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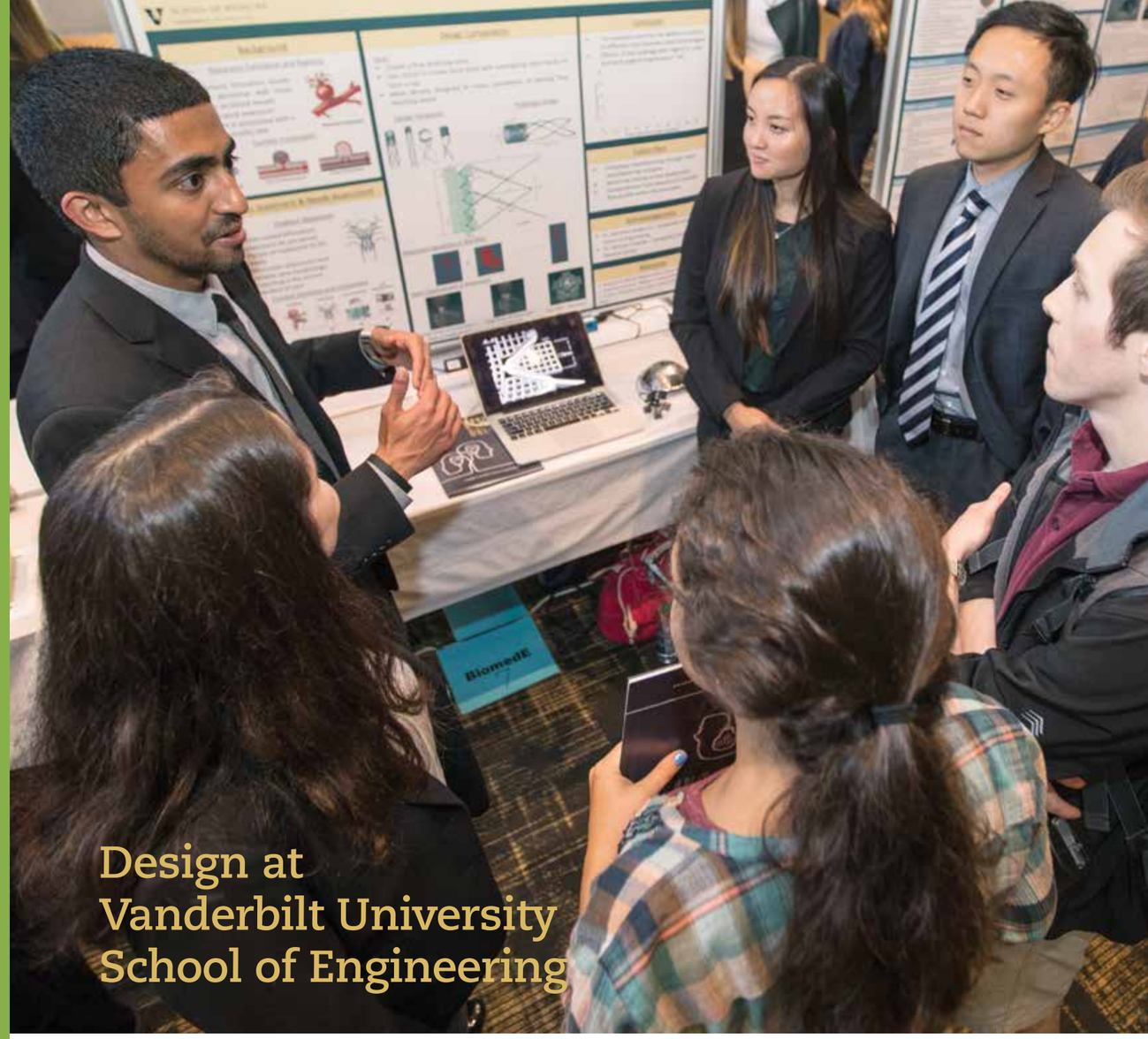


Design at Vanderbilt University School of Engineering

CONTENTS

Summer 2017

Engineering design is inherently an immersive process. It involves an enormous amount of time and demands focused attention. As projects grow in complexity, the design experience becomes even more immersive. The goal, of course, is showing, rather than telling, how something works or how a specific solution solves the problem at hand.

The best attempts change beliefs and open the gate to new possibilities.

Every year, thousands of engineering students in the U.S. and around the globe demonstrate their savvy by presenting senior design projects to their peers. While some have considered this a mere graduation requirement, we look at the deeper meaning of the experience. By throwing ourselves into an ill-constrained, multidisciplinary project, we at the School of Engineering learn how to defend decisions, work within constraints, and draw from the sum of our experiences.

This publication represents what is so fantastic about engineering design and problem solving as immersive experiences. The undergraduate and graduate students as well as the faculty members you will read about here immerse themselves in ideas, challenges, and projects that directly benefit people.

The benefits may be economic, social, medical, industrial, or personal. The ideas may be ready for implementation or the launch of further investigation and design en route to a finished product that changes or saves lives. With more and more interdisciplinary research at the School of Engineering, the scope of projects is remarkable.

This year, our featured projects range from a bridge to better the daily lives of residents to building cheaper batteries and from making a hospital stay more pleasant to more effectively diagnosing disease. I am so proud of the mix of work that unfolds here, and I hope you enjoy this glimpse into what we do as much as we enjoy doing it.

The diversity of ideas and solutions continues to advance our profession and improve the lives of many. I'm sure you join me in eagerly looking forward to the innovations from our students and faculty members next year.

Best regards,

Philippe M. Fauchet

Philippe M. Fauchet
Dean, School of Engineering
Dean's Chair in Engineering
Professor of Electrical Engineering

Bridge will improve Honduran villagers' lives

During the rainy season, the Rio Grande swells to such levels that residents of San Esteban, a village in the Agalta Valley of Honduras, struggle to reach schools, clinics and jobs. Getting to the nearest bridge means a four-hour walk, and the only other option is attempting a dangerous and potentially fatal river crossing.

Paloma Mendoza (BE'17), president of the Society of Hispanic Professional Engineers at Vanderbilt, and teammates Jake Van Geffen (BE'17) and Luke Van de Vate (BE'17), all civil engineers, designed a new pedestrian bridge for the village. Van Geffen and Van de Vate traveled to San Esteban in May 2016 to check out the site, take geotechnical samples and make initial calculations.

The 180-foot-long pedestrian bridge needed to be long-lasting as well as sustainable. The team decided a suspension bridge with wooden planks would be the most affordable while best addressing the site and the community's needs. Unlike a steel bridge, materials for a pedestrian suspension crossing are readily available and don't need to be imported. Additionally, should a board loosen or fall off, Esteban residents can make repairs without the need of a steel worker or expensive equipment.

"The trickiest part was finding how far back from the river we should build the towers," Mendoza said. "You want to figure out what you can do to make it work but not overdo it where the cost-benefit analysis doesn't make sense."

Each week, the team members set deadlines for themselves to complete difficult calculations. They worked closely with professional engineers and other experts, including advisers Kevin Colvett of CH2M Hill and Mark Warriner of LDA Engineering, to refine the design and ensure it would work.

Construction is scheduled to begin in August and finish in 2018. The project partner is HOI — formerly Honduras Outreach Inc. — a nonprofit organization that sponsors more than 50 mission trips to Honduras and Nicaragua each year.

Mendoza, whose summer internship conflicted with the team's trip to the Agalta Valley, hopes to see it someday.

"People there really do risk their lives trying to cross the river," she said. "Helping someone, even if I never meet them — that is what drew me to the project."

Facing page: Jake Van Geffen (BE'17) stands in the Rio Grande near San Esteban, Honduras, taking measurements for his team's pedestrian bridge.

Left: Paloma Mendoza (BE'17)

Below: A CAD model of the bridge that team members designed for workers to build later this year.

Bottom of page: Team members built one section of the bridge to show at the School of Engineering's annual Design Day event on April 24.

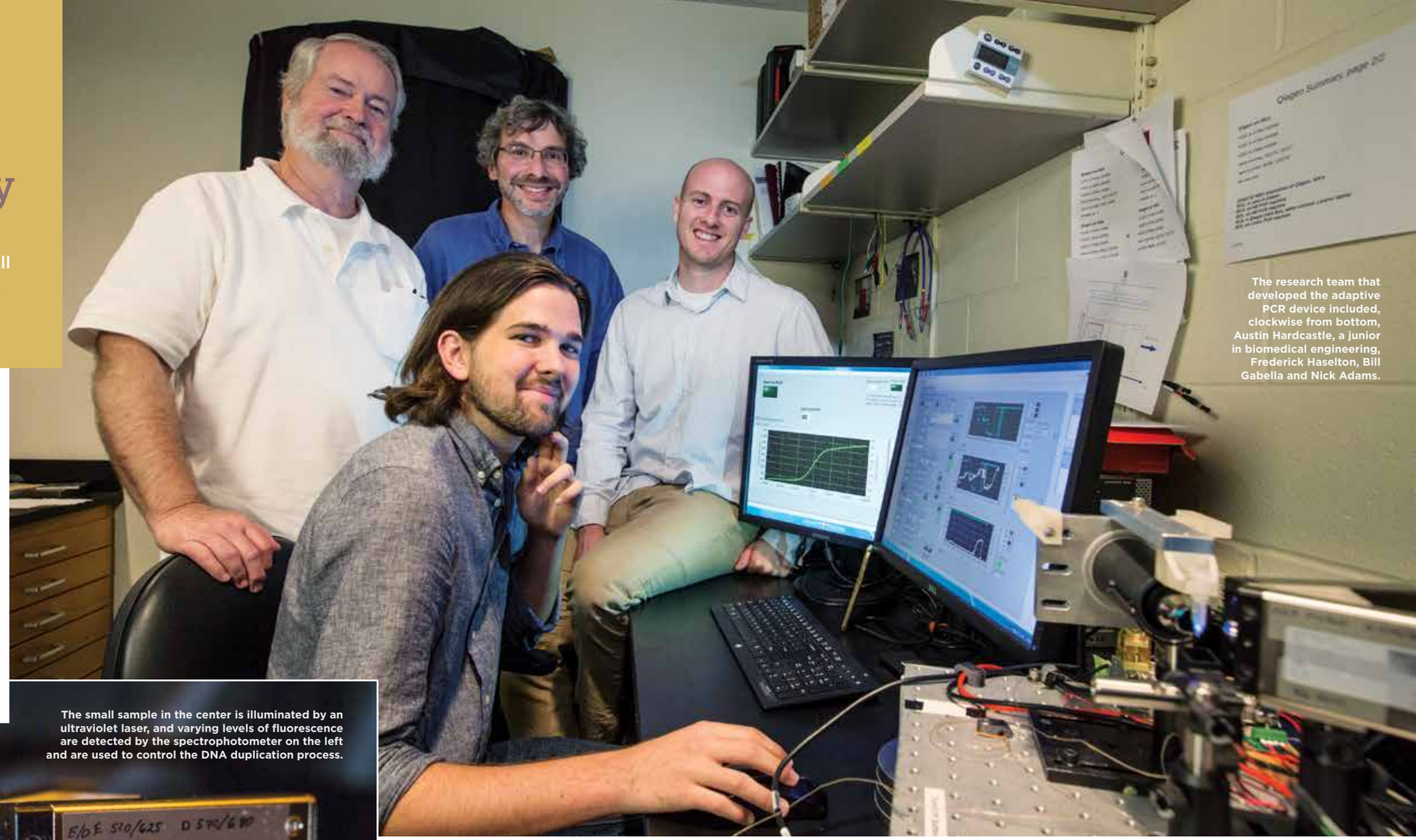
A quicker, easier way to copy DNA for research is on the way

To conduct molecular and genetic analyses, researchers need billions of identical copies of small DNA segments. Polymerase chain reaction, or PCR, has been the go-to process for nearly 25 years.

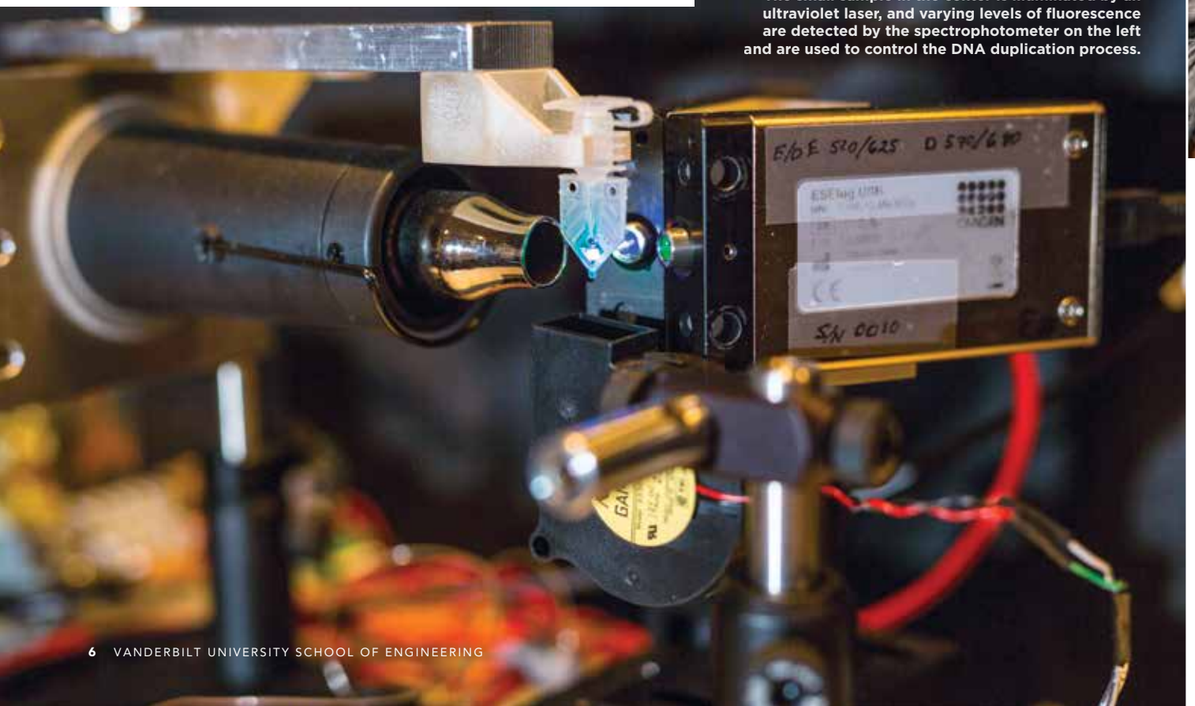
The process is powerful but finicky, requiring extremely controlled conditions, weeks of equipment calibration and running samples in triplicate in case one of the machines fails.

Enter "adaptive PCR," a new method for controlling DNA duplication that was devised by Frederick Haselton, professor of biomedical engineering, and Nicholas Adams, research assistant professor of biomedical engineering. Their breakthrough, for which Vanderbilt has submitted a patent application, makes copying DNA quicker, easier and more portable.

It could lead to a hand-held DNA photocopier that identifies the bacteria or virus causing an infection even before symptoms appear.



The research team that developed the adaptive PCR device included, clockwise from bottom, Austin Hardcastle, a junior in biomedical engineering, Frederick Haselton, Bill Gabella and Nick Adams.



The small sample in the center is illuminated by an ultraviolet laser, and varying levels of fluorescence are detected by the spectrophotometer on the left and are used to control the DNA duplication process.

Adaptive PCR uses left-handed DNA to monitor and control molecular reactions in the PCR process. Left-handed DNA, which mirrors the DNA found in all living things, has the same physical properties as regular, right-handed DNA, but it does not participate in most biological reactions. Adding a fluorescently tagged L-DNA to a PCR sample creates signals that monitor molecular reactions and can be used to control them.

The new method promises increased ease and reliability. It reduces PCR's sensitivity to environmental conditions and shrinks the machines themselves from desktop to handheld size. As such, adaptive PCR could be used at the bedside to identify different diseases by their DNA signatures.

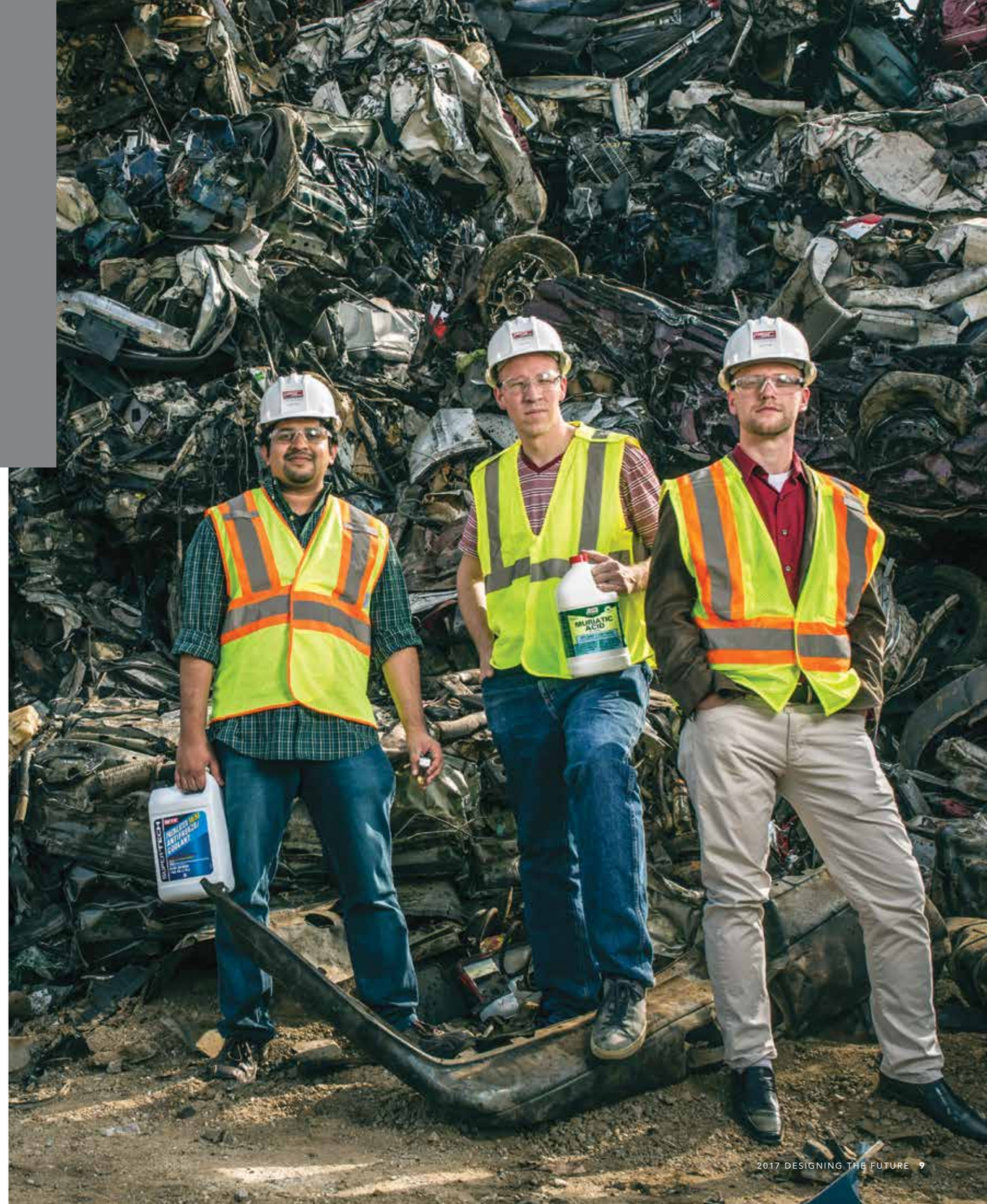
The prototype adaptive PCR machine has duplicated the results of conventional PCR machines in controlled conditions. It also amplified DNA under conditions where conventional PCR machines failed.

"These advantages have the potential to make PCR-based diagnostics more accessible outside of well-controlled laboratories, such as point-of-care and field settings that lack the resources to accurately control the reaction temperature or perform high-quality sample preparation," Adams said.

The development was supported in part by the Bill & Melinda Gates Foundation through its Grand Challenges in Global Health Initiative in Diagnostics program and the Vanderbilt-Zambia Network for Innovation in Global Health Technologies program funded by the National Institutes of Health.

Research team engineers high-performance battery from junkyard scraps

Take some metal scraps from the junkyard; put them in a glass jar with a common household chemical; and, voilà, you have a high-performance battery.



Above: A prototype of the high-performance junkyard battery.

Facing page: Nitin Muralidharan, Andrew Westover and Cary Pint, the team that created the prototype junkyard battery.

"Imagine that the tons of metal waste discarded every year could be used to provide energy storage for the renewable energy grid of the future instead of becoming a burden for waste processing plants and the environment," said Cary Pint, assistant professor of mechanical engineering.

Pint and a team of undergraduate and graduate students created the world's first steel-brass battery that stores energy at levels comparable to lead-acid batteries while charging and discharging at rates comparable to ultra-fast charging supercapacitors.

The key is anodization, a common chemical treatment that gives aluminum a durable and decorative finish. Anodizing scraps of steel and brass using nonflammable water electrolytes, which contain potassium hydroxide, commonly found in laundry detergent, and residential electrical current restructured the metal surfaces into nanometer-sized networks of metal oxide. The networks store and release energy when reacting with a water-based liquid electrolyte.

These nanometer domains explain the speedy charging, as well as the battery's exceptional stability. After testing for 5,000 consecutive charging cycles, the equivalent of more than 13 years of daily charging and discharging, the steel-brass battery retained more than 90 percent of its capacity.

"When our aim was to produce the materials used in batteries from household supplies in a manner so cheaply that large-scale manufacturing facilities don't make any sense, we had to approach this differently than we normally would in the research lab," Pint said.

Research project co-authors include Andrew Westover (PhD'16) and Nitan Muralidharan, a graduate student in the interdisciplinary materials science program. The team also included undergraduate and graduate students in mechanical engineering.

The next step is to build a full-scale prototype battery suitable for use in energy-efficient smart homes.

"We're forging new ground with this project, where a positive outcome is not commercialization but instead a clear set of instructions that can be addressed to the general public. It's a completely new way of thinking about battery research," Pint said.

The work was supported by grants from the National Aeronautics and Space Administration, the National Science Foundation, and a Vanderbilt Discovery Grant. PSC Metals in Nashville provided access to its scrap metal facility.

Innovation Garage teams work with the Wond'ry, Accenture pros to invent and disrupt

The two team names for Vanderbilt's Innovation Garage arguably cover most of what innovation is: Team Invent and Team Disrupt.

Jessica Banasiak, far left, a junior in chemical engineering, describes to her Innovation Garage team and advisers a specific element of an app she helped design.

Innovation Garage is the result of a partnership between the Wond'ry, Vanderbilt's epicenter for innovation and entrepreneurship, and Accenture PLC, a global consulting company that works with clients on strategy, technology and operations. The idea is to give cross-disciplinary teams of students a yearlong experience solving real problems with the aid of Vanderbilt professors and top Accenture executives.

The first team designed an app that matches qualified workers with oil industry tasks — basically, the TAKL of that industry. The second deconstructed a large manufacturer's supply chain to figure out why certain parts didn't show up on time and what could be done about it.

At one spring meeting, Team Invent came together — in person and on Skype — in a sunlit Wond'ry conference room to discuss progress on the app and the pitch video they wanted to make to promote it. The three-person team included engineering science major Luke Price and chemical engineering major Jessica Banasiak, both juniors who said they were there to learn from the pros, and a teammate who is pursuing his MBA.

"Most of my classes are with students who have the same major," Banasiak said. "Innovation Garage is helping integrate the things I'm learning about the oil industry through the lens of chemical engineering with other facets of that business."

She told her team, led by Doug Schmidt, Cornelius Vanderbilt Professor of Engineering and professor of computer science and computer engineering, about her idea to focus more attention on the toughest-to-fulfill tasks the app will address and integration of oil well location data.

At the same time, Team Disrupt was using multiple regression analysis, looking at more than a half-million purchases made across several years to produce an algorithm. Their instructor, Dave Berezov, associate professor of the practice of engineering management, said the Innovation Garage work mirrors assignments students are likely to receive in their first jobs.

"They're also getting direct working experience with professionals up to the senior executive level of one of the largest consulting firms on Earth," Berezov said. "I tell them that the first-year associates usually get a view of the parking lot, but they're getting a look from the C-suite."

His team developed the algorithm to enable their client to identify parts orders most likely to experience delivery delays and address those earlier, preventing interruptions in the manufacturing process.

Optic sensor lights way for faster IBD diagnosis

An optical sensor developed by Vanderbilt researchers may allow doctors to more objectively identify inflammatory bowel disease, distinguish among its two subtypes and better evaluate treatment effectiveness.

Anita Mahadevan-Jansen, photographed here in her laser laboratory, has developed a new optical sensor that can accurately detect different types of inflammatory bowel disease.

IBD is a chronic inflammation of the gastrointestinal tract, and its two main subtypes, ulcerative colitis and Crohn's disease, have different molecular signatures. The new sensor, which could be used during routine colonoscopies, not only can identify the subtype but also determine the inflammation level of the intestinal wall. With current technology, doctors can only identify the symptoms and then make their best guess at which underlying disease to treat.

IBD affects at least 1 million U.S. adults, including many whose symptoms are fairly advanced by the time of diagnosis.

"With current methods, ultimately the diagnosis is dependent on how the patient responds to therapy over time, and you often don't know the diagnosis until it's been a few years," said Anita Mahadevan-Jansen, Orrin H. Ingram Professor of Biomedical Engineering and director of the Biophotonics Center at Vanderbilt University.

She invented the first-of-its-kind sensor. The customized endoscope uses Raman spectroscopy, the chemical-fingerprinting technique, to detect molecular markers of IBD in the colon.

After further refining, the device should enable doctors to diagnose IBD more quickly and accurately. Doctors now use a combination of radiology and pathology to diagnose the subtype and guide treatment decisions.

Without an objective gold standard, up to 15 percent of patients are diagnosed with indeterminate colitis, meaning the subtype is unknown, and up to 14 percent have their IBD reclassified based on their response to treatment.

"Most people go through a baseline colonoscopy as part of routine care, and you could imagine using this to get a baseline Raman signal for each person," said Mahadevan-Jansen. "If someone presents with IBD symptoms later on, our system then determines if it's more likely to be UC or Crohn's. Once treatment starts, you have an objective measure to track the response because you can then use the device to quantify mild, moderate or severe inflammation."

The device also can detect early indicators of IBD before observable changes in the intestinal tissue.

The team is refining algorithms to help doctors interpret test results, looking at how gender, diet, demographics and treatment regimen influence the Raman signature.

"It's a unique way of thinking about personalized medicine that takes into account all sorts of information — beyond just the genome — including demographics and many other factors that make a person unique," said Mahadevan-Jansen.

PredictGov uses machine learning, Big Data to forecast congressional action

A recent Vanderbilt computer science Ph.D. is making waves with a platform that scores bills' chances of being enacted.

What elevates PredictGov above other tracking systems is that it accounts for hundreds of variables and updates the prognosis every 24 hours.

The company behind PredictGov, Skopos Labs Inc., was accepted into the inaugural class of the Law Tech Lab at Duke University and placed second in the accelerator's pitch competition in April. It also has partnered with GovTrack.us, a popular resource for tracking federal legislation. GovTrack embeds the score on the page for each bill, exposing the ranking platform to an audience likely to top 10 million unique users this year alone.

Creator John Nay (PhD'17) said PredictGov takes into account factors within the political process, such as the bill's sponsor, co-sponsor and amendments, as well as external factors, such as economic trends and financial indicators. Users easily can see how similar measures fared in the past and what main factors contribute to the current score.

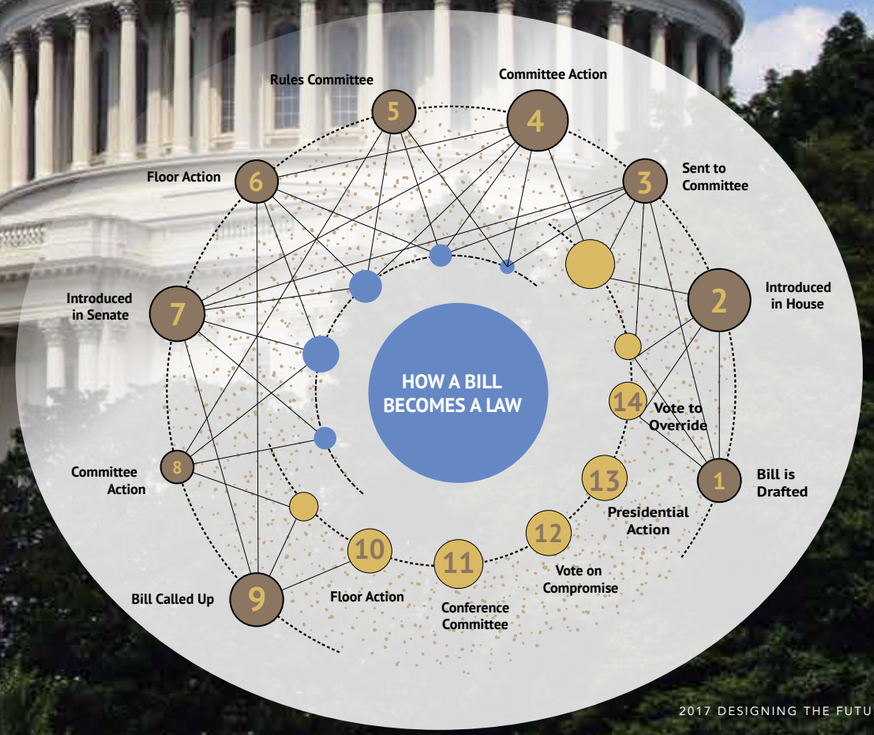
"Beyond predicting the likely outcome, we provide understanding of the context of the bill," said Nay, whose research focuses on machine learning, natural language processing and forecasting.

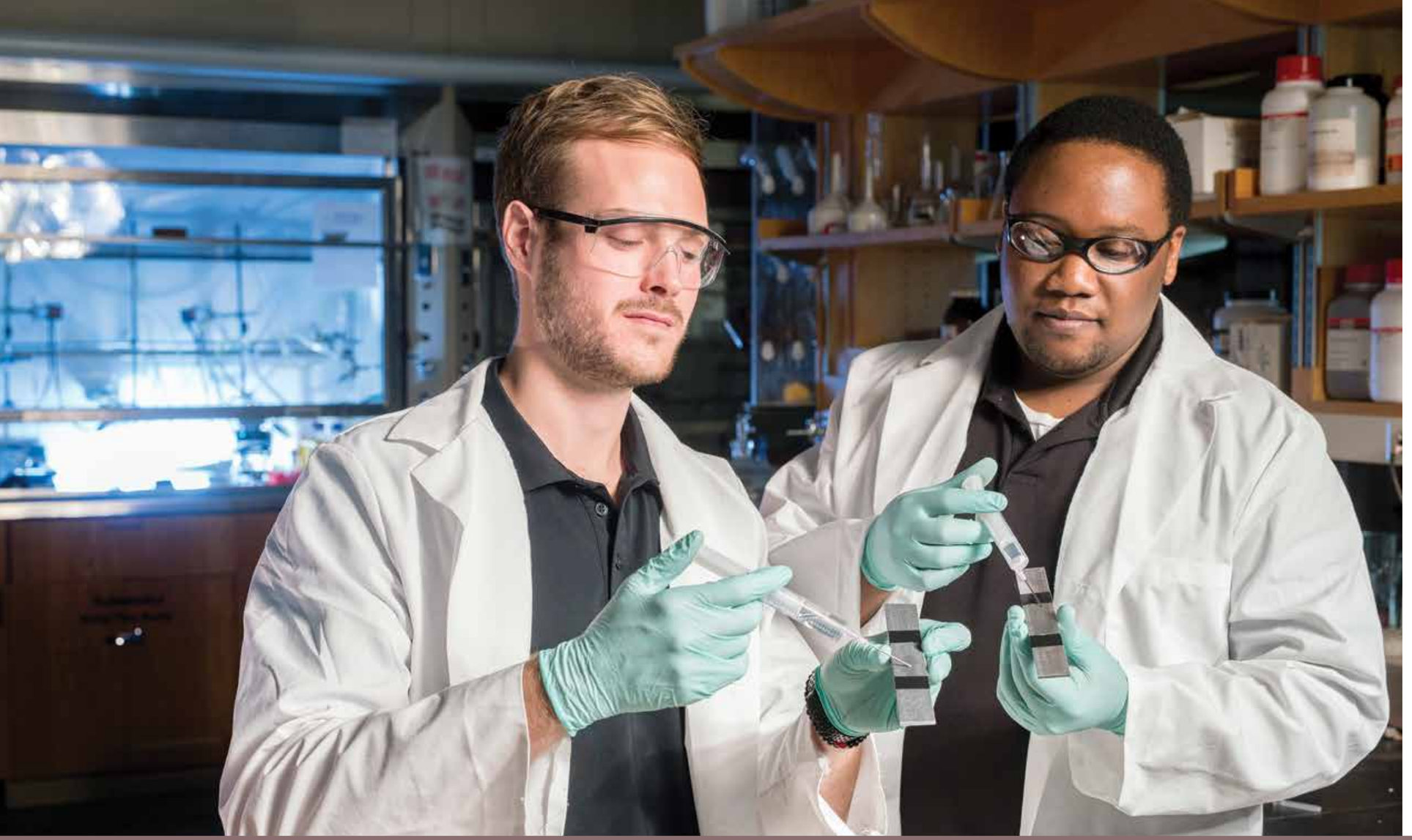
PredictGov will help lobbyists, advocates and citizens focus their efforts and fine-tune strategies as circumstances change. The platform is intentionally agnostic and not designed for any political party or group, Nay said.

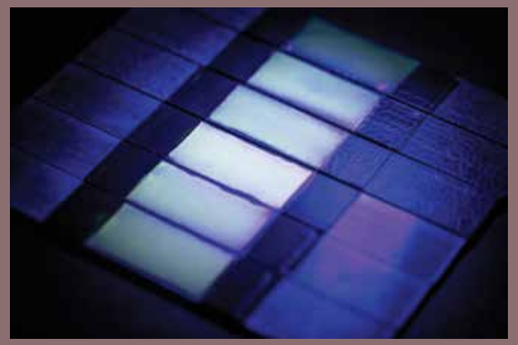
The underlying technology has the potential for broader applications, including the assessment of online news for so-called fake stories and, in the financial world, tracking changes in a company's value. Nay and two other co-founders — Professor J.B. Ruhl, who directs the Vanderbilt University Program on Law and Innovation, and Professor Oliver Goodenough, director of the Center for Legal Innovation at Vermont Law School — have incorporated as Skopos Labs with PredictGov as the first offering.

Even the most experienced congressional analyst couldn't sift through the sheer numbers of data points that PredictGov does, Ruhl said, and that makes it a valuable tool. "It doesn't replicate human judgment but provides insights that help people make judgments," he said.

The team's venture is aptly named. Derived from "teleskopos," the Greek word for far-seeing, skopos also is used to describe one theory of translating text.







‘Mood ring materials’ hold potential key to infrastructure’s future

Materials treated to show whether they’re structurally sound or failing could play an important role in minimizing and mitigating damage to the nation’s infrastructure.

Cole Brubaker, left, a doctoral student in civil engineering, and Ian Njoroge, a doctoral student in chemical engineering, manipulate quantum dots.

Far left: Fluorescent nanoparticles that can be incorporated into materials to indicate risk of structural failure.

The American Society of Civil Engineers has estimated that more than $3.6 trillion is needed by 2020 to rehabilitate and modernize the nation’s failing infrastructure. An important element in any modernization effort will be the development of new and improved methods for detecting damage in these structures before it becomes critical. That is where “mood ring materials,” as the team that developed the technology dubbed them, come in.

A cross-disciplinary team of researchers is incorporating fluorescent nanoparticles into construction materials. Those particles react to stress by changing their appearance, creating a new kind of detection system that can monitor structures in an efficient and cost-effective fashion, said Cole Brubaker (MS’16), a doctoral student in civil engineering at Vanderbilt University’s Laboratory for Systems Integrity and Reliability.

The team’s initial studies showed adding a tiny concentration of special nanoparticles — called white light quantum dots — to an optically clear polymer matrix produces a distinctive light signature that changes as the material is subjected to a broad range of compressive and tensile loads.

The researchers theorize that the quantum dots emit light in a broad spectrum because more than 80 percent of the atoms lie on the surface. They also know that the bonds between the surface atoms and molecules surrounding them play a critical role.

The result: A permanent record of how much stress the underlying material has experienced. The researchers have verified that the material can act as a new kind of strain gauge that records the cumulative amount of stress applied to it.

The team has many challenges to overcome before the mood-ring materials are ready for commercialization. Among them are reading the particles when stresses on materials force them closer together and light bleaching out the quantum dots, making them impossible to read.

Professor of Chemical and Biomolecular Engineering Kane Jennings, another member of the team, said they’re still working on why the quantum dots respond as they do. “Entrapping these quantum dots in ultrathin polymer films on metal surfaces can provide advance warning when the underlying metal is about to sustain physical or chemical damage,” he said.

The Wond'ry makerspace opens doors to Children's Hospital solutions

Solutions to real-life problems at the Monroe Carell Jr. Children's Hospital at Vanderbilt ranged from the delightfully whimsical to the disarmingly simple, designed by engineering undergraduates and MBA students teaming up in a state-of-the-art makerspace.

The New Product Design and Development course, offered for 15 years by David Owens, professor for the practice of management and innovation and professor of the practice of engineering management, got a priceless boost this year. Owens delivered lectures on intellectual property and took students through exercises in the design process inside the Wond'ry, Vanderbilt's new makerspace. They also used its work areas and equipment to build their prototypes.

In a screen-and-cubicle world, Owens said, opportunities to learn through tinkering are valuable but all too rare. It's one thing to talk about a solution and another to hand one to the client.

"It's not surprising that the maker explosion is happening as our world goes more virtual," Owens said. "It's energizing to put something you made in front of people, and we never had the space before to do that very well. We were scraping for shop space."

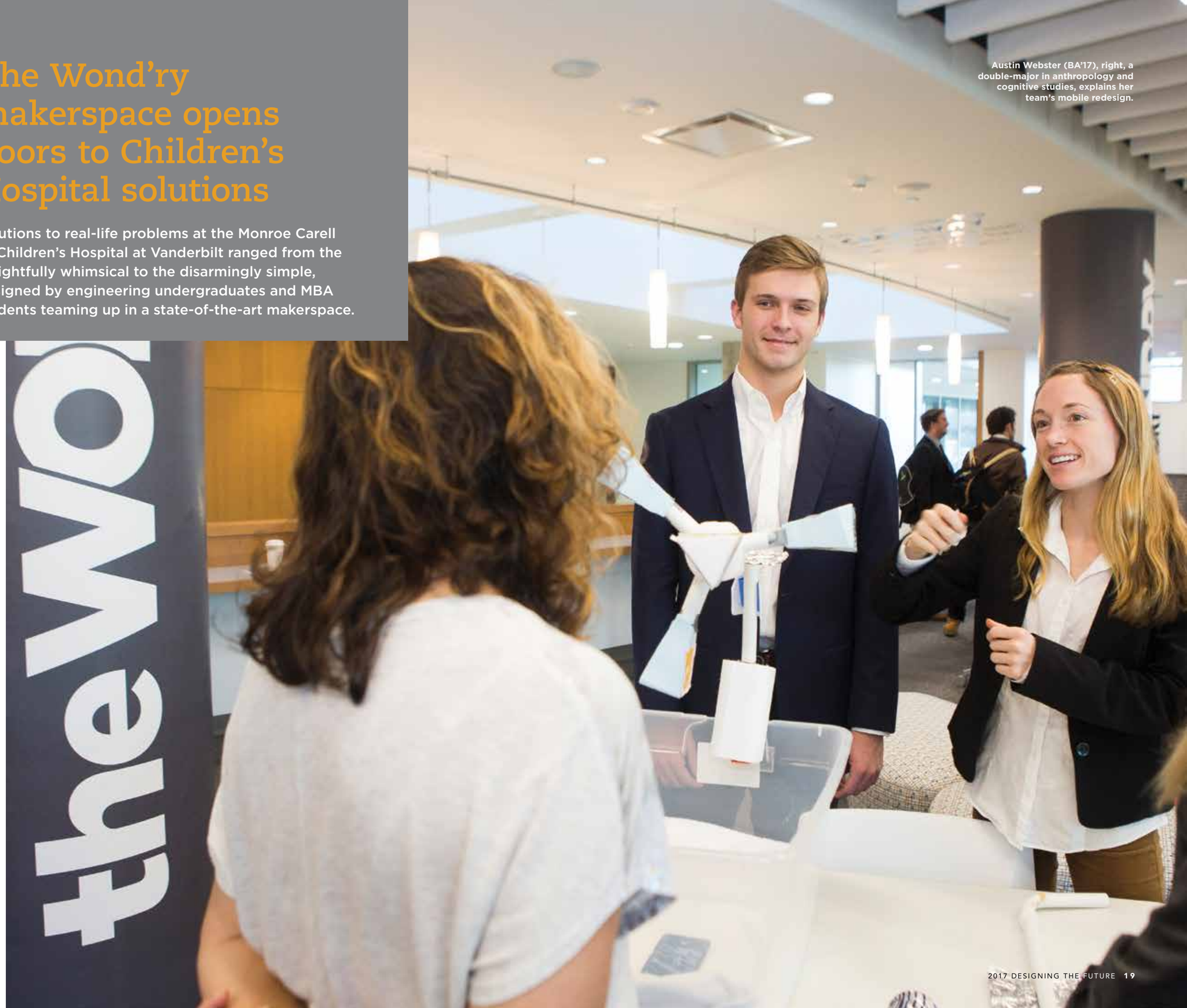
Teams present their designs tradeshow style at the end of the course and are prepared to discuss their process, per-unit cost, manufacturing challenges and a variety of other considerations for consumers. In the most recent round of presentations, a fragrant booth offered a solution to workplace stress — a stick-on aromatherapy pad that allows users to breathe in lavender and eucalyptus, the designers said, plus shows colleagues that they may need extra understanding and support.

A few feet away, Adetayo Ajayi (BS'17) showed visitors a better way to ensure ventilation equipment is easy to access, sterilized and ready to use. All the tools fit precisely into a vacuum-formed plastic tray made in the Wond'ry, he said.

Another team, asked to come up with an entertaining, educational mobile for cribs that was easy to clean, easy to remove and gender-neutral, presented one that moves vertically like a Ferris wheel.

New Product Design and Development gets students thinking in a different way, said Kyle Eason, an MBA whose team designed an easy way to check if children's IV lines are staying put. They installed a small, plastic window with an LED light inside the standard hand brace the hospital uses.

"You're working with very talented engineers and very smart people from all different backgrounds," he said. "The biggest thing I'm taking away is learning to adapt products to the needs of people. To know where products come from and what people do to get them to market is invaluable to my business education."



Austin Webster (BA'17), right, a double-major in anthropology and cognitive studies, explains her team's mobile redesign.

Professor Robert Webster and Sinead Miller with the device developed to treat sepsis.

Professor passes down lessons in entrepreneurship after I-Corps experience

Robert Webster III launched his first company, Virtuoso Surgical, in April 2016 and completed the National Science Foundation's I-Corps program for new tech companies a few months later.

By the start of fall semester, the associate professor of mechanical engineering was passing along the lessons he learned to eight young entrepreneurs in a new class for both graduate and undergraduate students. IMPACT (Initiating, Maximizing, Promoting, and Accelerating Commercialization and Translation) is a version of I-Corps that is adapted to medical devices and includes Webster's own experience.

"Making it applicable to medical devices meant adding information on regulatory and intellectual property issues," he said. "I-Corps also requires participants to speak to 100 potential customers, but I asked students to speak to 70 to accommodate their other classes and research."

IMPACT is a cooperative effort between the Vanderbilt Institute in Surgery and Engineering and the Vanderbilt Center for Technology Transfer and Commercialization aimed at helping students launch their own companies. They also heard from lecturers from the School of Medicine and various engineering disciplines and worked in labs.

For the final, students pitched their companies to an audience of engineering and medical professors, fellow graduate students, physicians and nurses, and fielded tough questions about devices.

For the inaugural IMPACT class, the teams were:

- **LumaSil,** biomedical engineering master's student John Mendoza (BE'16) and mechanical engineering Ph.D. student Patrick Anderson. Their device uses blue and infrared light to treat chronic diabetic wounds.
- **SpineX,** mechanical engineering Ph.D. students Matthew Yandell and Erik Lamers. The team created a $200 fabric exoskeleton to help nurses lift patients safely.
- **KickIt Health,** Kevin Cyr (BE'17) and mechanical engineering Ph.D. student Patrick Wellborn. They redesigned the IV stand for more base stability and to encourage patients to walk.
- **PATH EX,** Sinead Miller (MS'15, PhD'17) and mechanical engineering Ph.D. student Frederico Campisano. Their device treats the root cause of sepsis by removing bacteria and endotoxins from the blood.

Other IMPACT instructors were Byron Smith (MS'12) and founder of EndoInSight Inc., and Chris Harris, Vanderbilt Center for Technology Transfer and Commercialization's director of licensing.

Treating the root cause of sepsis

Sinead Miller (MS'15, PhD'17) said IMPACT was the most useful course she took at Vanderbilt. That's undoubtedly because she launched her company, PATH EX, in the middle of the semester.

PATH EX is testing a device that treats the root cause of sepsis by removing bacteria from the blood in a process similar to dialysis. With the oversight of Professor of Biomedical Engineering Todd Giorgio, she designed a device that captures and removes a multitude of blood-borne pathogens, including *Acinetobacter baumannii,* a leading cause of sepsis worldwide. Its associated mortality rate reaches upwards of 72 percent.

"At the beginning of the course, I did not know the first thing about starting a company, regulatory strategy or figuring out the customer's actual needs vs. what I think those needs are," Miller said.

After learning those fundamentals, she set out to advance her company by raising capital and applying to a business accelerator.

Nashville's artistic bike racks get maintenance boost from mechanical engineers

A problem must be defined before it can be solved — a lesson strengthened for a five-student team of mechanical engineering seniors by taking on a project for Nashville's Public Art Program.

Alexander Plevka, Aisyah Areena Zainal Abidin, Benjamin Streeter, Khairunnisa Aqilah Md Ridzuan and Emily Entrekin — all BE'17 mechanical engineering graduates — designed a locking mount so city workers easily can remove future decorative bike racks or similar public art pieces and take them in to the shop for repair or repainting.

The idea didn't come to them right away. With the city's entire public art collection to consider, the team decided to put their focus on the maintenance challenges of the unusual bike racks, which include some shaped as sound waves, flowers and even a banjo.

When a bike rack needs attention, workers are forced to break up the concrete posts or try to repair and paint the rack at the site. Those approaches have been difficult, inefficient and costly.

Anne-Leslie Owens, a Nashville Public Art project coordinator who worked with the team, said their plan made sense since the racks are prone to damage and pranks.

"They get a lot of wear and tear. Paint chips off and the metal starts to rust. One bike rack ended up in a tree," she said. "There are a lot of different maintenance issues, and we learned we needed a better system to install them."

The Vanderbilt team's creation went through four iterations of design, test and build. The final design features a sealed lockbox on a steel rod set in a concrete cylinder. The box fits into a compartment in the middle of the cylinder, which will be flush and not visible, allowing workers to remove and reinstall smaller bike racks and artwork as necessary. The device has the potential to cut the city's costs on such projects by half.

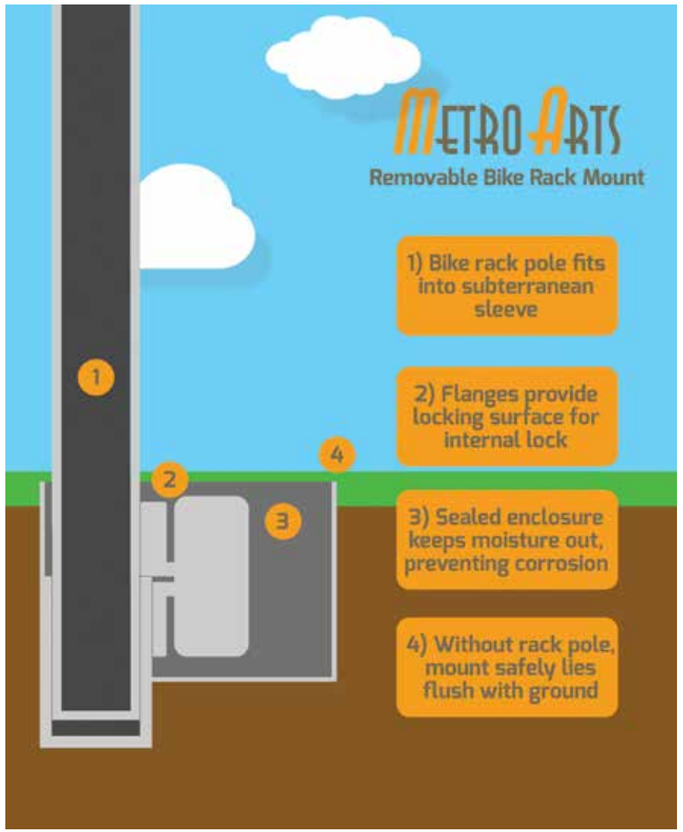
"We ended up with a very simple design," Plevka said. "For longevity, simple is better."

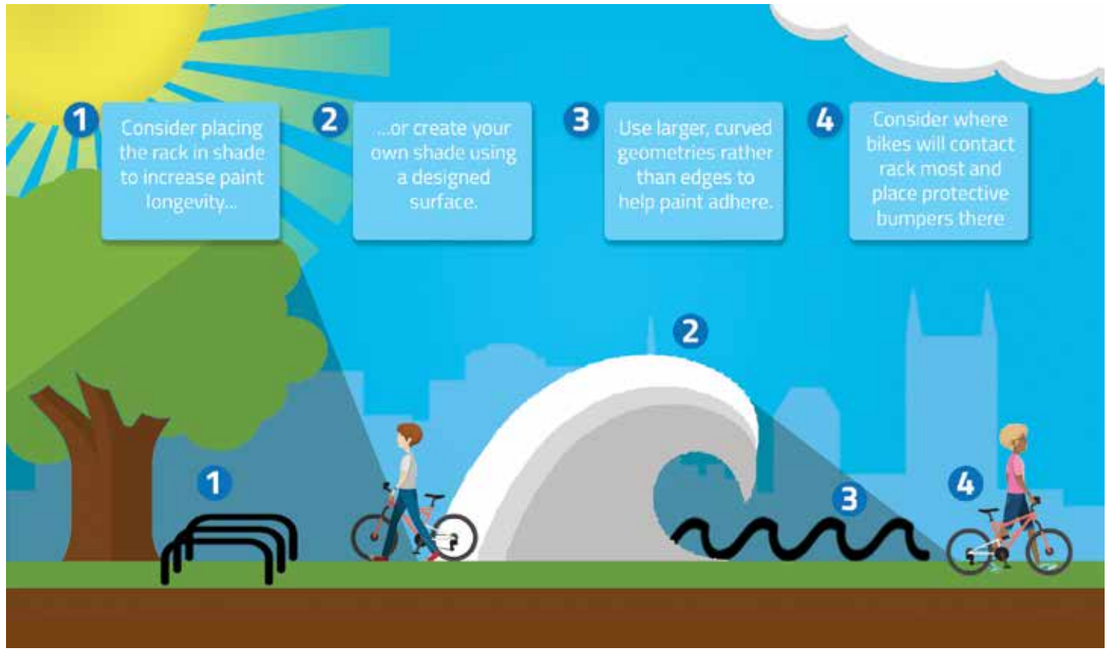
The team also created a series of infographics to accompany the mounting system.

"We definitely saw a need for more communication between artists and engineers," Streeter said.

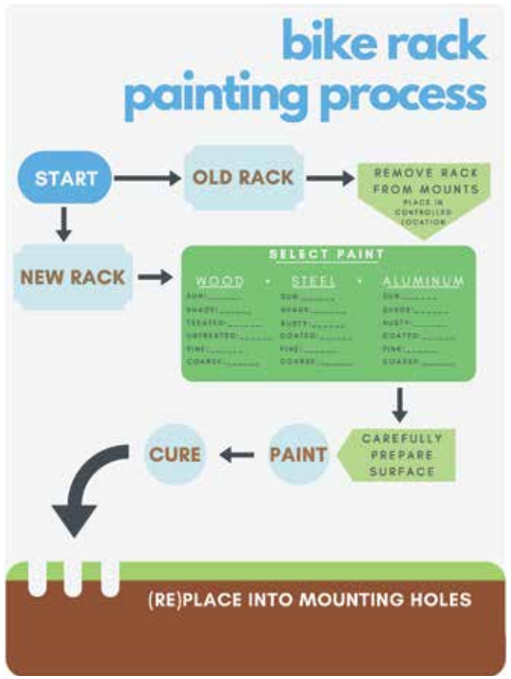
All five team members said they are interested in art, and Md Ridzuan is an art minor. This is the second year the Metro Arts Commission, the project sponsor, has worked with Vanderbilt engineering students.

"It has been great for us," Owens said. "I can see this design getting broader use as I look at other projects — in parks, on greenways, the MTA and even for traffic control."





The team developed infographics that show how the locking mount works and offered other suggestions on removing and repairing Nashville's bike racks.



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ABOUT DESIGN DAY

On behalf of the School of Engineering, welcome to Design Day 2017. This year you'll see more than 70 engineering and computer science capstone projects completed in partnership with sponsors including Nissan North America, Siemens, Fiserv, Camgian Microsystems, Sterling Ranch Development Company, DENSO, NASA Marshall Space Flight Center, and more.

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

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

Sincerely,

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Brochure data were collected and managed using REDCap electronic data capture tools hosted at Vanderbilt University[1].REDCap (Research Electronic Data Capture) is a secure, Web-based application designed to support data capture for research studies, providing: 1) an intuitive interface for validated data entry; 2) audit trails for tracking data manipulation and export procedures; 3) Automated export procedures for seamless data downloads to common statistical packages; and 4) procedures for importing data from external sources. REDCap is supported by a Vanderbilt Institute for Clinical Trials and Translational Research grant (UL1TR0000445 from NCATS/NIH).

[1]Paul A. Harris, Robert Taylor, Robert Thielke, Jonathan Payne, Nathaniel Gonzalez, Jose G. Conde, Research electronic data capture (REDCap)—A metadata-driven methodology and workflow process for providing translational research informatics support, J Biomed Inform, 2009 Apr;42(2):377 81.

BIOMEDICAL ENGINEERING

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High Hopes Preschool and Pediatric Therapy Clinic

FAST AND FURIOUS POWER WHEELS FOR MOBILITY-IMPAIRED CHILDREN

Children with mobility impairments lack a sense of independence, depth perception, cause and effect, and social acceptance. These children do not have access to power mobility because insurance doesn't cover power wheelchairs for this age group. The goal of our project is to give mobility-impaired children the independence and social interaction they crave by creating a highly-modified power toy car. Our team targets common limitations in children ages 2 to 5, and modifies one base car to fit the needs of many children, giving them development opportunities, independence, and the social interaction they crave, with a fun twist.

The organization GoBabyGo addresses the same need, but customizes a single car for a single child. Our design aims to be used by many children with varying limitations and diagnoses. The car features an adjustable seat, steering wheel, arm rests, and many possible inputs for motor activation.

6VDC ride-on power car to be donated to High Hopes Preschool.

High Hopes DEVELOPMENT CENTER

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VALIDATION MODEL FOR CATHETER-BASED DELIVERY SYSTEMS

Stem cells are poised to revolutionize modern medicine. Transplants today have vastly improved the outcomes of thousands of patients battling leukemia and severe hepatic veno-occlusive disease. Researchers now are actively developing many therapies. While *in vitro* and *in vivo* experiments generally verify the efficacy and safety of potential therapies, regulators must also consider the effect of specific parameters such as transport on the outcome. Current testing methods do not look into important stem cell outcomes such as differentiation, nor are they cost-effective. Catheter-based delivery systems are the current stem cell-transport method of choice yet they remain largely misunderstood and not well-characterized. Many untested stem cell therapies are currently in market and need to be validated by the FDA as safe and effective. To further characterize catheter delivery parameters, a mathematical model was developed. Our mathematical model, alongside current *in vitro* validation methods, will serve as a preliminary screening tool for future potential catheter designs.

A catheter delivers stem cells into a target region such as the heart. The catheter design is crucial to determine stem cell outcome. Our mathematical model assesses the feasibility of a catheter model depending on the catheter parameters.

USDA

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BIOMEDICAL ENGINEERING

REPRODUCIBLE STEREOTAXIC INJECTION SYSTEM FOR NEONATAL MICE

Stereotaxic injection rigs are primarily used to perform minimally invasive procedures on small animals for the purpose of research. The rig employs the use of a 3D coordinate system to accurately target small areas in the body. However, these rigs are designed for adult animals. Our objective is to design a supplemental platform adapted for neonatal animals, particularly mice, which fits into the existing rig. In addition to the platform, we have 3D modeled head molds based on microCT scans of neonatal mice at various weights, orientations, and stages of growth. This was achieved through the development of a pipeline that intakes 3D image files and produces a 3D printable mold based on an inversion of the file. The purpose of these molds is to stabilize the animals during injection, reducing movement and improving injection precision by combating the malleability of the neonatal skull.

Most research institutions induce hypothermia as the primary form of anesthesia. We are currently integrating a cooling system into the platform to safely prolong hypothermia, increasing potential procedure time. Additionally, our pipeline could be applied to CT or microCT scans of any animal model to produce a standard mold for other rigs or forms of research.

Head mold of neonatal mouse.

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BIOMEDICAL ENGINEERING

MULTIPLEXED SMALL-VOLUME STIRRED BIOREACTOR FOR BRAIN TUMOR ORGANOID DEVELOPMENT

Three-dimensional cell culture via rotating bioreactors is becoming a more appealing option for research as it distributes nutrients evenly throughout the cells under low shear stress conditions. However, current commercial techniques use inordinately large volumes and can only culture single cell types, making them ill-suited for high-throughput screening (HTS). The SpinΩ, a rotating bioreactor from Johns Hopkins University, paved the way for HTS bioreactors by incorporating gear-driven spinning impellers into a 12-well culture plate.

The STAM-24 spinning bioreactor for brain organoids expands on the SpinΩ by utilizing linked chain-and-sprocket systems to turn 3D-printed impellers. This system is integrated with 24-well culture plates to enable higher-throughput screening while fitting into a hypoxic chamber to better mimic the low-oxygen environment of brain tumors. With this bioreactor, further efforts can be made in screening drugs for patient-specific chemotherapy and understanding neural development.

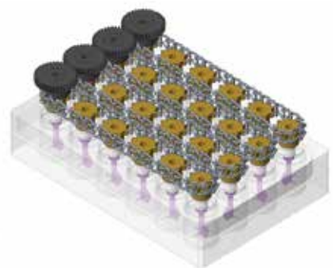

Illustration of STAM-24 spinning bioreactor system. Gears (black) drive train of chain sprockets (gold) connected by chains (gray), which turn the impellers (purple) in the cell culture wells.

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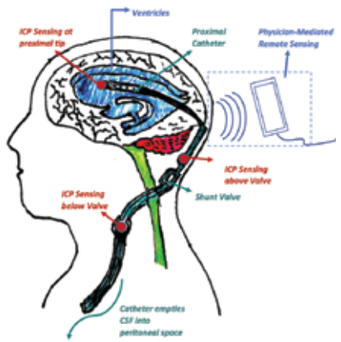
DEVELOPMENT OF A SMART HYDROCEPHALIC SHUNT

Our project is centered on ventriculoperitoneal shunt technology for pediatric patients afflicted with hydrocephalus. Hydrocephalus is a condition characterized by the excessive collection of cerebrospinal fluid (CSF) in the brain and affects 1 in 1000 live births, making its treatment the most frequent procedure in pediatric neurosurgery. The current shunt technology has seen no major improvement in the past 50 years, and has a 50 percent failure rate within two years of insertion. There is no proper way to detect this failure, which leads to severe neurological symptoms due to brain compression and swelling before the shunt is removed or replaced.

To address this issue, we are developing a "smart shunt" that will be able to detect failure before it is clinically apparent. This will be achieved through semi-continuous, remote monitoring of shunt function, represented by the Intracranial Pressure (ICP) of the ventricles in the brain. Not only will the shunt monitor its own function, it also will be able to detect failure and inform the patient and physician of this failure. This will allow for timely care and reduction in the prevalence of adverse, preventable symptoms.



Cutaway view of the ventriculoperitoneal shunt positioned in the brain. The proximal tip sits stationary in the ventricle where CSF builds up, and from there the fluid drains through the proximal catheter, past the shunt valve, and down into the abdominal cavity. Also depicted is the remote sensing mechanism used to communicate shunt failure detected at any of the three ICP sensor locations.

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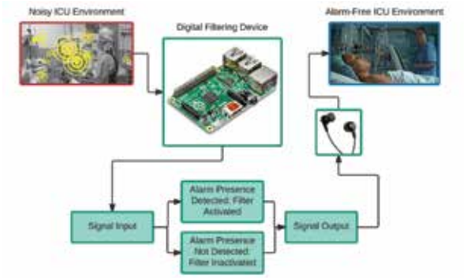
FREQUENCY-SELECTIVE SILENCING DEVICE TO ENHANCE ICU PATIENT RECOVERY

Audible medical alarms have created hazardous and cacophonous environments in intensive care units due to the frequent nature at which they sound and the low positive predictive value of the information they convey. These characteristics have created numerous problems for both physicians and patients. While physicians are prone to alarm fatigue and desensitization, patients may experience both delirium and PTSD during ICU stays, and alarms may contribute to or cause these psychological problems. This project attenuates these problems through the creation of a frequency-selective silencing device for patients to wear in the ICU that removes free-field alarm sounds.

The solution to this problem is a comfortable in-ear device that will be worn continuously throughout a patient's length of stay in the ICU. The device uses a Raspberry Pi to process incoming noise in real time, detect if an alarm is present, and digitally filter frequencies specific to common alarms. Importantly, environmental noise, like speech, passes through *without* distortion. This device surpasses previous solutions like traditional earplugs. It is more comfortable for long-term wear, is medical grade and reusable, and actively removes alarms rather than dampening all noise, making it more effective at preventing PTSD anchored to critical illness.



Frequency-selective silencing device.

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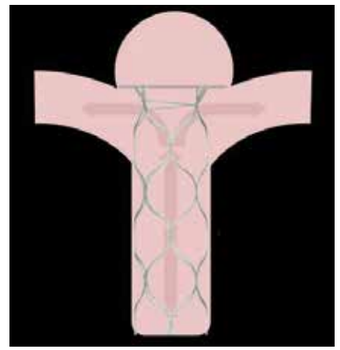
BIOMEDICAL ENGINEERING

A NOVEL CEREBRAL FLOW-DIVERSION STENT FOR THE TREATMENT OF BIFURCATION ANEURYSMS

It is estimated that 1 in 50 people in the United States has an unruptured intracranial aneurysm. Aneurysms can form anywhere in the brain but commonly occur in bifurcated areas such as the vertebrobasilar junction (VBJ). Constant pressure and blood flow at this junction increase the likelihood of rupture, a life-threatening event because the VBJ supplies blood to key brain structures. Current treatments of bifurcated aneurysms are either invasive or complex, making it difficult for both the patient and provider to ensure safety and efficacy. Our aim is to make treatments simpler and safer through the use of a single flow-diverting stent. The stent features layers of densely meshed leaves that expand within the aneurysm to reduce residual blood flow. These leaves are held up by a stent body in the luminal space featuring an open cell configuration to minimize the bodily exposure to metal. Our stent is recapturable and allows users to accurately position the device in various neck morphologies. We are testing the efficacy of our stent by running computational fluid dynamic models using parameters determined by Ouread et. al. Our goal is to achieve a two-thirds reduction in blood flow velocity to successfully treat the aneurysm.



Artist rendering of a flow-diverting stent to treat an aneurysm in the vertebrobasilar junction. Arrows represent diversion of blood flow into peripheral arteries.

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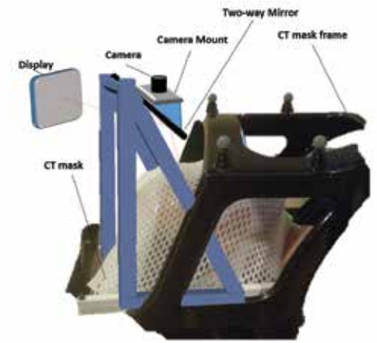
BIOMEDICAL ENGINEERING

OCULAR TRACKING TO AID RADIOTHERAPY GUIDANCE FOR EYE TUMORS (O-TARGET)

Choroidal melanoma treatment requires the immobilization of the eye during both pre-treatment imaging and radiotherapy procedures in order to locate and target the tumor. Current clinical methods for immobilizing the eye are either invasive, highly inaccurate, or both. At Vanderbilt, the standard of care is to direct the patient to look at the end of a pencil. Thus, a need exists for a device that can non-invasively limit eye movement during these procedures. Our solution is an optical system mounted to the patient's therapy mask that will provide a focus point for the patient, track eye motion, and prompt the patient to rectify deviations. Our system will provide improved accuracy in locating the tumor during the two pre-treatment imaging procedures and lead to a more specific treatment region for radiotherapy. This solution will improve the clinician's view of the tumor during therapy planning and correct error introduced by patient movement, preventing vision loss and tumor recurrence. We intend to produce a CT and radiotherapy compatible version of our design that will successfully track and guide patient gaze during imaging and treatment.



This model illustrates the proposed assembly; a white radiotherapy mask, black stereotactic frame, and our system in blue.

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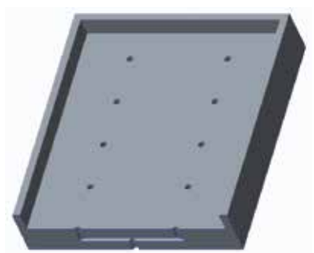
TEMPORALLY MODULATED CELL CULTURE SYSTEM

Cell culture systems allow simulation of *in vivo* conditions without necessitating the use of live model organisms. These systems allow science to study biological interactions on a fundamental level. However, there are still model discrepancies such as the lack of temporal modulation — varying the environment with time — which are needed for truly accurate physiological representation. Our goal is to create a more robust experimental apparatus that allows for temporal modulation and increases fidelity to *in vivo* conditions. This has been accomplished through the creation of a new cell culture plate lid that is compatible with commonly available commercial well plates and allows generation of temporal profiles for any delivered solution. With built in channels for flow and lids for varying numbers of wells, our epoxy molded lid is an accurate, precise and easily reproducible device. Our lid additionally improves sterility by eliminating the need to expose cells in culture to conditions outside the well plate, thereby greatly reducing exposure to contaminants. When completed, this new design will decrease the preparation time per trial, allowing for greater concurrency among projects, while also minimizing external confounding variables through material standardization and improving the power of each experiment.



Cell culture plate lid.

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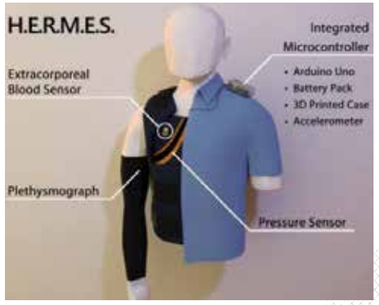
GPS-911

DEVELOPMENT OF A SMART BALLISTICS VEST FOR POLICE OFFICERS

Nearly 50,000 police officers were physically assaulted in 2015. Of these officers, nearly 60 percent were alone and 30 percent were seriously injured. The inability of an incapacitated officer to automatically communicate with dispatch exacerbates the dangers faced by officers. Providing an integrated system capable of biometric sensing and automated dispatch alerts could improve police communication and safety should an officer be incapacitated.

Our device, the HERMES (Health Evaluation with Real-time Monitoring-based Emergency Signaling) system, is an integrated system that retrofits ballistic vests regularly worn by officers. The system consists of an array of biometric and force sensors, including a photoplethysmograph, blood glucose sensor, accelerometer, and pressure conductive sheeting. These sensors allow for acquisition of data on heart rate, presence of extracorporeal blood, officer orientation, officer acceleration, respiratory rate, and external forces associated with blunt force and bullet impacts.

Our device integrates existing biometric sensor modules while taking into account customized design considerations for ballistic vests. In addition, sensory data is wirelessly transmitted and analyzed using an independently developed thresholding algorithm. These unique capabilities allow for continuous monitoring of vital biometric parameters of an officer's condition as well as rapid threat assessment and communication.



3D rendering of the HERMES system, retrofitting bulletproof vests with an integrated series of biometric and force sensors to monitor and assess officer condition. Sensory data acquired is transmitted via Bluetooth before threat assessment based on an established algorithm.

GPS-911

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BIOMEDICAL ENGINEERING

OPTIVENT: PERSONALIZED INTERVENTION FOR ACUTE RESPIRATORY DISTRESS SYNDROME

Acute Respiratory Distress Syndrome (ARDS) is characterized by fluid buildup in the lungs, which results in a significant loss of usable lung volume and susceptibility to ventilator-induced lung injury (VILI). ARDS is found in 10 percent of ICU patients and has an average in-hospital mortality rate of 40 percent. The current standard of care is one-size-fits-all, with recommended ventilator settings based on patient height alone. To minimize the risk of VILI, tidal volume (TV) and positive end-expiratory pressure (PEEP), settings should be chosen based on patient-specific respiratory mechanics and updated regularly to reflect changes in the patient's condition. Stress index is a measure of stress placed on the lungs. Prior research has shown that patient outcomes improve when TV and PEEP are chosen such that stress index is optimized.

We are developing OptiVent, a software that recommends optimal ventilator settings based on stress index, ideal body weight, and other patient-specific data. OptiVent collects data from a ventilator, then isolates relevant portions of each breath to calculate stress index and elastance. After stepping through different combinations of ventilator settings, the program recommends the TV and PEEP settings that minimize the risk of lung injury..

Optivent recommends optimal ventilator settings based on patient-specific data.

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BIOMEDICAL ENGINEERING

ADDRESSABLE LED BANK FOR STUDYING SENSORY INTEGRATION IN PRIMATES

Currently, there is not an effective way to study how the brain processes individual stimuli in a stimulus-rich environment. A device that meets these needs will provide valuable insight into multisensory integration and lay the foundation for further clinical research of neurological disorders like autism and schizophrenia.

We aim to build a concave display of LED lights to interface with a pre-existing speaker scaffolding that will project specific stimuli in a controlled space. A Rhesus Macaque monkey will experience the complicated stimuli. The Vanderbilt Department of Hearing and Speech will analyze its response with infrared eye tracking and electrodes to gather data from the superior colliculus, a midbrain structure where auditory and visual stimuli are processed.

Our design uses 672 addressable LEDs. A user can configure the desired location and intensity of the lights with a MATLAB GUI. The LEDs are anchored to a detachable scaffolding, which does not block the speakers. Previously, researchers were only able to study a monkey's perception of sound in an enclosed space, but our attachable LED display allows researchers to study monkeys' neurological responses in a more complicated environment. We expect researchers to easily project the lights and sounds in concert with one another.

VANDERBILT UNIVERSITY MEDICAL CENTER

The LED bank will be attached to the speaker apparatus currently used in the Ramachandran Lab, shown above. By creating an LED bank that covers the frontal visual field of a monkey, we hope to aid researchers in the Vanderbilt Department of Hearing and Speech in their study of sensory integration.

BIOMEDICAL ENGINEERING

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IMPROVING FOOTBALL HELMET DESIGN TO LIMIT MILD TRAUMATIC BRAIN INJURIES

Mild traumatic brain injuries alter the lives of American football players of all ages. Football related concussions affect more than 400 professional and Division I athletes each year and result in long-term medical costs that can exceed $700 million, as in the case of the most recent National Football League settlement. Despite the high incidence rate, most football helmets do little to prevent concussions but focus instead on preventing skull fractures.

The goal of this project is to limit concussion incidence by designing a helmet to reduce both the linear and rotational acceleration experienced by football players during impact. The design incorporates external dynamic shock absorbing packets containing a non-Newtonian material. This helmet dissipates energy through the translocation and transformation of the shock absorbing material upon impact. The air-tight, water-tight packaging of the shock absorbing material allows the helmet to be used in intense weather conditions while the snap on attachment allows the packets to be easily replaced on the sideline in case of damage.

A frontal cross-section of a football helmet provided by the Vanderbilt University football program. A thin layer of shock absorbing material is enclosed inside of an air-tight, water-tight packet that is snapped to the traditional helmet shell.

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GPS-911

BIOSENSING BALLISTIC VEST

Currently, the only methods of communication for police officers are the radio and the panic button, which is found either on the radio or the officer's belt. The manual process of having to reach for the radio or panic button to communicate can contribute to officer danger and sometimes death. The Biosensing Ballistic Vest aims to improve officer safety through physiological monitoring and enhanced, automated communication. The vest will read an officer's vital signs and discriminate between his/her resting and alarm states depending on deviations from his/her personalized baseline readouts. These monitoring capabilities, coupled with the ability to recognize blunt force impact, allow the vest to determine if the officer is in danger. If in danger, the vest will automatically communicate to other officers and/or the police department through a mobile phone app, which allows for seamless integration into the existing communication system. The vest will also house a Bluetooth beacon to provide closer-range location tracking ability so that backup can easily identify the location of the officer in danger. While existing vest designs offer passive protection, the Biosensing Ballistic Vest improves upon this protection by actively helping officers when they are unable to help themselves.

The Biosensing Ballistic vest monitors the physiological state of an officer and automates the call for assistance if his/her safety is at risk.

GPS-911

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BIOMEDICAL ENGINEERING

SYTE: THE INFANT MONITOR

Babies are social beings. The Bucharest Project in Romania found that infant orphans were stunted in their development due to the lack of personal care in understaffed orphanages. However, if the orphans were placed in a foster family by age 2, they were indistinguishable from a community control by age 8.

The SYTE system is a monitor built to detect the human interactions encountered by babies in the NICU to assure that they are receiving the interactions they fundamentally require. An Xbox Kinect is used both visually and phonically within NICU rooms to track visits as well as word counts. Previous attempts to monitor infant interactions have focused purely on the auditory realm. Research using these methods have raised questions about whether a parent or a nurse talking to an infant are equivalent in regard to future development. Use of the SYTE monitor will provided observations about the type and amount of interactions, and whether parental interactions are especially potent.

Monroe Carell Jr. Children's Hospital

An Xbox Kinect and a Minnowboard within its case. The single board computer (SBC) operates the Kinect within NICU rooms to monitor infant interactions.

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American Society of Civil Engineers

AISC-ASCE STUDENT STEEL BRIDGE COMPETITION

The overarching objective of the 2017 AISC-ASCE Student Steel Bridge Competition was to simulate a real structural engineering project from conception to completion in the form of a small-scale bridge competition. For the competition, the four members of the Vanderbilt Steel Bridge Team (Mr. Steel Yo Girl) developed a cantilever design capable of being constructed in under 30 minutes and to withstand a combined load of 2,500 pounds with minimal deflection. The three-dimensional deck truss provided excellent stiffness to resist both lateral and vertical deflection, and the upper chord and diagonals were optimized to reduce the number of members without sacrificing strength. The team learned all necessary shop skills to fabricate the bridge, including how to operate the steel saw, belt sander, cutting wheel, hand-grinder, and MIG welder. At completion, the finished product was an aesthetically-pleasing bridge that was strong, easy to construct, and, most importantly, a competitive entrant into the ASCE Southeastern Regional Conference at Florida Atlantic University in March 2017.

A member of the Vanderbilt Steel Bridge Team MIG welds steel lacing between three foot tube sections for the lower chord of the bridge.

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SPONSOR
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STERLING RANCH HOME FOR RACE TO ZERO COMPETITION

Sterling Ranch is a master-planned "smart city" currently under development 20 miles southwest of Denver, Colorado. Sterling Ranch's developers recognize that the energy usage in both residential and commercial buildings accounts for 40 percent of the United States' total annual energy consumption, and they intend to design and build sustainably. Our team's mission is to help Sterling Ranch and their predominant homebuilder, Lennar, modify their existing Colorado ranch home plan so that it achieves net-zero energy. We plan to design a home that is cost-effective, comfortable for its users, and easily reproducible nationwide. Additionally, our sustainable home design was entered into the U.S. Department of Energy's "Race to Zero" competition.

To achieve net-zero energy we used BEopt, a building science energy and cost optimization program, to simulate various home design alternatives. We looked at innovative insulation methods, HVAC systems, household appliances, window types, and lighting systems, and we ultimately selected the alternatives that were both energy efficient and economical. Our design also includes solar panels on the roof that enable the home to achieve net-zero energy. It is our hope that this home inspires similar sustainable home design by proving that net-zero energy homes can be both architecturally stunning and affordable.

Elevation of the Colorado ranch home to be built in Sterling Ranch.

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Honduras Outreach, Inc.

CIVIL ENGINEERING

HONDURAS PEDESTRIAN BRIDGE

During the rainy season in Honduras' Agalta Valley, the Rio Grande reaches high water levels. San Esteban residents must travel four hours to the nearest bridge, limiting access to schools and clinics. We partnered with Honduras Outreach, Inc., a nonprofit organization serving communities in Central America, to design a safe, constructible, and cost-efficient pedestrian bridge for the 700 residents affected.

In May 2016, two members of the design team traveled to Honduras, conducted a site survey and collected geotechnical samples. The team evaluated the geotechnical and hydraulic conditions in order to select the type of bridge and foundations. The team chose a 165-foot-long cable-suspended bridge in order to span the river without a pier and to simplify construction. The bridge deck, steel cables and concrete foundations were designed after careful consideration of pedestrian usage, wind, and hydraulic loads. Construction of the bridge is scheduled to begin in August 2017.

3D rendering of the student-designed 165-foot-long suspended pedestrian bridge over the Rio Grande in Honduras.

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Sterling Ranch

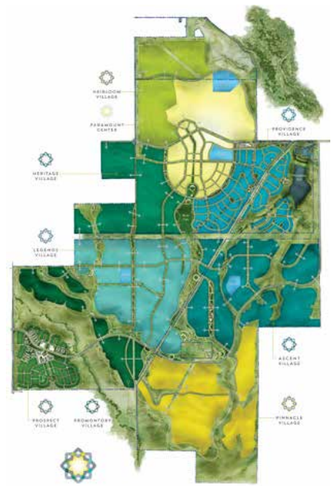
CIVIL ENGINEERING

STERLING RANCH MULTIMODAL TRANSIT SYSTEM

Sterling Ranch, a sustainable community located southwest of Denver, Colorado, lacked a comprehensive and innovative transit plan that would connect residents between major hubs inside and outside the 5-square-mile community. The goal of this project was to develop a multimodal, accessible and extensive transit plan that would allow residents to travel conveniently throughout the community and surrounding areas.

The team developed transit user profiles, performed a benefit analysis for transit modes, and analyzed traffic impact studies for Sterling Ranch. Additionally, the team determined how the transit system would alleviate traffic congestion and create a comfortable environment for the community members. The deliverables for the project included identifying the best alternate modes, locating major transit hubs, and devising the most efficient transit routes. The final transit system includes multiple low cost, convenient, and sustainable modes that efficiently transport residents between schools, recreational locations, and commercial centers.

This transit system provides safe and accessible transportation options for all members of the community. It improves the quality of life of Sterling Ranch residents while delivering the sustainable and eco-friendly practices promised. Perhaps most importantly, this innovative transit system enhances Sterling Ranch's already strong image as the city of the future.



Generations of homeowners in Sterling Ranch will benefit from an innovative and sustainable transit system within the community.

CHEMICAL & BIOMOLECULAR ENGINEERING

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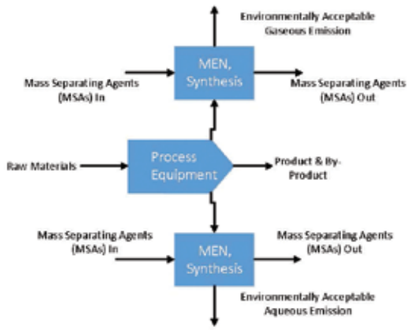
MINIMIZING WASTE USING MASS EXCHANGE NETWORKS (MENS)

High demand for environmental regulations has forced chemical production companies to spend money on waste treatment. Production cost can be reduced substantially by integrating waste streams and recycling valuable materials in the system. A software interface is one of the holistic ways to implement Mass Exchange Networks (MENs), because it can reduce the pollutants released to the environment.

Our software, an Excel user interface, is capable of identifying an optimal MENs while being cost-effective and energy-efficient. It provides graphical representations of the optimal MENs and data for all streams (up to 10 rich streams and 10 lean streams). The software considers various user inputs, design parameters, mass separating agents and environmental constraints. This user-friendly software contains features that allow users to adjust the minimum composition driving force for each MENs. The program is also equipped with a cost estimator that predicts the return on investment for the design. This prediction allows the engineers to create the most economical chemical plant.



The general schematic design of Mass Exchange Networks (MENs).

CHEMICAL & BIOMOLECULAR ENGINEERING

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DEVELOPING SOFTWARE FOR VOLATILE ORGANIC COMPOUND RECOVERY IN AIR POLLUTION CONTROL

Volatile Organic Compounds (VOCs) are among the most important classes of chemicals used in the process industry and are a class of pollutant present in many gaseous and aqueous emission streams. In response to environmental regulations aimed at reducing air pollution, corporations are required to design innovative, cost-effective methods of eliminating VOCs from emission streams. The recovery and recycle of VOCs within a chemical process has the potential to control air pollution, increase process efficiency, reduce chemical waste and improve process profitability. Despite this, the widespread implementation of VOC recovery methods remains incomplete.

To address this, our team has designed a software package capable of analyzing a variety of recycling technologies and determining the most cost-effective method for recovering one or more pollutants from one or several emission streams. The software package is built within Microsoft Excel and performs calculations related to the design and cost of equipment and materials required to construct and operate adsorption, absorption, biofiltration, condensation, membrane separation and flaring processes. By constructing our software within Microsoft Excel, we hope to make our work accessible to a wide audience and encourage the widespread adoption of improved process methodologies.

Volatile organic compounds in waste streams are often discarded, but recovery of these compounds can reduce pollution and improve process profitability.

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SOFTWARE FOR ECONOMIC COMPARISON OF VOLATILE ORGANIC COMPOUND RECOVERY TECHNOLOGIES

Volatile organic compounds (VOCs), due to their properties and prevalence in chemical processes, are susceptible to release into the atmosphere in a large variety of industrial situations. This issue signifies not only a massive loss of usable material, but also violates statutes dictating the legal limits of pollution meant to protect the environment from the effects of foreign emissions. A number of technology types, namely adsorption, absorption, and condensation/filtration, can be employed to collect and recover these VOCs within a process before they are released to the environment. In this project, a pioneer software comparing the performance and economic impacts of each technology is produced to evaluate the best possible technology choice for a given VOC recovery problem. This software, designed to be a companion program to a popular textbook about the engineering of emissions reduction, provides students with a streamlined, easy-to-use method to solve VOC recovery problems without the need to calculate by hand or research the financial parameters of each recovery technology.

The tendency for VOCs to be released into the atmosphere in the form of vapor from large, factory-scale plant processes necessitate an efficient means to perform a cost-benefit analysis of VOC recovery technologies before installation in factories such as the one pictured above.

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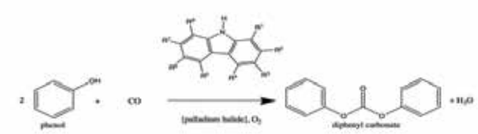
CHEMICAL & BIOMOLECULAR ENGINEERING

PHOSGENE-FREE ROUTE TO POLYCARBONATE PRODUCTION

Polycarbonates are a group of thermoplastic polymers that have high impact strength, heat resistance, optical clarity, and malleability. Thus, these plastics have a wide range of uses and applications. Polycarbonates make up many products ranging from DVDs and electronic components to fighter jet cockpits and sturdy construction materials. During the production of polycarbonates, it is necessary to synthesize an important intermediate, diphenyl phosphate (DPC). Historically, DPC production requires phosgene, a reagent toxic to humans and the environment. Not only is this process hazardous, but it also produces a solid sodium chloride (NaCl) byproduct that must be discarded as waste. An alternative to the phosgene route is desired and is possible by the direct oxidative carbonlyation of phenol to DPC using palladium halide catalysts with nitrogen containing heterocyclic co-catalysts. The goal of the project is to design a process for synthesizing DPC using the direct oxidative carbonlyation of phenol rather than the traditional phosgene route. Direct carbonylation is a much safer and economical route to form DPC because handling of phosgene and treatment of NaCl byproduct are avoided. We are designing a process capable of producing 100 million pounds of DPC per year.



This is the reaction mechanism for oxidative carbonylation of phenol to product diphenyl carbonate (DPC).

CHEMICAL & BIOMOLECULAR ENGINEERING

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DESIGNING AN IDEAL HEAT EXCHANGER AND WASTEWATER RECOVERY NETWORK FOR A PVC COMPLEX CHEMICAL SITE

Tackling energy and wastewater problems is essential to reduce their impact on the environment. According to the Energy Information Administration (EIA), chemical industries consumed about 5 quadrillion BTU of primary energy in 2010, and the number has only increased since then. Most plants lack optimum energy and wastewater recovery networks, which lead to energy waste, environmental pollution and unnecessary expenditures. Energy recovery networks allow the plant to use high-temperature streams to heat low-temperature streams, and vice versa, reducing the need of hot and cold utilities. Wastewater recovery networks allow the plant to reuse streams with low contaminants to dilute more concentrated streams for use in chemical processes or for disposal.

In this project, our main approach includes analysis using the Heat Exchange Network Optimization Software (HENOS) and the Water Treatment Recycle (WTR) software, which were developed at Vanderbilt University, to design the optimum energy and wastewater recovery networks. We provide several design proposals that meet the client's requirement and consider safety analysis and the current plant design to determine the feasibility of each proposed network. Ultimately, our recommendation to the client is based on the design that has the best trade off between energy and freshwater savings and cost.

Distillation columns are common in chemical plants and they require a lot of utilities. Heat and mass integration could heavily reduce their utility consumption.

CHEMICAL & BIOMOLECULAR ENGINEERING

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DESIGN OF A HEAT EXCHANGER NETWORK AND A MASS EXCHANGE NETWORK (HEN-MEN) TO REDUCE UTILITIES FOR A PVC SITE

Energy exchange and treatment of waste are major components of chemical site design. In both cases, expensive utilities are necessary to operate the plants. The reduction of external heating, cooling and waste treatment translates to lower operating costs. Our team designed a heat exchanger network that integrated process streams and designed a water network that eliminated unnecessary fresh water to reduce the utility usage across a site. Networks were examined through a combination of graphical methods, rigorous calculations and software manipulation and compared to the optimal networks to validate the designs. Options including cogeneration and pressurization were considered. Safety concerns, design limitations and the cost of implementation were evaluated for each design. The heat exchanger network achieved significant energy savings by judicious pairing of appropriate streams to offset cooling and heating utilities. The water network permitted a sizable amount of wastewater recycling that decreased both the need for freshwater utility and disposal of the wastewater the site produced. The implementation of the proposed designs offers significant savings.

This is an example shell-and-tube heat exchanger for an integrated PVC site.

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CHEMICAL & BIOMOLECULAR ENGINEERING

DESIGNING A MULTI-PRODUCT MICROBREWERY

Beer is one of the most widely consumed beverages, predating the construction of the Great Pyramids in Egypt. In the U.S., more than 19 billion barrels are produced annually, and in the 2015 fiscal year, total revenues exceeded $105.9 billion. As compared to large-scale breweries, microbreweries focus more on quality, flavor and brewing technique in their varieties over mass production. In recent years, sustainability efforts have become mainstream with manufacturers, placing a greater emphasis on reducing waste and energy consumption.

Our team designed a microbrewery for the production of six year-round, four limited-edition, and four seasonal brews. We present two operations: constructing a new facility and contracting to an existing one. Our overall approach is to design the two operations from the ground up and then perform an economic analysis to determine the viability of both. We aim to reduce operating cost and negative effects to the environment, focusing on producing quality beer that exceeds expectations. Our proposed solution produces 100,000 barrels per year, with production facilities in the Midwest and negligible emissions to the environment.

The four simple ingredients of beer are water, yeast, hops and barley.

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CHEMICAL & BIOMOLECULAR ENGINEERING

NITROGEN TRICHLORIDE PREVENTION AND CONTROL WITHIN THE CHLOR-ALKALI INDUSTRY

The synthesis of chlorine via membrane electrolysis of brine solutions has the potential to produce nitrogen trichloride as a contaminant. Chlorine ions react with ammonia derivatives in the feedstock, which are frequently present due to animal waste and fertilizers in the water used to create the brine stream. Nitrogen trichloride is a dangerous compound capable of auto-detonation. The project analyzes various points of intervention to eliminate synthesis routes and degrade or remove generated nitrogen trichloride. In addition, the team attempts to develop methods for nitrogen trichloride detection using continuous process methods. Product is stored in on-site pressurized vessels, creating potential for concentration of nitrogen trichloride contaminants. Existing methods rely on the removal of nitrogen trichloride through controlled purge streams, creating dangerous conditions for chemical operators and wasting product. The proposed solution reduces the need for operator intervention and provides secondary safety controls to prevent failure. Costing, safety and efficacy analyses were conducted to explore the inclusion of this process in existing chlor-alkali facilities.

This is a reactor clarifier for use in brine treatment within a chlor-alkali process.

CHEMICAL & BIOMOLECULAR ENGINEERING

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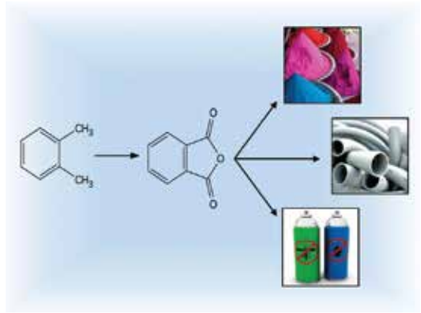
DESIGNING A FACILITY TO PRODUCE PHTHALIC ANHYDRIDE FROM O-XYLENE USING A NOVEL CATALYST

Phthalic anhydride and maleic anhydride are two common intermediates in the production of plastics. These two anhydrides can be formed by the oxidation of o-xylene or naphthalene. The primary product, phthalic anhydride, is a toxic chemical compound with several applications, including phthaleins, dyes, resins, plasticizers and insecticides. Phthalic anhydride is a key component in the plasticizers used to produce PVC, which is currently manufactured at 3 million tons per year.

A new catalyst for the oxidation of o-xylene to phthalic anhydride recently has been developed with the capability to minimize most of the side products associated with the reaction. The objective of our project was to design a new, grassroots facility to accommodate this promising new catalyst to produce 100,000 metric tons per year of phthalic anhydride. The production facility will be designed with consideration of potential reactor schemes, separation methods, heat exchange networks and waste management solutions that satisfy the product quantity and purity requirements. Energy consumption, production of waste, safety and economic feasibility will be key criteria in the design process. Potential designs will be modeled and analyzed using simulation software such as Aspen, Matlab and ChemCad. The novel catalyst used in the process can produce a high yield of product while significantly decreasing the amount of by-products incurred.



Oxidation of o-xylene to produce phthalic anhydride, followed by its multiple commercial uses, including dyes, polyvinyl chloride pipes and pesticides.

CHEMICAL & BIOMOLECULAR ENGINEERING

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DESIGN OF A GRASSROOTS PLANT TO PRODUCE 100,000 METRIC TONS PER YEAR OF CUMENE

Cumene is mainly utilized as chemical feedstock to manufacture phenol and acetone and, subsequently, bisphenol-A and polycarbonates. Recently, demand for phenol-based products in the plasticizer industry has raised production requirements of cumene. Consequently, the global market value of cumene is projected to reach $24 million by 2018. Our goal is to handle this increase by designing a grassroots plant to produce 100,000 metric tons of cumene annually. The overall process involves alkylation of excess benzene with propylene, using a new proprietary catalyst with provided kinetics.

Our design consists of a two-step process. The first step uses a shell-and-tube-packed bed reactor to convert preheated substrates into cumene. The second step separates this product from by-product p-diisopropyl benzene and unreacted feedstock for recycle. The design also considers the economic impact of using propylene with 5 percent propane impurity vs. purer propylene feed on annual operating cost.

The facility minimizes utility costs, particularly of steam, through appropriate usage and generation of economic credit. Our environmentally friendly design outperforms incumbent solutions in cost-efficiency and energy conservation.

A cumene production plant.

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CHEMICAL & BIOMOLECULAR ENGINEERING

DESIGN AND OPTIMIZATION OF A CHLOR-ALKALI BRINE CONCENTRATION PROCESS FOR IMPROVED RECYCLING OF SPENT ELECTROLYSIS BRINE

Chlor-alkali plants generate three of the most vital commodity chemicals through manufacturing processes: sodium hydroxide, chlorine and hydrogen. The sodium chloride electrolysis reaction to produce these three commodity chemicals requires a feed of concentrated brine. However, as the reaction takes place, the concentration of the brine decreases at the outlet of electrolysis. For recycling purposes, it is necessary to increase the concentration of the spent brine solution to produce sodium hydroxide, chlorine and hydrogen in an economical, efficient and viable way. In this project, the chlor-alkali process was analyzed, optimized and designed to utilize the spent brine. The approach developed to solve this important process design issue included research and examination of the performance, viability, economics and other merits of the various brine concentration techniques. The analysis will provide the advantages and disadvantages of several brine concentration techniques and determine the cheapest option to meet the design specifications with best efficiency. Different concentration techniques considered include crystallization, evaporation, addition of salt and reverse osmosis. The recommended design is the most cost effective and operationally effective process for concentrating the spent brine to a specification that can then be recycled back into the chlor-alkali process.

A sodium chloride electrolyzer.

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CHEMICAL & BIOMOLECULAR ENGINEERING

USING A NEW CATALYST TO ENHANCE THE SELECTIVITY OF LINEAR ALPHA OLEFIN PRODUCTION

Linear alpha olefins (LAO) are straight chain alkenes — unsaturated hydrocarbons containing double bonds — where the double bond is in a terminal position. They are used as co-monomers in the production of polyolefins such as polyethylene plastics, detergents, surfactants, synthetic lubricants and plasticizers. LAO are synthesized from the oligomerization of ethylene. However, this route produces a wide variety of olefins, resulting in a significant yield loss of 1-hexene (C6=) and 1-octene (C8=), the LAO of greatest commercial interest.

Our team has developed an economically feasible plant design that reacts an inexpensive ethylene feedstock with a new catalyst that greatly enhances the selectivity for 1-hexene and 1-octene. This plant produces 100 MM lb/yr of LAO and includes the option to adjust the mass split of the desired products based on fluctuating market demand. Additionally, it operates within federal and state safety and environmental regulations. This plant has the potential to yield greater profits than existing competitors because of its higher yield of commercially useful LAO.

A linear alpha olefin (LAO) production plant.

CHEMICAL & BIOMOLECULAR ENGINEERING

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CREATING USEFUL CHEMICALS FROM NATURAL GAS

A nighttime image of a natural gas plant.

Mixtures of the aromatic chemicals benzene, toluene and xylene have conventionally been produced from crude oil byproducts. However, the expansion of American natural gas exploration has uncovered extensive methane reserves that could provide an economic and sustainable substitute for petroleum feed stocks in the production of aromatic hydrocarbons. Our goal is to design a process to increase selectivity of para-xylene, be operable under EPA guidelines, and adhere to appropriate safety precautions.

The initial stage of the process uses a dehydrocyclization catalyst to convert methane into an aromatic mixture. This process is highly endothermic, necessitating constant heating of the reactants to maintain a high product yield. The following stage is alkylation and subsequent methylation to produce para-xylene. Procedure options include using olefins, zeolite catalysts, methanol streams or syngas streams to alkylate the various aromatic streams. These alternative reactions are compared for economic efficiency. The process concludes with a separation scheme to purify para-xylene.

The utility of para-xylene as an intermediate in the petrochemical and polymer industries drives the economic success of this plant. Optimizing selectivity for para-xylene will result in the most profitable plant design.

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Sterling Ranch

ELECTRICAL ENGINEERING & COMPUTER SCIENCE

STERLING RANCH LOW-ENERGY HOME DESIGN

Rising environmental awareness and advances in sustainable technologies have given yield to communities like Sterling Ranch, an environmentally focused master planned community outside of Denver, Colorado. The Low-Energy Home Design team aims to provide a variety of potential building alternatives that could be applied to Sterling Ranch homes to improve energy efficiency and push toward net zero, a home that produces more energy than it uses. Using BEopt modeling software, we are able to analyze a large number of building options, including the envelope, appliances, major systems, lighting, on-site power production and more. The resulting simulations will help us determine which changes are both beneficial for energy consumption and financially feasible. The breadth of the software allows us to look at options and components that may have not been considered in the previous design process and make an argument for their implementation or consideration. We intend to produce a set of proposals that show a range of potential options varying in cost and efficiency with the most efficient option being a net zero design. In addition to the modeling, alternative options that go beyond the ability of the software will be analyzed and considered.

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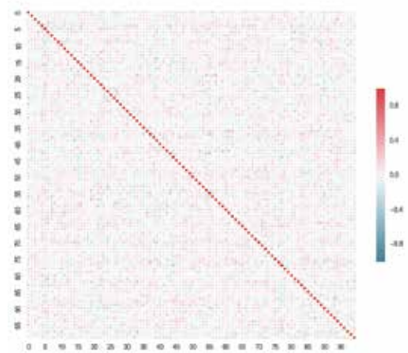
ELECTRICAL ENGINEERING & COMPUTER SCIENCE

BUILDING A CORRELATION ENGINE INTO CAMGIAN EGBURT



The high volume stream of sensor data being generated by large industrial systems like bridges, locks and dams, presents an obstacle for data analytics. Petabytes of data from a wide variety of sensors must be transmitted back to data centers for analysis — a process requiring an expensive and impractical amount of bandwidth. Camgian's Egburt platform performs the data processing and analysis on site, allowing for real-time extraction of actionable intelligence for inspection by the end user.

Our project will expand on Egburt's data processing capabilities, supplementing the eventual data presented to the end user. The deliverable is a correlation engine, i.e. a platform that can receive real-time data from a network of sensors, calculate the correlation over time between each pair, and visually represent those relationships in an intuitive and informative way. Our design will be integrated into Camgian's Insight Portal, a cloud-based user interface for interacting with the data Egburt produces. A visualization of the subtle relationships between components in these structures will help engineers refine their understanding of the system, allowing them to efficiently and effectively track anomalies and resolve issues.

ELECTRICAL ENGINEERING & COMPUTER SCIENCE

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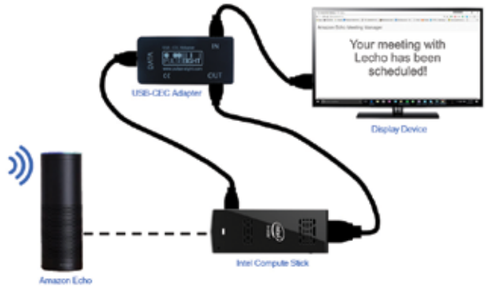
AMAZON ECHO DISPLAY

Meetings are an integral part of any business, and a good deal of time is spent organizing the event and operating the display devices in a meeting room. Traditional interfaces, such as Google Calendar and remote controls, are not always intuitive and users need to have prior knowledge in order to operate them effectively. Productive meeting time is reduced as a result of this management overhead. Our system will improve meeting management by allowing users to manage meetings and control display devices using simple, intuitive voice commands.

The system uses an Amazon Echo to receive and respond to verbal user requests. The requests are then sent to an Intel Compute Stick, which is attached to the meeting's display device via HDMI. The Compute Stick translates the requests using a USB-CEC Adapter into commands that control the display. This allows users to conduct meetings easily using only their voices. This is more intuitive than existing interfaces, and can be used by people with physical disabilities who cannot operate a standard computer or remote. Our system will simplify meeting management, improve productivity, and save businesses time and money.



Schematic of the overall communication flow for using natural language processing to control a display device using an Amazon Echo.

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ADVISER
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SPONSOR
Vanderbilt University Department of Public Safety

VANDY VAN BUS SHELTER

Vanderbilt University currently provides an immensely valuable service to students through the Vandy Van system. This system is used by hundreds of students each day to move across campus quickly and safely. However, the program currently lacks designated shelters to make stops easily identifiable and protect students from inclement weather. Working with many campus stakeholders, our team designed a Vandy Van bus shelter that not only shields students from the weather but also keeps them safe and up-to-date on the status of the Vandy Vans. The design is highly modular to be more sustainable and practical as the campus continues to grow and develop. It incorporates safety elements such as a security camera and blue light system, and the shelter includes a screen to provide riders live route information and arrival times. The shelter will serve as a useful contribution to student life and will further roll out as the Vandy Van program continues to develop and evolve.

Digital rendering of the proposed bus shelter.

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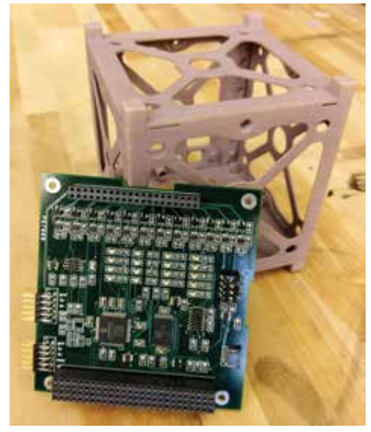
SPONSOR
Institute for Space and Defense Electronics

ELECTRICAL ENGINEERING & COMPUTER SCIENCE

FPGA VERSION OF A CUBESAT EXPERIMENT

Approximately one year ago, the Institute for Space and Defense Electronics (ISDE) at Vanderbilt designed and launched a CubeSat experiment to monitor data errors in commercial memories on-orbit. This design used a microcontroller to operate the experiment. In future experiments, ISDE is looking to expand the capabilities of the design implementation to include control of the guidance and navigation of the spacecraft bus as well as replace multiple ICs with a single chip. The objective of this project is to enable this goal by designing a board that uses a Field Programmable Gate Array (FPGA) in place of a microcontroller to operate an experiment.

The team has designed a board that meets the power and form requirements of a CubeSat experiment board. In operation, the FPGA writes and reads from an on-board memory every five minutes. When errors are detected between what was written to the memory and what was read, those errors will be corrected by the FPGA. The team can also communicate externally with the FPGA and receive the number of errors that have taken place.



TEAM
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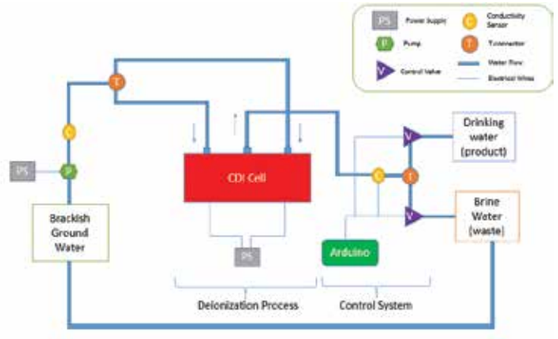
SPONSOR
Vanderbilt University School of Engineering

ELECTRICAL ENGINEERING & COMPUTER SCIENCE

SOLAR POWERED CAPACITIVE DEIONIZATION

Access to safe drinking water is a significant challenge in many communities, especially those in typically remote areas without access to large-scale infrastructure of power and water supply. Furthermore, some of these communities' only water source is brackish groundwater. Existing water treatment technologies all have significant limitation when applied in small-scale and off-grid brackish groundwater desalination. For example, reverse osmosis is more suitable for continuous operation, which poses a challenge using periodic solar energy, whereas distillation processes are energy inefficient. In order to address the issues presented by the lack of potable water and the problems in existing water treatment, we will use an emerging technique known as Capacitive Deionization (CDI). CDI can provide drinkable water to these regions in an energy efficient, sustainable manner by means of solar energy. CDI works by removing ions from water flowing through charged supercapacitors. These supercapacitors have a positively and negatively charged plate which attracts ions of opposite charge, pulling the ions from the brackish water. Additionally, unlike previous CDI systems, our system will feature real-time feedback to control the destination of the output flow, be entirely solar powered, and significantly reduce the concentration of ions in brackish water.



The solar powered system will deionize the input solution by attracting ions to charged supercapacitor plates and send the output to reservoirs via an Arduino-controlled switching mechanism, based on conductivity readings.

ELECTRICAL ENGINEERING & COMPUTER SCIENCE

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SPONSOR
Siemens

SMART HOME ANALYTICS AT STERLING RANCH

Though sustainability continues to be a hot topic in modern architectural development, much of the research in this area focuses on developing resource-efficient appliances and buildings. Sterling Ranch, a housing development in southwest Denver, Colorado, is working to couple its focus on sustainable facilities with the addition of software that can help residents develop sustainable habits. Each home at Sterling Ranch is equipped with sensors that monitor water, electricity, and energy use as well as photovoltaic energy production.

Our system uses information from these in-home water sensors to help Sterling Ranch residents understand their water consumption patterns. The software analyzes collected sensor data to produce a time-segmented water consumption summary and tips about how residents can reduce their overall use. The graphical results of this analysis are displayed in real time on an in-home tablet application, making these insights easy to access and understand. It is our hope that access to this analysis will motivate residents to develop more sustainable habits and fully understand the environmental and financial benefits of reducing their water consumption.

In-home water sensors feed meter readings to data analysis software, which communicates with the in-home tablet application to display a visual analysis of the home's water consumption to residents.

SIEMENS

ELECTRICAL ENGINEERING & COMPUTER SCIENCE

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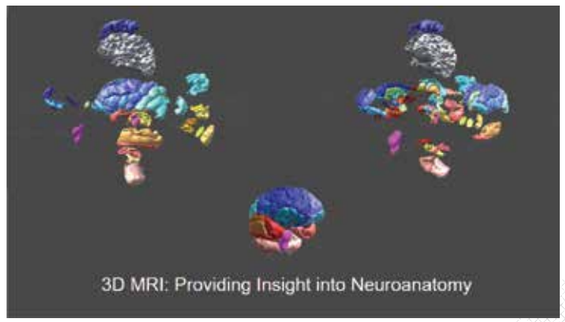
SPONSOR
Vanderbilt University Institute of Imaging Science

3D MRI PROVIDING INSIGHT INTO NEUROANATOMY

Our project's overarching goal is to harness the transformative power of virtual and augmented reality to reduce the ambiguity of radiological data for medical students and clinicians. We provide a clear visualization of radiological medical data with a multi-platform, easy-to-use application. Clinicians and medical students often have difficulty analyzing traditional radiological data because it is presented in only two dimensions. Even when these images are combined and 3D printed anatomical regions of the brain are created, they are often difficult to analyze due to the medium's rigidity and opacity. Our application, coded in the game engine Unity3D, displays a three-dimensional model of the brain taken directly from a set of magnetic resonance images. With our application's intuitive user interface, users can manipulate, rotate, expand, and visualize the model clearly. Further applications of the project include assisting with neurosurgery, diagnoses of pathologies of the brain, and inviting other anatomical regions to be segmented and modeled.



This 3D model of the brain was created using segmented structural MRI data. Top left: The brain segmented into 204 different anatomical regions in expanded view seen on one axis. Top right: The expanded model shown with a 45-degree rotation along one axis.

VUIIS

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SPONSOR
Vanderbilt University Medical Center, Department of Pediatrics

ELECTRICAL ENGINEERING & COMPUTER SCIENCE

iOS APP INTEGRATED WITH HEXOSKIN SMART SHIRT TECHNOLOGY

A Department of Pediatrics research team studies the physiological effects that slowed breathing has on the body. The research involves subjects following breathing protocols while wearing a Hexoskin Smart Shirt, a shirt that transmits the subjects' biometric data to Hexoskin's servers. Currently, the research team manually requests the data from the servers and then inputs the data into a third party program for analysis. This mobile app retrieves the data from the servers to analyze the results. The main advantage of the mobile app is that it handles the data retrieval and analysis automatically. Additionally, the app contains breathing exercise interfaces that help subjects follow the exercises more precisely. Previously, subjects memorized the exercise, but this app makes the exercise requirements easier for them to follow.

VANDERBILT UNIVERSITY MEDICAL CENTER

Screenshot of the app's breathing exercise interface.

MECHANICAL ENGINEERING

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ADVISERS
Lizard Walker, Aerial Dance Artist
Thérèse Keegan, Aerial Dance Artist

SPONSORS
Lizard Walker, Aerial Dance Artist
Thérèse Keegan, Aerial Dance Artist

AERIAL DANCE APPARATUS

Aerial dance is a subgenre of modern dance that incorporates a structure suspended in the air to allow for full three-dimensional creative movement. Lizard Walker and Thérèse Keegan are local Nashville aerial dancers who have asked us to create a custom apparatus for their performances. The apparatus must remain safe and portable while designed to be different than other, existing aerial dance apparatuses to ensure that it provides the opportunity for a unique performance. Additionally, each individual part of the apparatus needs to be replicable at a high volume level and designed so that a customer or performer can easily piece the entire configuration together with simple instructions. This will allow for other artists in the field to experiment with the apparatus as well. Our solution is a two-piece pyramidal steel structure suspended with structurally graded spansets. The custom joints provide the opportunity for complete disassembly of the apparatus. The upper tier fits within the lower for ease of transportation, and the painted steel bars provide comfortable gripping for the performers.

Lizard Walker practices with the two-piece pyramidal aerial dance apparatus.

MECHANICAL ENGINEERING

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SPONSOR
Vanderbilt School of Engineering, Biomechanics & Assistive Technology Lab

NEXT-GENERATION ANKLE EXOSKELETON

For centuries, people have strived to enhance human performance, and our aim is no different. We are trying to enhance human walking by reducing the metabolic energy consumption by 10 percent. In order to do this, we are designing an ankle exoskeleton that stores energy and transfers it back to the user. Our ankle exoskeleton contains an energy storage device (i.e. spring or resistance band) that is placed parallel to the user's Achilles tendon. When the user takes a step, some of the energy produced is stored in the device (i.e. the spring or resistance band stretches). When the user then pushes his foot off the ground, the stored energy is transferred back to the user (i.e. the spring or resistance band is released and returns to its original position).

A key element for the success of the ankle exoskeleton is a clutching mechanism that allows the energy storage device to engage and disengage at the appropriate times in order to not interfere with the natural walking motion of the user. The exoskeleton is completely passive, meaning that it does not contain actuators, such as motors, and it does not require batteries or any other external source of energy. This gives the user the freedom to wear the ankle exoskeleton in any situation.

BAT

This is how the next-gen ankle exoskeleton is worn.

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ADVISERS
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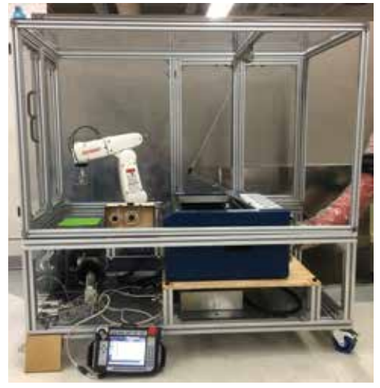
SPONSOR
DENSO Manufacturing Tennessee Inc.

MECHANICAL ENGINEERING

DENSO AUTOMATED MANUFACTURING AND ASSEMBLY CELL

DENSO engages in many educational outreach programs, demonstrating manufacturing techniques and robotics projects to teach basic engineering principles and inspire young students to pursue higher education and careers in STEM fields. This project aims to integrate a variety of systems in a cell that automatically manufactures cardboard figurines. Individual slices of a model are produced by a laser cutter, and a six-axis robot is utilized to move and stack the pieces. The cell also includes several custom-designed components which enhance the automation of the assembly process and display a wider range of electromechanical systems. Upon completion of the laser-cutting process, the robot applies tension to a cord that opens the laser cutter's door, enabling easy access to the cut pieces. A vacuum chuck with suction cups is attached to the robot's flange and used in conjunction with a compressor and vacuum generator to lift and move the cardboard pieces. Adhesive is affixed to the bottom of each slice before being added to the assembly. The completed figurines are given to students attending DENSO's programs as souvenirs and reminders of the vast capabilities of engineering systems.

DENSO



The cardboard figurine manufacturing and assembly cell.

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SPONSOR
Vanderbilt University Plant Operations

MECHANICAL ENGINEERING

DESIGN OF AN ALGORITHM FOR EFFICIENT COOLING TOWER CONTROL

Modern cooling towers operate under a simple cycle system. Cooling towers provide buildings with cold water and receive hot water back from the buildings after air and water heat exchange has taken place. Large fans inside the cooling towers are responsible for cooling the hot water that enters the towers. The purpose of this design project is to develop an algorithm for more efficient cooling tower operation with Vanderbilt University Plant Operations. Cooling towers are often operated at unnecessarily high loads under certain weather conditions. The main goal is to establish relationships between atmospheric conditions and cooling tower fan speed to find the most efficient use of power. In order to research and test these relationships, the Polar Power team has built several prototypes of small-scale cooling towers in order to test fan operation speeds based on different atmospheric conditions. As a result of this testing and analysis, the team is developing a flowchart to map the algorithm based on the team's findings. A proper algorithm will lead to significant savings through lowered power use and provide a universal guideline for cooling tower operation.

VANDERBILT UNIVERSITY

Cooling tower prototype used to find cooling results through different fan speed operations and atmospheric conditions.

MECHANICAL ENGINEERING

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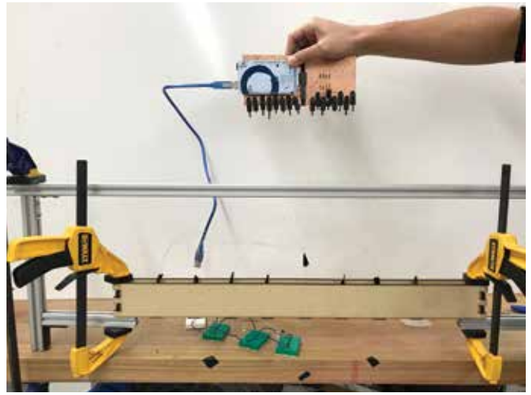
SPONSOR
Fiserv

FISERV'S MAGNETIC STRIPE QUALITY PROJECT

Fiserv Output Solutions (FOS), a credit card manufacturer in Nashville, is facing challenges in the factory. The FOS facility is responsible for manufacturing secure and non-secure credit, debit, gift, and other bank or membership cards. Using either or both an offset lithography or silk screen press, we print the desired image onto sheets of 56 cards. These sheets receive a plastic overlay, including the magnetic data stripe, are laminated and die cut into cards. Cards are then inspected for defects before being sent elsewhere for personalization.

We have identified one common defect that affects the functionality of the cards, which is the location of the magnetic stripe on the back. When the mag stripe is not in the right location, it is called "mag float." There are a number of possible sources of this error. When mag float occurs, cards no longer fall within ISO specifications for the location of the magnetic stripe on financial cards, which are set in place to ensure that any card reader can read the data from any mag stripe. If a job fails due to mag float, FOS incurs the cost of reprinting the entire job from the beginning.

The goal of this project is to build a system that can detect when mag float occurs on rolled overlay to prevent these defective cards from traveling through the finishing processes, wasting time, energy and money.



The solution devised to the problem of magnetic float.

fiserv.

MECHANICAL ENGINEERING

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SPONSOR
NASA Marshall Space Flight Center

IN-SPACE MANUFACTURING

NASA wishes to investigate the feasibility of 3D-printing tools and parts on the International Space Station. As a part of the in-space manufacturing feasibility studies, NASA also intends to study the effects of doing these prints in microgravity environments. Marshall Space Flight Center in Huntsville, Ala., is heading NASA's project to explore these in-space manufacturing capabilities. In conjunction with MSFC, our goal is to develop hand tools, an arm cast, and hybrid rocket fuel, as well as a 3D part file library with an interface. With this, the astronauts on the ISS will be able to create tools in a variety of sizes by inputting only a few dimensions, as well as have immediate access to a cast print in case of injury. (NASA currently does not have a 3D part file library, and there is no existing process which provides this service.) We anticipate to have an interface capable of providing intuitive access to the part models we create.

Sample 3D prints: lattice pattern used for casts (left) and hand tools of varying sizes (right).

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Liyun Guo, Product Engineer

SPONSOR
MAX Mobility

MECHANICAL ENGINEERING

TWO-WHEEL DYNAMIC CENTER OF GRAVITY WHEELCHAIR

The current power wheelchair market is dominated by four-wheel devices that are often bulky, have large turning radii and are potentially unsafe when operating on steep inclines. A two-wheel, self-balancing wheelchair addresses many of these issues. It allows the user to remain vertical on an incline, minimize their physical footprint, turn with a smaller radius, and overcome obstacles with its large wheels.

The Nino Robotics wheelchair currently employs self-balancing technology, but in order to make the product more accessible for users with disabilities, the team modified the Nino device by removing the leaning motion required to accelerate and replacing its obstructive steering handle with an integrated steering and motion control device. A mass displacement system simulates the leaning motion required to accelerate and includes a feedback control system to regulate the user's speed, all of which is integrated with steering via a single, user friendly joystick. With this solution, the accessibility and safety is improved for individuals with disabilities while maintaining optimal performance for an innovative transportation experience.

max mobility

The self-balancing NINO Robotics wheelchair.

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SPONSOR
Nashville Metro Arts Commission

MECHANICAL ENGINEERING

METRO ARTS PUBLIC ART COLLECTION: CONSERVING PUBLIC ARTWORKS

Metro Arts' public artwork installations cover many notable pieces, including the large number of artistic bike racks seen throughout Nashville. These bike racks, despite each being unique, face the same problems such as paint chipping, metal rusting and disruptive removal from the ground. This daily wear and tear is the result of the racks serving as "usable artwork." Additionally, commissioned artists have been making design decisions based on aesthetic, not sustainability, thus adding to the maintenance and upkeep required.

With the ultimate goal of extending the bike rack lifespan and time between maintenance, the team began to design subterranean mounting systems that would not detract from the artist's original intentions but would allow for easy bike rack removal. This mounting system is welded during fabrication to the bike rack posts and consists of an industrial hidden hasp lock, subterranean compartment containing the lock and a lid covering the compartment. In addition to fabrication, the team collected data and research throughout the year to compile into an infographic series. This series will allow for the rack's required technical specifications to be communicated to the artists in a clear, concise way.

A Metro Arts removable bike rack mount.

METRO ARTS

MECHANICAL ENGINEERING

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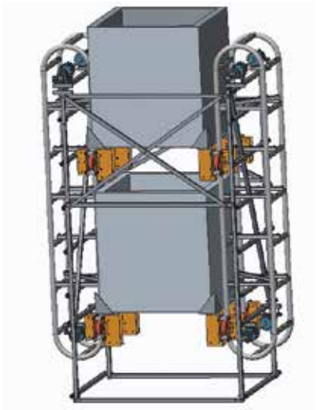
SPONSOR
Nissan

NISSAN OVER-UNDER MATERIAL HANDLING SYSTEM

In Nissan's Smyrna, Tenn., Vehicle Plant — the highest-volume auto plant in North America — parts are often kept in large containers near the assembly line where workers may access them for use in a specific manufacturing task. A large portion of the plant floor is kept clear for cart and worker traffic, leaving limited space for parts containers. Currently, Nissan uses forklifts to place these containers in designated areas where they remain until emptied of parts. A forklift is then used to remove the empty container while the assembly line worker waits for a full container to arrive. Often, multiple parts containers are lined up and interfere with traffic. This process results in a significant amount of wasted time and movement. This design project aims to improve this process through the implementation of a gravity-driven, over-under material-handling system that allows for three containers to be stored in the footprint of two. This system will allow for a full container to be ready and easily accessed after the emptying of the previous container. The worker will be able to switch out empty and full containers with minimal effort, which will improve the efficiency of the Nissan assembly line.

NISSAN



A computer rendering of the material-handling solution.

MECHANICAL ENGINEERING

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ADVISER
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SPONSOR
Kevin C. Galloway, Director of Making, School of Engineering

DEVELOPMENT OF A LOW-COST SOFT ROBOTIC DEEP SEA SAMPLE COLLECTION TOOL

While deep coral reefs and other deep sea environments have impressive ecological significance, they remain largely unexplored due to limitations in exploration and sample retrieval methods. The primary obstacle to studying deep coral reefs is depth. SCUBA divers rarely dive deeper than 30-50m underwater. Deep sea environments, such as deep sea coral reefs, located between 50-200m underwater, have been mostly inaccessible.

Using a growing selection of small remote operated vehicles (ROVs), biologists are able to collect samples at these previously unattainable depths. Despite these advancements, this research has been limited by a lack of low-cost, lightweight tools that can be mounted on a ROV and used to collect biological samples without damaging them. Conventional grippers, modeled after the Jaws of Life, are unfit for the delicate collection of soft biological samples — some of which are hundreds of years old and rare.

Using the previous work of our sponsor, our team has developed a solution. We have refined the soft robotic grippers, developed new cable-actuated cutters and joined them with a robust interface for use on an ROV. This provides a gentle grip on delicate ocean samples in a low-cost, lightweight package designed for continued use in seawater.

VANDERBILT
School of Engineering

Illustration of a remotely operated vehicle (ROV) collecting samples from the sea floor. Circled is the portion that our team has redesigned.

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SPONSOR
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MECHANICAL ENGINEERING

JUNCTIONAL HEMORRHAGING CONTROL DEVICE

Modern-day military body armor provides defense to critical areas such as the abdomen, thorax and head, but it does not protect the limbs or their areas of attachment to the torso. Consequently, these areas are prone to injury from energized fragments such as IED shrapnel, blasts and gunshots. Trauma to junctional zones is particularly troublesome because they are inaccessible with traditional tourniquets, thus hemorrhaging from major blood vessels cannot be controlled. In fact, 20 percent of U.S. soldier casualties deemed savable in Middle Eastern conflict from 2001-2010 were caused by junctional injuries.

The First Responders Junctional Hemorrhaging Control (JHC) team is addressing hip area junctional injuries with a low cost, hand-sized rapidly deployable junctional tourniquet. This is an improvement over FDA-approved JHC devices, which are rarely used by military field medics due high manufacturing costs, bulk, unreliable hemorrhaging control and cumbersome application procedures. Application of this new device relies on a custom-made ratchet mechanism, which allows a simple turning motion to tighten straps around a specifically designed pressure application block. This device has the potential to save hundreds of lives by equipping field medics with a quick and easy method for stopping junctional hemorrhaging.

VANDERBILT
School of Engineering

Diagram of how the prototype is applied to the hip junction, anterior to the femoral artery.

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SPONSOR
Symmetry Surgical

MECHANICAL ENGINEERING

LAPAROSCOPIC TOOL DEVELOPMENT

Laparoscopic surgery is a minimally invasive surgical technique with many advantages to the patient. The surgery is performed through small incisions, approximately 1 cm in length, in the abdomen of a patient. By operating through these small incisions rather than an open procedure through a large incision, surgeons can reduce the overall pain and recovery times for the patient.

The overarching goal for our project was to develop a new laparoscopic instrument set that features intuitive assembly, ratcheting and non-ratcheting ergonomic handles of different sizes, comfortable operation and sturdy overall design. We also focused on designing modular tips that could be easily disposed of. These will provide surgeons the ability to quickly interchange tips, minimizing cost and effort.

The main issue with Symmetry Surgical's current laparoscopic tool line is the vast quantity of tools. In many cases, they have several tools that represent similar functionalities, which makes customer interactions more difficult. We created a basic package that can be purchased to perform most laparoscopic surgeries.

Shown here is an earlier design of a laparoscopic tool, including a finger-actuated handle and a removable tool tip.

symmetry surgical

MECHANICAL ENGINEERING

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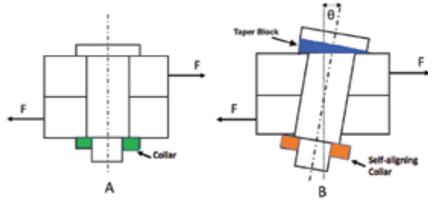
Melissa Holobach, Vice President, Operations

SPONSOR
Triumph Aerostructures

INSTALLATION ANGLE ANALYSIS OF WING FASTENERS ON GULFSTREAM G-650

Airplane wings are constructed from wing skins, ribs, spars, stringers and thousands of Hi-Lite pin/collar fasteners. The fasteners are installed manually to connect the wing ribs to other components, and thus, there is innate human error associated with drilling holes into difficult-to-reach locations. Some holes are unintentionally drilled at an angle instead of perpendicular to the parent aluminum material. This phenomenon is called a slant-drilled hole and is the basis of this design project.

Triumph currently fixes slant-drilled holes by installing an angled block of metal, called a taper block, under the head of the fastener in order to recreate a perpendicular surface and regain some of the lost joint strength due to the angled configuration. The team performed a full analysis of various sized Hi-Lite pin/collar fasteners for both perpendicular and slant-drilled holes. The analysis involved analytical by-hand calculations, finite element modeling solutions and physical testing in order to determine the loss of joint strength from the perpendicular configuration to the angled configuration — a quantitative value that has been coined as the knock-down factor. The goal was to prove a consistent loss of strength across all three analysis platforms.



The team performed a full analysis of various sized Hi-Lite pin/collar fasteners for both perpendicular and slant-drilled holes.

Triumph Group, Inc.

MECHANICAL ENGINEERING

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SPONSOR
Vanderbilt Aerospace Design Laboratory

POST-BOOST ROLL CONTROL USING COLD GAS THRUSTERS

As one half of this year's NASA Student Launch Competition team, we are responsible for the fabrication, testing and integration of the physical system that will perform our in-flight experiment. The objective of the experiment is to launch the rocket to an altitude of exactly one mile and perform a roll and counter roll about the main axis of the rocket using two pairs of thrusters. The team has fully designed and machined these thrusters to expel air from the onboard high pressure tank supersonically, generating enough thrust to roll the rocket in the face of the extreme resistance experienced during high speed flight.

The high-acceleration takeoff (~14 g's) requires an innovative carbon fiber reinforced airframe that is fabricated in-house. A dual-parachute deployment system allows us to safely recover and reuse our rocket. Subscale testing of a shorter rocket with single-directional control and the construction of a ground-based testing facility for roll control have allowed us to verify the efficacy of our vehicle and thruster design before the construction of our 95-inch, dual-directional, full-scale rocket. Our design and experiment have far-reaching implications outside of model rocketry alone, such as fine attitude control for satellites.

The rocket on a launchpad and the thruster system CAD model.

VANDERBILT AEROSPACE DESIGN LABORATORY

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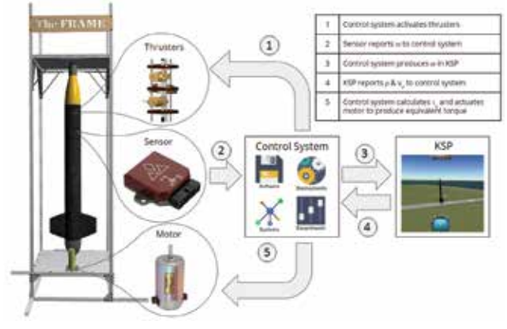
MECHANICAL ENGINEERING

SUBORBITAL LAUNCH VEHICLE ROLL CONTROL SYSTEM AND AVIONICS

The ability to control the movement of a rocket or other aircraft can improve vehicle performance and provide mission-critical maneuverability. Thus, the team's design directive is to successfully design, build, test and fly a fully integrated electromechanical payload that imparts two rotations about a rocket's vertical axis during ascent by using an onboard cold gas thruster system. Design of a control system for the rocket is a large portion of this challenge. This control system consists of a sensor that will detect when the primary rocket engine has stopped burning and inform the onboard computer that it is time to start firing the aforementioned thrusters to perform the roll experiment. After two rotations, the control system will fire the counter-roll thrusters to halt rotation. Using an onboard sensor and controller allows the rocket to make decisions in real time and thus be robust to any disturbances such as a sudden wind. This control scheme has been and will continue to be tested and refined on a ground-based test facility designed and built by the team, known as the FRAME, to ensure success on launch day.



Schematic of the testing procedure for our control system and how it communicates with real rocket on the FRAME and simulated rocket in Kerbal Space Program (KSP).

VANDERBILT AEROSPACE DESIGN LABORATORY

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MECHANICAL ENGINEERING

THE NEEDLESCOPIC OPERATION FOR SINUS ENDOSCOPY (THE NOSE)

Chronic sinusitis is a condition characterized by the swelling of the sinuses that affects over 29.4 million Americans, with symptoms including congestion, sinus pressure, runny nose and headaches. Currently, doctors use patient-reported symptoms and larger endoscopes that only reach the entrances of the sinuses. This limitation commonly results in a misdiagnosis. The goal of this project is to develop a tool that navigates a fiberscope through the nasal passage to observe the various sinus cavities. This will prevent unnecessary antibiotic or steroid medication and radiation exposure through CT scans for the patient.

The project is divided into two components: the handle and the flexible tip. The handle needs to be intuitive, ambidextrous and capable of housing a bending mechanism and ports for the camera, catheters or balloon sinuplasty device. The design of this is refined through an iterative 3D printing process. The tip, made of a biocompatible material, has a mechanical wrist (small notches cut by CNC and a wire tendon) that can bend up to 135 degrees to enter the various sinuses. The final device is expected to prove its viability, after phantom and cadaver testing, as a better alternative to current nasal endoscopes.

A 3D-printed endoscopic tool and sinus model used for demonstration and testing.

VANDERBILT UNIVERSITY MEDICAL CENTER

DESIGN AND PROJECT FACULTY

We take great pride in recognizing these faculty members who are the core of our design program. Their outstanding contributions and excellence as instructors, advisers, and mentors in our senior design and project courses have led to the work exhibited at Design Day 2017 and have transformed our Class of 2017 into young professionals.

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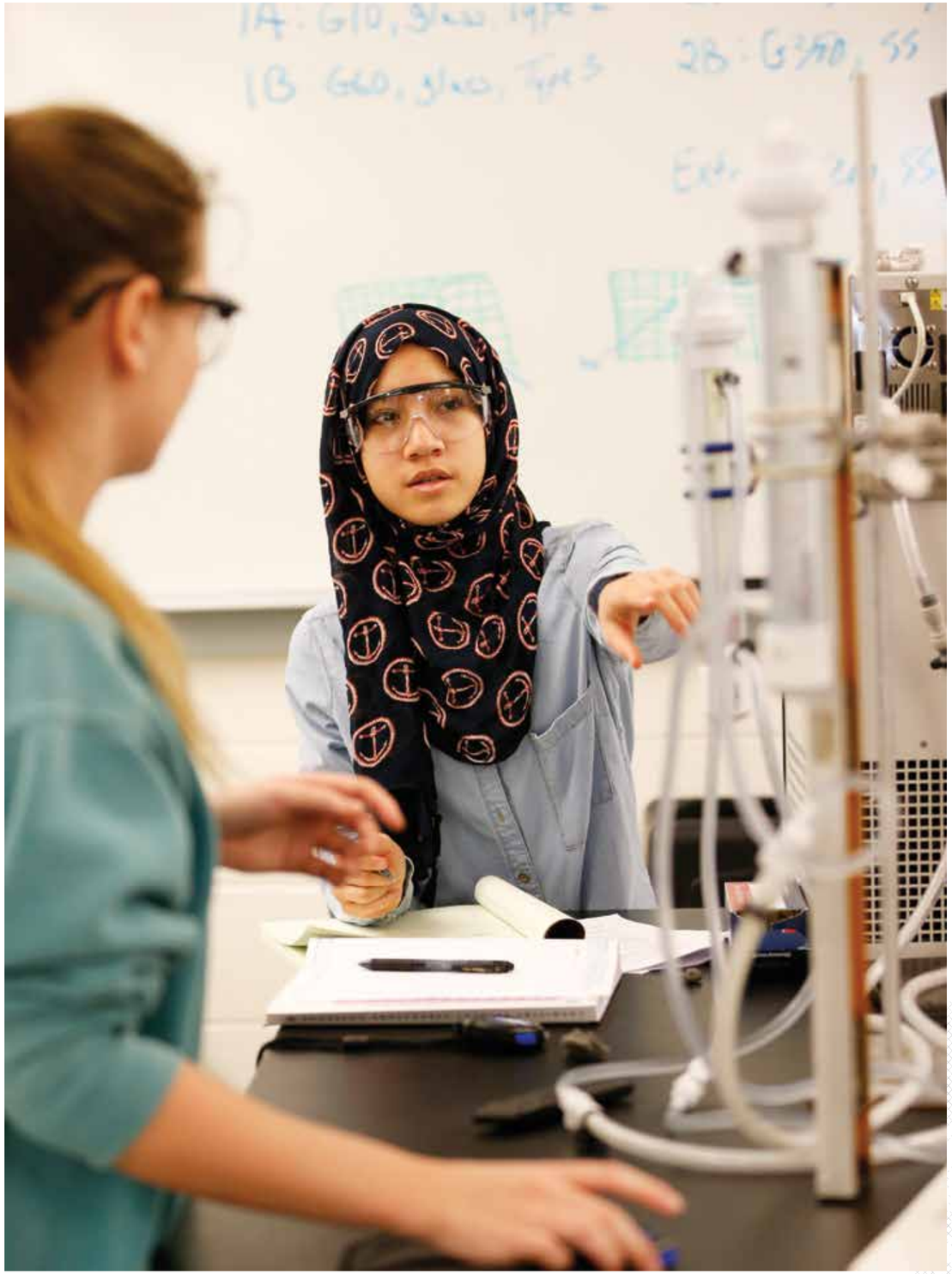

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