality process safety module system to allow students to gain situational awareness.

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CHEMICAL AND BIOMOLECULAR ENGINEERING

Innovative sulfuric acid plant design in Nashville, Tennessee

Each year, 270 million tons of sulfuric acid are produced globally, making it the most produced industrial chemical in the world. Sulfuric acid is a critical component in the fertilizer, wastewater processing, oil refining, and mineral processing industries, with a total market value over $70 billion. Our project goal is to design a chemical plant in Tennessee that is able to produce 500 tons of sulfuric acid per day using elemental sulfur as our starting reactant. This production process is highly exothermic, allowing us to harness excess heat and convert it to useful steam, which we intend to both sell to neighboring plants and use internally. The team approached this challenge in a way that maximizes the plant's profitability while maintaining high safety and environmental standards in the production, storage, and transportation of our sulfuric acid products.

A typical sulfuric acid plant

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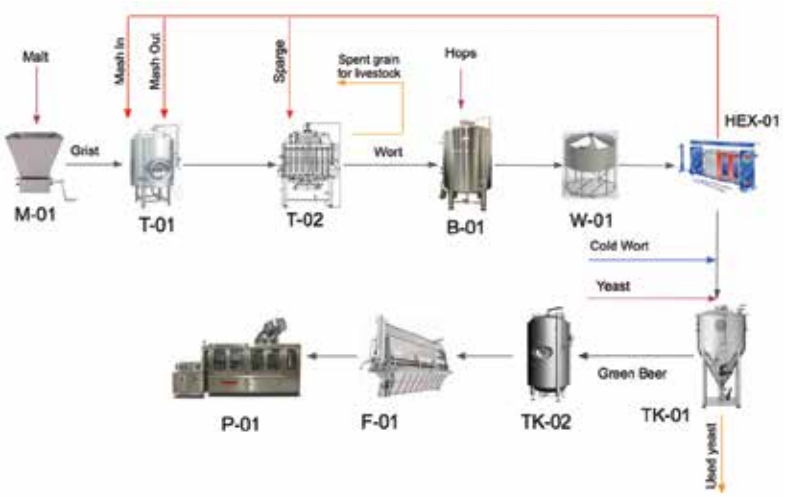
CHEMICAL AND BIOMOLECULAR ENGINEERING

Multi-product brewing

In 2019, the overall demand for craft beers increased and more than 1000 new microbreweries opened. The maturation of beer consumers has pushed the industry toward more varieties, fuller flavors and greater efficiency. Our team designed a fully functioning grassroots microbrewery that produces 100,000 barrels per year, starting with 13 unique craft beers, for contracted investors. After researching the brewing process, the recipes were created and scaled up to 50-barrel batches. Through process modeling, equipment costing and scheduling, and external analysis, the team was able to justify their recommendation to either proceed with a startup brewery or produce the beers under contract. The craft beer grassroots brand appeals to consumers because of its novel recipes, zero emission target, and economic viability. Our grassroots facility meets the requirements requested by our investors and is the best option after two years of production.



Process flow diagram showing production of one batch.

CIVIL AND ENVIRONMENTAL ENGINEERING

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Nashville Civic Design Center

Design implications of detached accessory dwelling units (DADU)

Sample plan for a DADU that can increase housing density in Nashville.

With the human population growing and a finite amount of resources and land available, there is need to create housing for population density. In urban environments it is preferable to do this with minimal construction while maintaining safety and environmental standards of the community. One solution is the successful implementation of detached accessory dwelling units (DADUs), which are accessory apartments that serve as secondary living spaces on the grounds of single-family homes and are separate from the primary living space. Our team created a preliminary design with a method of manufacturing a DADU behind a family's home in the Germantown community in Nashville, Tennessee. LEED sustainability standards and the historic neighborhood's preservation requirements were considered.

CIVIL AND ENVIRONMENTAL ENGINEERING

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Predisan Health Ministries
Lipscomb University Design Group

Honduras pedestrian bridge design

Team members Nathan and Caroline survey the riverbed in order to draw a topographic map and complete a hydrologic analysis for the proposed bridge in Bacadillas, Honduras.

For several communities near the rural village of Bacadillas, Honduras, access to the local medical clinic is restricted by a steep riverbed that becomes impassable during the rainy season. In recent years, local residents have constructed makeshift bridges annually to allow access to the clinic, only to have them washed away as the river level inevitably rises. The Vanderbilt civil engineering design team aims to eliminate this issue by producing construction-ready documents for buidling a long-term pedestrian bridge. The design includes input from the community and measurements taken of the area, gathered during a team trip to the village during fall semester 2019. The design emphasizes safety, constructability, economic feasibility, resiliency and sustainability. These documents will inform the construction of the bridge in summer 2020 as part of a mission trip with Predisan, the health ministry that sponsors the clinic. We anticipate the results of this project will allow for safe and sustained travel to the clinic and will improve the quality of life for those in the surrounding communities.

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SPONSOR
Sterling Ranch Development Corporation

CIVIL AND ENVIRONMENTAL ENGINEERING

Foundation design on expansive soils

The geology of the Colorado Front Range causes many problems for developers. The existing soils can cause cracking of building foundations. Currently, Sterling Ranch, a massive planned community southwest of Denver, overexcavates the soil and mixes it with water to remove its expansive potential. This solution is both expensive and time consuming. The goal is to provide the best foundation solution for Sterling Ranch. To do this, the native soil was tested and a Tella Firma foundation was designed for three different sizes of Sterling Ranch homes. The Tella Firma foundation should decrease the time it takes to build a home because the native soil is left in place, avoiding overexcavation. It is anticipated that the Tella Firma foundation will be a more cost effective solution for Sterling Ranch.

The team performed a geotechnical exploration of the native soils on site at Sterling Ranch.

STERLING RANCH COLORADO

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Mary Vavra, Barge Design Solutions

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Nashville Civic Design Center

CIVIL AND ENVIRONMENTAL ENGINEERING

Redesign of Nashville's Spaghetti Junction

Nashville's rapid growth creates widespread impacts, especially on housing and transportation. As a result, it is important to use the city's existing spaces efficiently and effectively. East Nashville's intersection of Ellington Parkway, I-24, Main Street, Spring Street and Dickerson Pike, nicknamed "Spaghetti Junction," consumes 95 acres of space with interchanges and unusable land. The goal is to redesign this area to meet current and future traffic demands while salvaging operable space and providing recommendations for future planning and land use. We worked with the Nashville Civic Design Center, Barge Design Solutions, and the Greater Nashville Regional Council to conduct a preliminary traffic analysis. Traffic and planning data informed conceptual designs of Spaghetti Junction and allowed the team to forecast new uses of the space. The results are intended to help evaluate future Nashville projects and to gain support for the redevelopment of Spaghetti Junction.

NASHVILLE CIVIC DESIGN CENTER

A preliminary design for Spaghetti Junction is superimposed on the current layout of the project area.

ELECTRICAL ENGINEERING AND COMPUTER SCIENCE

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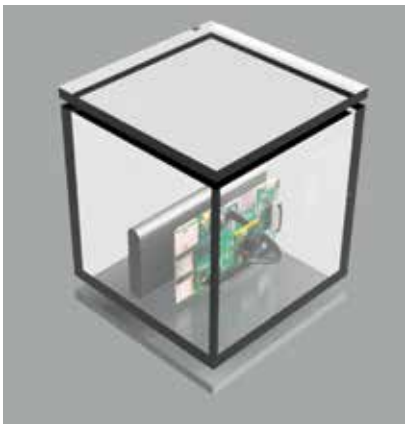
SPONSOR
Camgian Microsystems

Designing and building an AI camera

Camgian Microsystems creates augmented intelligence systems for financial and government markets. In the national security sector, Camgian provides real-time situational awareness in austere environments. For Camgian, we are creating a low power, artificial intelligence-enabled camera that detects and captures humans and passenger vehicles in motion. The HD camera operates autonomously and classifies 2M pixel images in under 15 seconds. The camera will also be in a 5"x5"x5" enclosure, withstanding temperatures between 32 - 95°F and windblown rain. The team's design employs a Raspberry Pi night vision-enabled camera and Raspberry Pi Model 3B to serve as the computing platform. The camera system uses YOLO (You Only Look Once), a deep learning network, to classify the incoming stream of images in real time. The best frame for each classified object is selected and stored locally on the system along with the bounding box data for later retrieval. The Raspberry Pi draws power from a 12Ah lithium-ion battery and features a power management system to preserve battery life. The system is housed in a clear acrylic enclosure to protect the electronics from the elements. This camera system has potential to be employed for national security applications.



Fusion360 rendering of the team's watertight, laser-cut acrylic enclosure that contains a Raspberry Pi Model 3B, a Pi camera module v2 No-IR, and a 12Ah power supply. The bottom plate is a machined aluminum heat sink, and the enclosure is assembled around a 3D printed ABS frame. The removeable top cover is sealed to the body with a custom Viton gasket.

ELECTRICAL ENGINEERING AND COMPUTER SCIENCE

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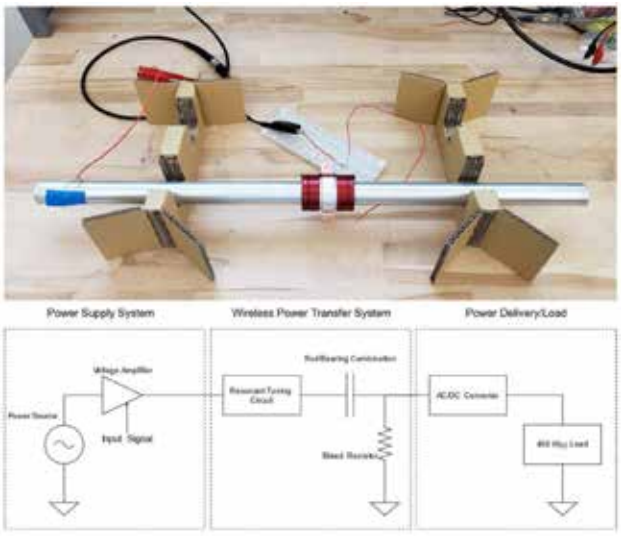
SPONSOR
DENSO Manufacturing Tennessee

400W wireless power transfer system

DENSO utilizes six-axis robotic arms operating along the length of a workbench via a linear track to automate their automotive components production. This operation rapidly deteriorates the robots' power supply cabling, requiring frequent replacement of the cables. We built a wireless power transfer solution suitable for microelectronics production in clean room environments. The solution can power a robotic arm with a continuous 400W (50V, 8A) DC supply. We designed a prototype circuit for capacitive power transfer using a PTFE-lined linear motion sleeve bearing on an aluminum shaft powered with an AC voltage acting as a capacitor. This solution can transfer AC current from rod to bearing for eventual rectification and DC conversion to power DENSO's robotic arms. It can be incorporated easily into the existing linear tracks and will require less maintenance as the power transfer system will not support any mechanical load.



Above, shaft and bearing capacitive power transfer prototype. Below, the full system circuit diagram from power supply to 400 W load.

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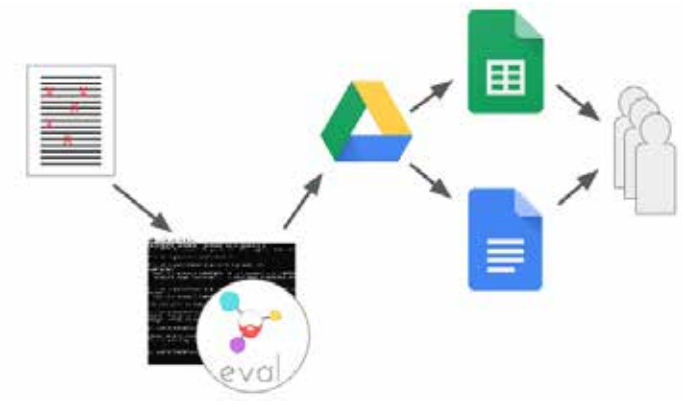
SPONSOR
Inventiv, LLC

ELECTRICAL ENGINEERING AND COMPUTER SCIENCE

Project Eval: automated code review report generator

This project addresses Inventiv's need to reduce the amount of work time spent on manual code reviews and explanation of the technical errors for non-technical individuals. Eval is expected to automate this process to reduce the workload burden on Inventiv software engineers and provide an editable Google document that will list and organize errors found while providing some general explanations of the issues and bugs found in their code. The automated program will include an error parser utilizing open source software to analyze Ruby, PHP, and Java, categorization and classification of the program errors, and writing documents to the Google drive via Google API. The anticipated results will be to reduce by two hours the time spent on code review and to provide a rudimentary generalized code report and analysis that is easily readable to non-technical audiences and Inventiv clients.



The general evaluation process starts by reading in project code, analyzing it through the Eval program, and publishing Google sheets and doc review reports for the end user to edit and use.

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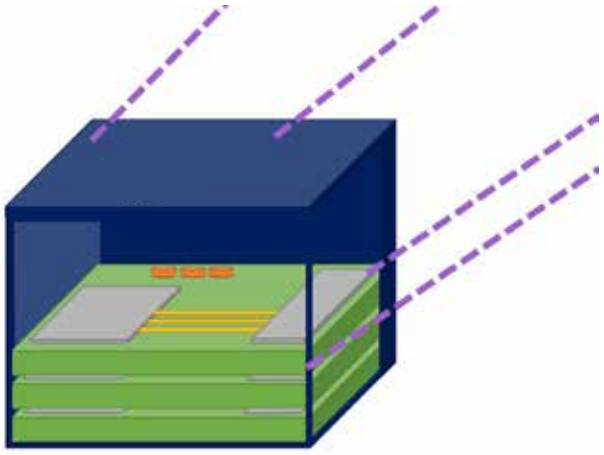
ELECTRICAL ENGINEERING AND COMPUTER SCIENCE

Lunar science payload to test radiation effects on NAND flash memory

The radiation environment of the moon is generally unknown. In upcoming years, NASA plans to begin collecting data and mapping that environment using its Lunar Gateway, an in-development space station. ISDE currently studies the effects of radiation on electronics and some of these effects can be used track radiation events. By employing ISDE's research on cube satellites, this project will be able to aid in the tracking of radiation through a combination of radiative hardware effects on NAND flash memory and algorithms that generate possible radiation paths. The data collected and paths generated will provide valuable information about the moon's radiation environment and how it may affect space travel, research and further exploration.



The printed circuit board within the cube satellite tests the effects of the incoming lunar radiation by interfacing between the microcontroller and NAND flash memory chip.

ELECTRICAL ENGINEERING AND COMPUTER SCIENCE

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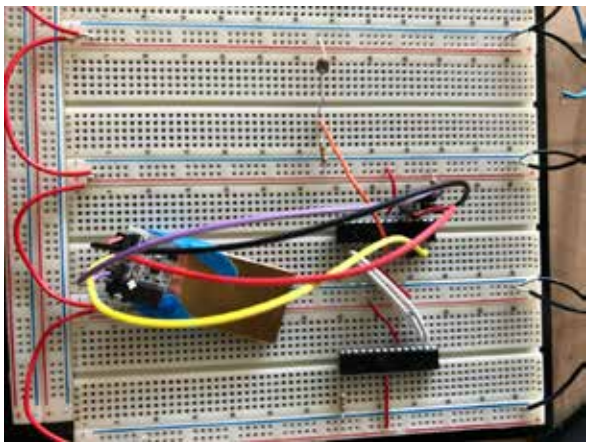
Science payload for the Lunar Gateway

Satellites orbiting the moon may be impacted by ionizing radiation that can affect the function of electronic components. This project continues ISDE's series of CubeSat experiments in which electronic testing systems are economically deployed using the small modular satellites. Our design targets the launch of NASA's Lunar Gateway, an in-development space station destined for lunar orbit. This year's team developed a novel experiment to test the functionality of microcontrollers that may be exposed to ionizing radiation and gather data on particle strikes and radiation levels using onboard sensors. The experimental setup was implemented on a printed circuit board (PCB) that forms one "layer" within a CubeSat. The results of these experiments will be reported to a control unit, which can pass the data along to scientists on Earth.



The breadboard prototype features a power supply breakout, two microcontrollers, a photo resistor, an IR sensor, and a Geiger counter.

ELECTRICAL ENGINEERING AND COMPUTER SCIENCE

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SPONSOR
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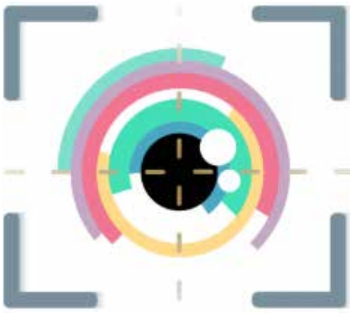
Low-cost eye tracking system for user assessment in an instructional video environment

The internet brings access to education across the globe and revolutionizes the way students and teachers interact. However, online education falls behind the classroom in terms of student engagement. In search for a better learning experience, the team researched and built software that enables eye-tracking technology to engage students in a new way, and offer insights into to how students learn. The overall team goal is to create an application that allows multiple users to record their gaze on a video and analyzes their gaze to create artistic displays of the eye-tracking information. This project uses the Tobii 4c eye-tracking board and software developed by the team. This solution creates a new way for students to interact with their learning material and new ways for instructors to analyze learning styles. We plan to create an application that allows users to record their gaze while watching a video and play back the video with gaze data overlaid in an interesting and customizable way.



Creating eye-tracking software for an instructional environment

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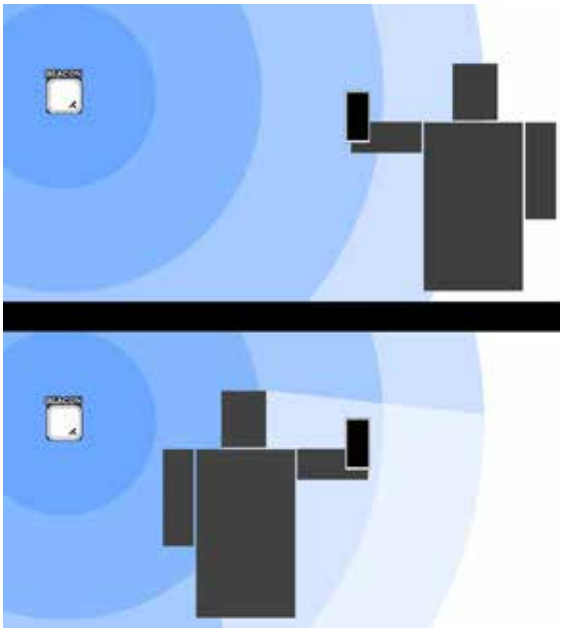
Universal Lighting Technologies

ELECTRICAL ENGINEERING AND COMPUTER SCIENCE

ULT—IPS beacon tracking

Our project aims to develop an Indoor Positioning System (IPS) mobile application compatible with conventional market Bluetooth beacons for Universal Lighting Technologies. The IPS mobile tracking application has several potential commercial applications. If implemented, it can provide tracking for users or equipment, which could help determine heat maps of human traffic or equipment movement inside a retail store or an industrial warehouse. Also, it could guide a user to a specific indoor location using turn-by-turn instructions. In collaboration with another design team that is implementing the algorithm, we are developing the beacon configuration and the data retrieval process in order for the other team to perform position calculations, which will lead to an Android app.



The beacon signals are affected by physical objects that intercept them and the connecting device. The relative signal strength decreases even when a human is holding the device in different orientations. While the data loss is minimal, this will be taken into account in the positioning algorithms.

Universal Lighting Technologies

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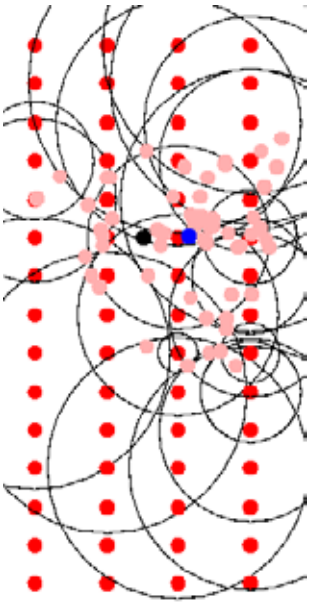
ELECTRICAL ENGINEERING AND COMPUTER SCIENCE

Internal positioning system using Bluetooth beacons

Big box warehouses and retailers are seeking ways to track people and products indoors. Camera tracking systems are expensive and can feel intrusive. Our project is an Android application that uses Bluetooth signals to determine a user's location. In a large indoor space, bluetooth beacons can be integrated subtly into ceiling light fixtures. Our app records the received signal strength indicators from surrounding beacons and uses the corresponding signal strengths to triangulate a user's location. The app also implements a pedestrian dead reckoning algorithm, which estimates a moving user's position based on their previous position and current acceleration. Our goal is to track and display a user's position overlaid on a floor plan map within two meters 95% of the time. The app could be used to give consumers step-by-step directions to products in a store.



User location estimation from a developer mode simulation. The screenshot represents an indoor space. The black dot is the user's true position. The blue dot is the app's location estimation. Red dots are Bluetooth beacons. Pink dots are triangulation results.

Universal Lighting Technologies

ELECTRICAL ENGINEERING AND COMPUTER SCIENCE

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National Aeronautics and Space Administration

Autonomous UAV for in-flight lunar ice sampling

The Vanderbilt Aerospace Design Laboratory is designing an unmanned aerial vehicle payload that will be capable of collecting a 10mL lunar ice sample during flight for the 2019-2020 NASA Student Launch competition. With the future of planetary exploration in mind, the team has added the three additional challenges of achieving repeatable, autonomous, and air-based sample collection missions. The UAV will collect samples from extreme terrain in other planetary environments, such as mountains or uneven slopes, and deposit the sample in a station integrated into the rocket. The UAV will autonomously search for, find, and navigate to the sampling zone, collect the sample, and return it to the depositing station. The UAV will then dock with a charging station to prove reliability for multiple mission cycles. This payload will provide the foundation for robust, real-time planetary sample collection missions.

The UAV will perform repeatable, autonomous sample collection in challenging planetary environments.

ELECTRICAL ENGINEERING AND COMPUTER SCIENCE

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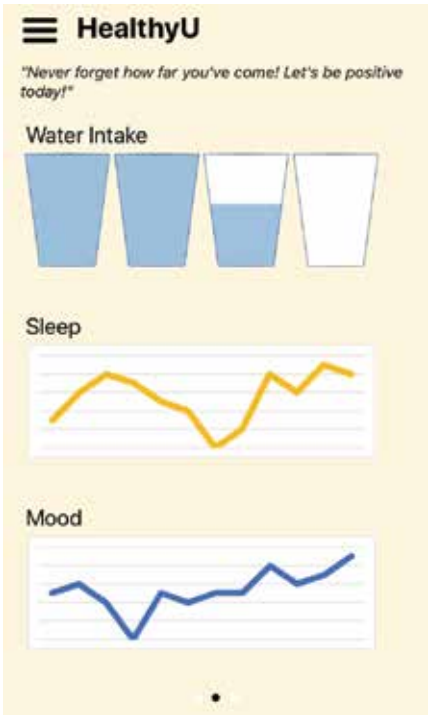
HealthyU

HealthyU is a mobile app to help users live and maintain healthy lifestyles by tracking physical and mental health habits. Features include tracking water and food intake, medicine and mood, breathing exercises, guided meditation and emergency call options for quick call and response with user-defined contacts. HealthyU's interface is customizable and simple, allowing users to comfortably navigate through the app quickly and intuitively, encouraging frequent usage and allowing easy access to vital resources during times of urgency. The app also provides a more holistic overview of the user's mental and physical health. The goal of this project is the app's ease of use, allowing the app to become an integrated part of a user's daily routine with minimal effort.



The application homepage displays trackers for the user's basic health and wellness information along with the option to navigate to more detailed reports and other features.

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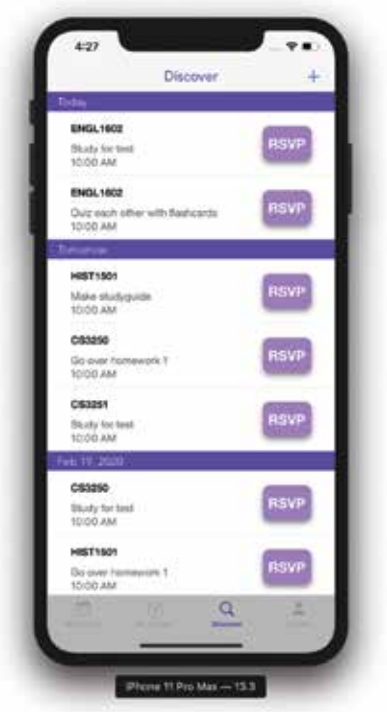
ELECTRICAL ENGINEERING AND COMPUTER SCIENCE

Synapse

Synapse is a study group event-planner iOS application for college students. Users can view a list of study groups on campus organized by class, purpose, date, and time. In our application, users will sign up with their university and then have the opportunity to add themselves to courses, browse and join available study groups, create their own study groups, and track all of their events in our built-in, calendar-type view. Our development team created an iOS application using XCode as the development environment, Swift for front-end development, and Firebase for the database. While there are a few study group applications available in app stores, no application is widespread across most college campuses. Some college campuses have their own applications, but students from other universities do not have access to those. The goal of this application is to provide a generalized platform to help connect students within classes to promote an inclusive team-oriented environment among college campuses.



On Synapse's Discover Page, users can browse all events for classes in which they are enrolled. Events are sorted by date, which makes finding them easy. Users can click on the RSVP button to attend an event and it will appear on their My Events page.

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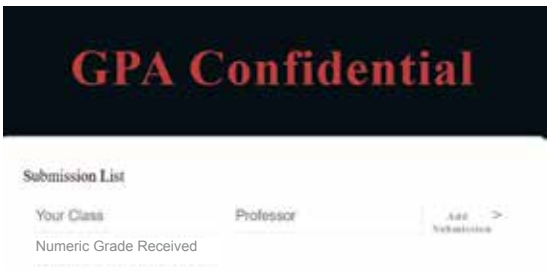
ELECTRICAL ENGINEERING AND COMPUTER SCIENCE

GPA Confidential

Vanderbilt students, especially first-year students, have limited knowledge about whether or not to take a class. The course evaluations conducted at the end of each semester are not available to students, and websites like ratemyprofessor.com may not accurately reflect the difficulty level of a specific class. For instance, a harsh-grading professor may teach a beginner-friendly intro class. For most students, an effective indicator of class difficulty is its average grade. Our management system app, supported by Firebase, uses a Chrome extension that reprograms the webpage of YES (Your Enrollment Service), the academic records and registration portal for Vanderbilt University students. The software collects and displays class grades; students can preview the average GPA in a professor's course. It will display the GPA information similar to BerkeleyTime, but the seamless UI is akin to Rate My Vandy Professor, as it displays the students' average GPA next to a course on YES.



The designed Chrome extension reprograms the webpage of YES and allows users to review average grades of most classes.

VANDERBILT. SCHOOL OF ENGINEERING

ELECTRICAL ENGINEERING AND COMPUTER SCIENCE

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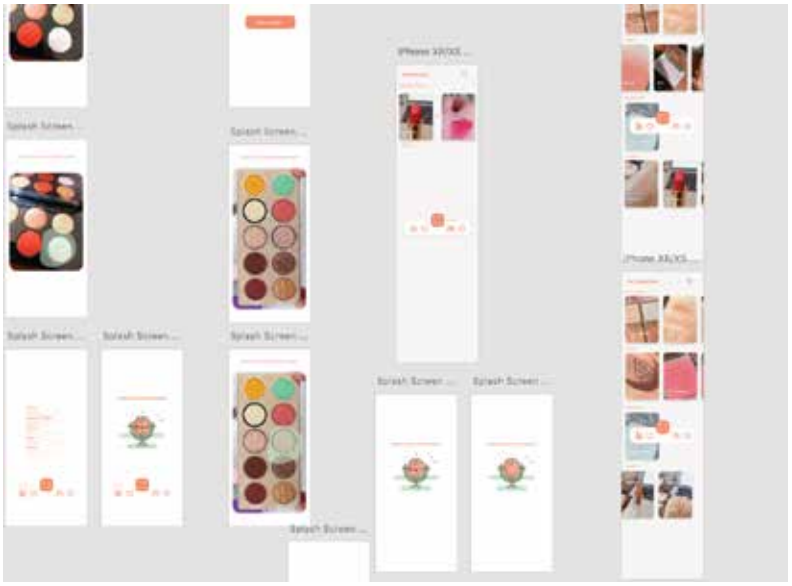
Vanderbilt School of Engineering

Dupelt

The cosmetics industry is saturated with products. Our app creates a useful way for users to compare new products to existing products they already own. A "dupe" of an item is an alternative item (usually cheaper) that looks and performs very similarly. Currently, the programs that exist to find dupes put the burden of comparison on the users. Our app automates the process of finding the best matching dupe in a user's current collection. There are three main features of our app: an image-selector to pick something to be duped, a library of a user's current cosmetic collection, and a community for users to share dupes they enjoy. We anticipate that our app will help users find dupes in their collection and decrease their spending on cosmetics.



Our app schematic illustrates some of the capabilities of our program, like the image-taking dupe functionality and the collection layout for the user

VANDERBILT. SCHOOL OF ENGINEERING

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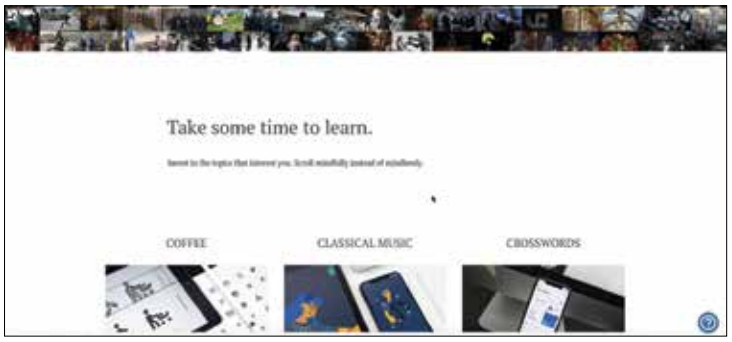
Content Curation

The goal of Content Curation is to encourage mindful scrolling—changing an existing time-consuming habit to be productive and, hopefully, educational. Content Curation is designed as a web app with Google's Firebase supplying most backend capabilities. Firebase supplies data storage, traffic information, website hosting and user authentication. User authentication originally was developed using PHP and MySQL but was eventually replaced with Firebase authentication for improved security and ease of implementation. The front end of the site is designed using Javascript, HTML and CSS. The user experience should emulate that of a social media platform. The user is able to follow friends and view content friends have added to the site as well as populate their feed with content from the topics they choose to follow.



Users can choose from a range of topics to populate their feed with specially curated content.

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ELECTRICAL ENGINEERING AND COMPUTER SCIENCE

Authenticoin

Counterfeits plague in-demand luxury goods such as high-end electronics and designer and luxury apparel, which account for up to 70% of the total counterfeit product trade. Our project goal is to build a non-fungible token (NFT) on the Ethereum blockchain that can be used to verify the authenticity of purchased products. A blockchain is a decentralized, immutable record of data. Each block represents a transaction and is verified by a network of computers. When a block is added to the chain, it documents all transactions placed on the blockchain to a public ledger and record that is mathematically verified. In large systems like the Ethereum blockchain, forgeries are prohibitively difficult and expensive for any person or group to achieve. NFTs are unique tokens on the Ethereum blockchain that can digitally represent products, such as clothing, house deeds or other assets. Our NFT implements the ERC-721 standard for Ethereum-based NFTs. Our team aims to create a unique token associated and sold with individual products that can be used to verify the authenticity of the product by way of its transaction record on the blockchain.

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The mobile application allows users to view their assets.

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VandyHacks

ELECTRICAL ENGINEERING AND COMPUTER SCIENCE

Vaken

Vaken is a free open-source application to help organizers of hackathons and events of all size manage their events with a fully featured registration system. The team added innovations to a VandyHacks product, implementing a plugin architecture, which means features outside the core application can be installed and uninstalled with ease. Thus, event organizers can customize Vaken to their specifications. The team developed OAuth with GitHub, Google and Microsoft plugins, and extracted NFC into another plugin, making the process easier for new developers in the VandyHacks organization. To support this, the team also is developing complete documentation to ensure longevity of Vaken and VandyHacks' development processes.

Full management of all applicants with integration using NFC tracking, resume tracking and more.

ELECTRICAL ENGINEERING AND COMPUTER SCIENCE

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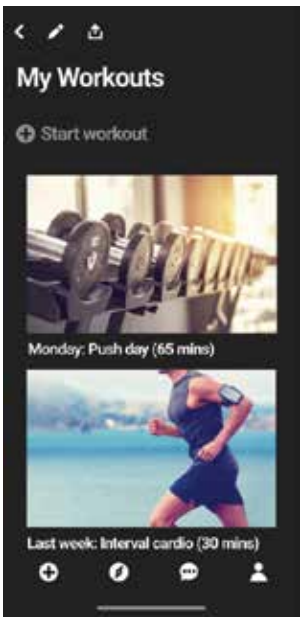
VanderBuilt

Many Vanderbilt students use the Recreation and Wellness Center on a daily basis. However, no up-to-date mobile application designed to enhance the rec center experience exists. The goals of the VanderBuilt app are to connect rec center patrons, provide useful information, and encourage increased use of the center. The app has four main components. The workout component allows users to log workouts. The social media component allows users to post their workouts and view friends' workouts. The group component allows users to belong to groups for the purpose of scheduling pick-up games, and the information component gives up-to-date information on rec center hours and classes. VanderBuilt uses React Native on the frontend to provide functionality on both iOS and Android. The backend uses Node.js and Express for the server, GraphQL for the API, and MongoDB for the database.



User interface for the My Workouts screen.

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ELECTRICAL ENGINEERING AND COMPUTER SCIENCE

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Transcrybit

Currently, there is no method to search an audio or video file for keywords like one can for text documents. With an increase in online media content it is becoming increasingly important to be able to quickly find specific information. Our team developed a web-based application, Transcrybit, using Python and Mozilla's DeepSpeech API, as well as the React Library, JavaScript, CSS, and Amazon Web Services. Using these tools our team has been able to transcribe audio from uploaded audio/video files into text with timestamps, so that the content from these files can be searched as a text file. The associated timestamps from the results of these searches can then be used to direct the user to the keywords in the audio or video file they are searching. The goal for this software to be applied to applications such as Netflix, YouTube, and Spotify as it allows users to more efficiently parse through movies, shows, music, and podcasts.

TRANSCRYBIT

The Transcrybit logo in Weibei SC font, where the i is represented as a magnifying glass looking at audio waves.

VANDERBILT. SCHOOL OF ENGINEERING

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SPONSORS
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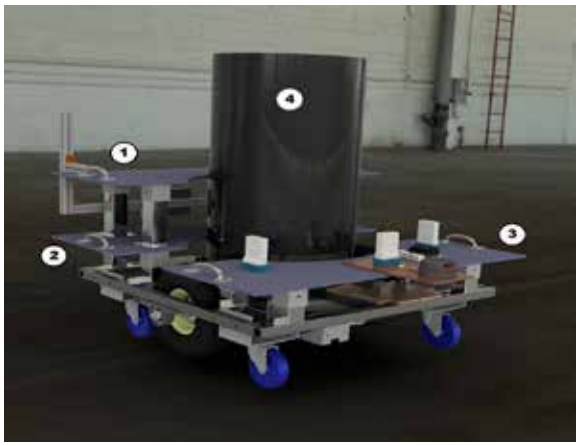
CertaPro Painters North Nashville

MECHANICAL ENGINEERING

Autonomous painting robot

The rising cost of labor and a shortage of workers in the construction/painting industry has prompted automated solutions to reduce time and labor costs. Our team is automating the process of applying finishes to large, horizontal areas such as warehouse floors and roofing systems. We designed an autonomous robotic control workflow conducive to real painting projects, including place localization anchors in the environment, a 3D map of the room, and a starting location for the robot. We selected a sensor suite and developed robot-agnostic autonomy algorithms so that they could be reused on future painting projects. We designed a custom robotic platform. The team focused on modularity by dividing the system into easily removable, serviceable, and upgradeable components. Currently, there are modules for autonomous control computation, power distribution, and coating application. The base robot and frame is able to carry up to 480 pounds and has an open central section to transport a 16-gallon (200 pound) drum of paint, allowing the robot to cover up to 3,200 to 5,600 square feet of floor space without a refill.



A model of the autonomous painting robot in a warehouse environment: (1) Paint Application Module, (2) Power Distribution Module, (3) Computation Module, and (4) 16-gallon (200 pound) central paint vessel.

CertaPro Painters

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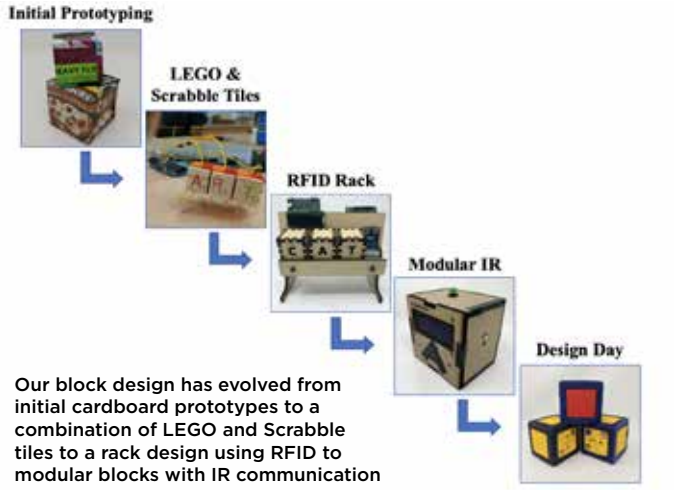
Vanderbilt School of Engineering

MECHANICAL ENGINEERING

Smart alphabet blocks

Alphabet blocks are a classic children's toy, however, without the guidance of an adult, they do not teach children how to spell. We designed and built a set of smart alphabet blocks that communicate whether or not a word spelled with the blocks is a real word. The blocks snap together with magnets, which triggers the sending and receiving of infrared (IR) signals between blocks. The IR signal sent from one block is received by the neighboring block and decoded as a numeric value corresponding to a letter (or letter combination) using the ASCII standard. Once the blocks know what order they are in, the sequence of letters is checked against an onboard dictionary. The blocks then create sensory feedback to communicate to the user if the word they spelled is real or not. These blocks improve over our previous designs because they are modular, wireless, battery-powered, and durable. As a final product, smart alphabet blocks must be safe, durable, affordable, intuitive, and fun.



Our block design has evolved from initial cardboard prototypes to a combination of LEGO and Scrabble tiles to a rack design using RFID to modular blocks with IR communication and to our final design: 3D-printed blocks with silicone edges that communicate using IR signals.

VANDERBILT. PEABODY COLLEGE

VANDERBILT. SCHOOL OF ENGINEERING

MECHANICAL ENGINEERING

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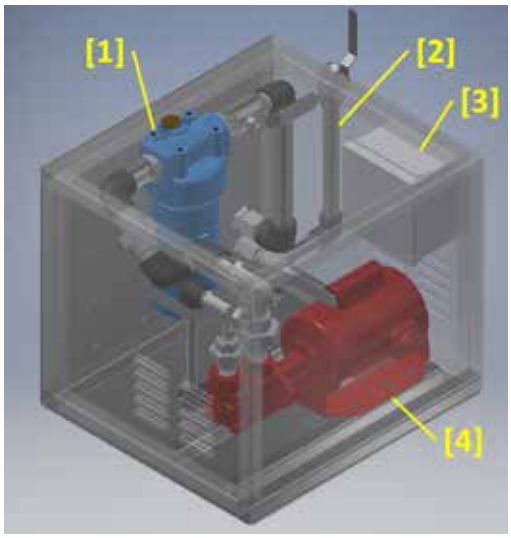
TexTenn Design and Consulting

Comprehensive oil management system for cooling tower gearboxes

Cooling towers use fans to eject heat to the surrounding environment. The fan gearbox is a common point of failure due to the degradation of its lubricating oil. The degradation normally results from particle contamination and overheating. Failures of these gearboxes represent significant financial losses for tower operators. Our project addresses this problem by managing the lubricating oil within the gearbox. The system incorporates two main elements: a base filtration kit and a cooling kit. The base filtration system contains a fine particulate and water filter, a pump, and a level monitoring element. The cooling kit contains a stainless-steel coiled heat exchanger, which addresses the runaway thermal issues common to many gearboxes. Our oil management system allows cooling tower operators to have a stationary solution to the core oil degradation issues, as opposed to the temporary solutions commonly on the market. The system can filter out fine particulates, absorb water, and reduce oil temperature to extend the usage life of the gear oil and ultimately the gearboxes themselves.

TexTenn Design & Consulting



This is the base filtration system with [1] filter assembly, [2] level monitoring attachment, [3] electronics box, and [4] pump with included sensor array, which in combination with the cooling kit [not shown] provide for oil management of a cooling tower gearbox.

MECHANICAL ENGINEERING

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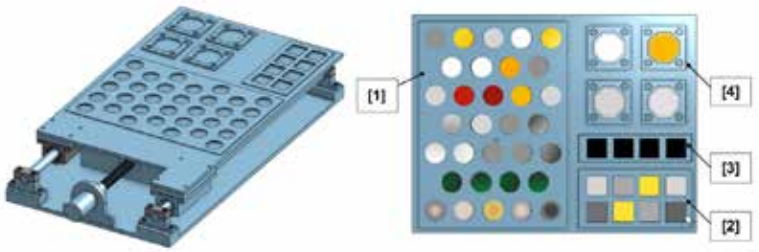
SPONSORS
NASA Marshall Space Flight Center

Lunar specimen holder and materials trade study

NASA's goals for the Artemis and Gateway programs and the long-term goal of lunar ization require better understanding of the adverse effects of lunar dust, micrometeoroid impacts, radiation, and rapid temperature changes. The first undertaking required the team to construct a specimen holder for materials testing on the lunar surface, as well as design a stable deployment method for the experiment's one-year duration. In order to populate the sample tray, the team conducted a materials trade study of promising materials for lunar longevity. The variety of the selected materials from the trade study and their exposure in the designed sample tray will not only allow for a holistic investigation of lunar environmental effects, but also provide valuable insight into future materials for lunar missions.



Left: The Vulcan specimen holder uses linear actuation to deploy and retract the tray populated with the selected promising materials from seven classes. Right: Schematic of the populated sample holder with a total of 48 samples from seven material classes. Holder [1] houses absorbers, radiators, structural materials, environmental sensors, and control samples, [2] houses mirror samples, [3] houses solar cells, and [4] contains multi-layer insulation materials.

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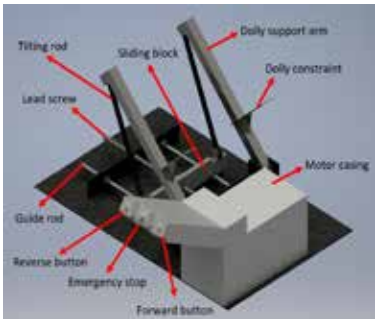
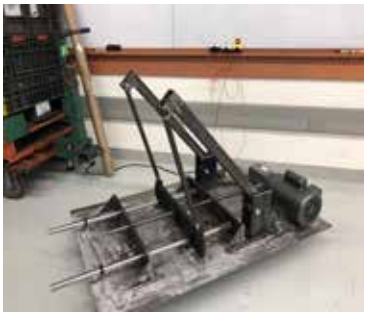
MECHANICAL ENGINEERING

Dolly tilt project

The Nissan plant in Smyrna, Tennessee, uses large dollies to store parts in their work areas. Workers have been climbing on them or using custom platforms to reach parts inside the containers. The goal of this project was to design a safe, repeatable method to tilt these dollies to provide easy access to the parts. Design constraints included that the device must be pneumatic or electric powered, tilt to 50 degrees, fit under the dolly, and have simple operator controls. The team designed and prototyped a device that uses an electric motor to power a leadscrew that drives the tilting mechanism. This design allows for a lower cost device in comparison to many existing hydraulic solutions. The design uses a sliding block that lifts a pair of supporting arms. The finished system will tilt the Nissan part dollies safely into a more ergonomic position for workers.





The dolly tilting system consists of an electrically powered lead screw that moves a sliding block to tilt a dolly to a more ergonomic and safe position for workers. Left, current system; a worker stands on the dolly to reach parts inside. Center, the detailed CAD of the system. Right, the foundation of the newly fabricated device undergoing initial testing.

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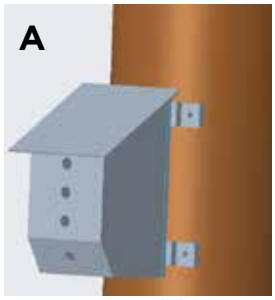
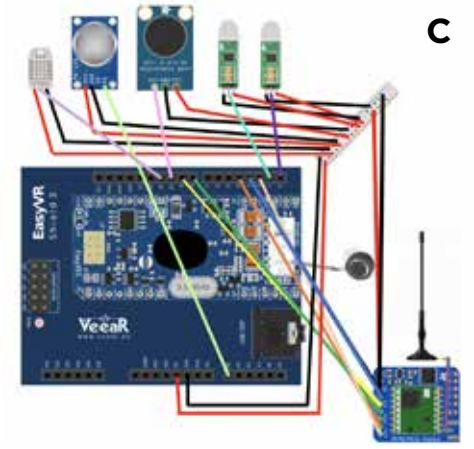
MECHANICAL ENGINEERING

Forest fire prevention and detection system

The goal of this project was to develop a low power, sustainable and affordable forest fire prevention and detection system, with an emphasis on prevention. The final objective was a sensor node that determines the fire risk level based on the following key inputs: passive infrared motion detection, speech recognition, sound level monitoring, temperature, relative humidity, and smoke (air quality) monitoring. The measurements from sensors are analyzed by a microcontroller within the node that wirelessly transmits the calculated risk level via LoRa wireless frequency radio technology. The sensors focus on the detection of human-caused fires, which account for 90% of forest fire events. The project focused specifically on monitoring environmental conditions and human presence for deployment in the San Bernardino National Forest in Southern California. A cost assessment was performed for a mesh network implementation of the nodes that would target key areas of activity in the forest. The sensor node, cost analysis, and risk model create a comprehensive prevention and detection system.

The housing for the sensor system [A] has weather-resistant features, strategically placed holes for optimal detection of humans, and an enclosure designed for easy maintenance. [B] A spring and washer system for the attachment screws allows for tree growth without damaging the tree or the sensor housing. [C] The sensor package and wiring diagram for the forest fire prevention and detection system.





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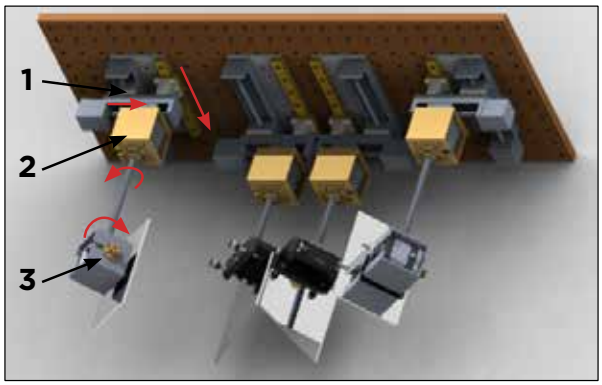
MaierLab Neurophysiology Laboratory, College of Arts and Science

Multi-axis motorized system for visual neurophysiology study

MaierLab is a neurophysiology research laboratory intent on understanding the condition of amblyopia, a form of cognitive blindness, by studying visual pathways and neuronal circuitry in the brain. Testing is performed using a stereoscope system, a mirror assembly used to fuse the test subject's field of view on two identical images in the visual cortex. MaierLab's previous stereoscope was manually calibrated, meaning the operator had to make small adjustments to each mirror by hand while traveling between the control room and the testing room, which took up to 8 hours. We have designed an automated stereoscope system that can be calibrated and controlled from the control room. This automated system has 14 degrees of freedom (DoF): 8 translational and 6 rotational. Each DoF is actuated by a high-precision stepper motor and controlled with modular motor driver board. Precise calibration can be achieved with these actuator units— rotations of less than 0.5° for the rotational components and minimum steps of less than 0.1 mm for the translational components. This automated stereoscope will be controlled through a custom Simulink interface, allowing accurate positioning for calibration and testing of the visual pathways.



Fully automated stereoscope system allows the testing of a subject viewing two identical images to combine the two images together as one in the subject's brain. Translation [1] via linear actuators and a frictionless slider carriage, rotation [2] via stepper motor with attached shaft, and tilt [3] via a dual shaft stepper motor. Red arrows indicate different achievable movements.

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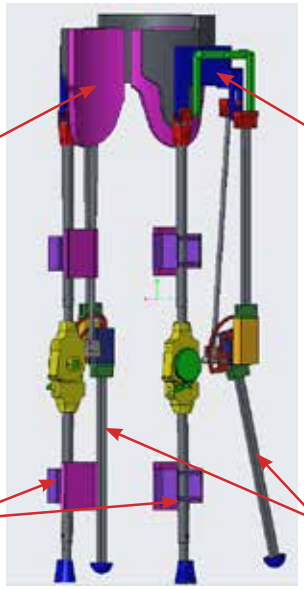
Passive, weight-bearing exoskeleton to assist first responders

Rescuers and first responders must carry heavy loads over long distances. Most lower-limb exoskeletons on the market that aid first responders are powered, making them heavy and expensive. Many are so heavy that the user can walk only at low speeds over short distances, causing delays in response time. We developed an unpowered, weight-bearing, lower-limb exoskeleton that features a rigid harness spanning around the back of the wearer. A backpack straps around the harness to transfer over 80% of the load through the waist and down the legs. Two legs (termed the exo-legs) are securely strapped to the wearer. Two additional legs (termed the free-legs) are offset next to the wearer. The hip joint uses a reciprocal gait orthosis to control the motion of the free-legs. At any point in the gait cycle, two legs are on the ground supporting the weight of the load. This design is self-standing, allowing the user to step out of the exoskeleton to load the backpack or attend to the task at hand. Ultimately, this design will allow first responders to avoid fatigue and injury while carrying heavy equipment.



The passive exoskeleton features [1] a rigid waist harness, [2] reciprocal gait orthoses at the hips, [3] two "exo-legs" and [4] two "free-legs," each with lockable knees.

CREATE CENTER FOR REHABILITATION ENGINEERING + ASSISTIVE TECHNOLOGY

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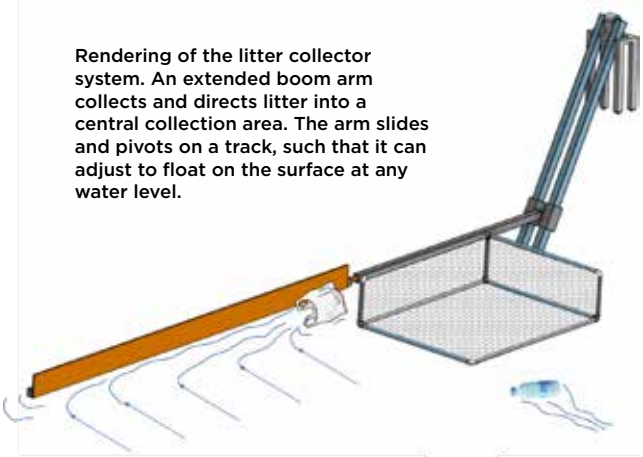
MECHANICAL ENGINEERING

Repeatable river litter collector

The Cumberland River experiences a high concentration of litter after rainfall events, mostly flowing into the river from tributaries. The litter eventually degrades into micro particles that negatively impact wildlife and human health. The Cumberland River Compact enlisted our team to design a litter collection system that can be placed in streams in Nashville to capture surface litter before it reaches the Cumberland. Our passive system uses the flow of the water to direct trash along an angled arm into a floating collection bin. The collection bin will slide on an anchored rail, allowing it to account for water level changes of over 20 feet while staying firmly planted in any river bank. Our goal is to provide a long-term and cost-effective alternative to the CRC's events during which volunteers collect the surface litter in these tributaries. These cleanups happen a few times a year and cost approximately $500 per cleanup day. Ideally, this device will keep the Cumberland River cleaner and protect the health of wildlife and the local population.



Rendering of the litter collector system. An extended boom arm collects and directs litter into a central collection area. The arm slides and pivots on a track, such that it can adjust to float on the surface at any water level.

CUMBERLAND RIVER COMPACT

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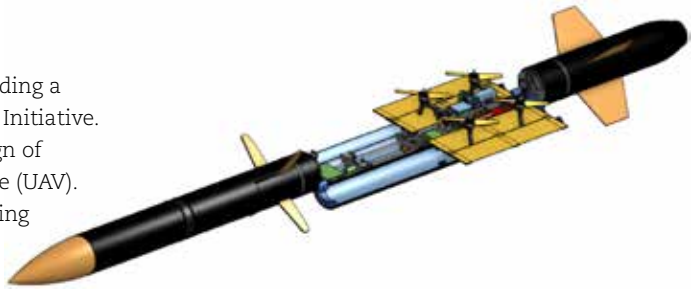
MECHANICAL ENGINEERING

Vehicles for planetary ice sample collection

The Vanderbilt Aerospace Design Laboratory is designing and building a rocket and payload to compete in the 2020 NASA Student Launch Initiative. Our design team is primarily responsible for the mechanical design of the launch vehicle (rocket), charging station, and excursion vehicle (UAV). The rocket will fly to a target altitude of 3,750 feet before descending under two parachutes. Upon landing, the payload bay section of the rocket will orient skyward and open, releasing the UAV and charging station payload. This UAV will autonomously navigate to a sampling zone containing a planetary ice simulant. There, it will actuate a sampling tool to collect 15 mL of simulant without landing, enabling sample collection in challenging environments and without remote communication. The UAV will then navigate back to the rocket and land on the charging station to recharge for another sampling mission, enabling sample collections from multiple locations. Further, air-based sampling, recharging, and autonomous navigation/control will demonstrate robust, repeated, and communication-free planetary sampling missions.



The 10-foot long launch vehicle carries a UAV and charging station for repeatable, autonomous, air-based sampling missions.

VADL VANDERBILT AEROSPACE DESIGN LABORATORY

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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 demonstrated on Design Day 2020 and have transformed our Class of 2020 into young professionals.

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