# DESIGNING the FUTURE

2015

## Student Projects

at Vanderbilt University School of Engineering

INSIGHT ◦ INNOVATION ◦ IMPACT®

# Summer 2015

In the real world, design can defy time constraints and obvious solutions, leading engineers down any number of roads to find solutions. At the Vanderbilt University School of Engineering, we aim to capture that experience for our students in their capstone design projects. The work is done through a two-semester course sequence where they divide into interdisciplinary teams, are matched to industry or university sponsored projects, and receive the equipment, space, and instruction to be successful.

Starting on page 14 of this publication, you'll find the amazing array of projects our students completed in just two semesters. Their projects ranged from a remote-control oxygen flow regulator to a new kind of digital musical instrument. The design faculty recognized on page 49 helped them understand the difficulties inherent in the design process, receive the needed support to overcome those difficulties, and become ready to apply their problem-solving skills in postgraduate studies or careers. My expectation for all graduates of the School of Engineering is to engage in work that has meaning, creates value, and solves real problems.

In this publication's initial section, we provide a deeper look at design

from not only our undergraduate students, but also our alumni, faculty, and graduate students. Some work in our research labs here while others launched their own startup companies, attracting national and international audiences for their work.

After reading *Designing the Future 2015*, I am sure you will understand why I am so proud of these Vanderbilt engineers—whether they are newly minted or they graduated years ago. Their work is inspirational.

Best regards,

**Philippe Fauchet**
Dean

# Design at Vanderbilt University School of Engineering

## Contents



# More Than an Inconvenience

*Hygiene and safety innovation for developing countries*

Violent attacks on women in the Indian countryside motivated a team of engineering students to develop a product to help keep the women safe.

Women in Kurmaali, a small village in India, have to walk 15 minutes to reach a place where they can relieve themselves. They have been attacked while taking that long walk.

Vanderbilt students developed a safe, plumbing-free toilet that won first place in the School of Engineering's Senior Design class—and it has the potential to change lives in nations where plumbing is considered a luxury.

Biomedical engineering majors Siji Oluwadara and Julia Dmowska, electrical engineering major Caroline Henley and mechanical engineering major Jeremiah Afolabi, all members of the Class of 2015, teamed up for the project.

They were inspired by a June 2014 BBC report titled "India's Long, Dark and Dangerous Walk to the Toilet." It told of the women of Kurmaali and the dangers they face every day.

The team's solution to lack of bathrooms in developing nations: an affordable toilet that requires no plumbing, sucks away waste with a vacuum pump, traps odors, and features a detachable, easy-to-carry container for disposal.

The Senior Design course is led by Associate Professor of the Practice of Biomedical Engineering Matthew Walker III, a former Merck & Co. head of technology transfer and drug development. In the course, Walker encourages students to consider their work more than a class project—to think about taking it to market to solve real-world problems. He also schedules lectures from experts covering the challenges of sustainability, cost, marketing, safety and ethics, so students can think about what those problems might be.

Seniors Siji Oluwadara, Jeremiah Afolabi, Caroline Henley and Julia Dmowska (not pictured) developed a solution to a real-world problem: affordable toilets for developing nations.

Alumnus Jack Minardi's new Voxel8 3D printer can make custom circuit boards in 30 minutes. It also produced this working UAV.

# Not Just Plastic

*Game-changing breakthrough in 3D printing*

Jack Minardi's degree from Vanderbilt University is in electrical engineering, but the cross-collaboration and real-world design experiences he gained here put him on the path to his current role with a buzz-attracting startup.

Minardi, BE'12, is the co-founder and software engineering lead for Voxel8, which grabbed tech media's attention in 2014 by introducing its custom electronics-producing 3D printer.

It uses silver ink to print metal electronic components inside plastic. That means the printer Minardi programmed can produce working pieces in one run. Voxel8 is the first printer to print with both plastic and metal in the same part.

Presently, Voxel8's printer can make a working four-propeller UAV. Future applications will include custom hearing aids printed with the electronics already inside, plus other wearables such as Fitbit-style pieces customized with the look and features users want.

Although Minardi was an electrical engineering major, he took lots of programming classes—both required and not—and found himself designing "little throwaway utilities" just for fun. He took a software design job after graduation, then joined the Voxel8 team.

The key to the technology is a paste with silver particles that comes out in the consistency of peanut butter but dries like any other metal component. Right now, the technology can create circuit-integrated chips down to the 800-micron pitch, or pin-to-pin distance, which are common in many components. That allows for custom circuit boards to be made in 30 minutes instead of days, and they're less expensive.

Voxel8's custom electronics-producing 3D printer is already a darling of tech media—attracting attention from sites such as *Wired* and *Popular Mechanics*. *Fast Company* named it one of the 9 Best Ideas from the 2015 International Consumer Electronics Show. It represents a giant leap in a technology that's already making giant leaps.

The company will be shipping units by the end of 2015, with standard models selling for $9,000, including a supply of polylactic acid and silver ink.

# You Can't Get Lost

*Brilliant navigation with Music City Center Wayfinder*

Jules White's new Wayfinder app for iPhone and Android provides photo-based, step-by-step directions to guide visitors through huge, unfamiliar buildings.

The app debuted last year when White, assistant professor of electrical engineering and computer science, joined Nashville Mayor Karl Dean, JD'81, to demonstrate it at the city's massive new convention hall, Music City Center.

The turn-by-turn wayfinding system is the first of its kind used in a convention center. It features low-energy Bluetooth signals interacting with 62 small, wall-mounted beacons called iBeacons.

Users download the Music City Center app from their smartphones' app store. The app uses the beacons to automatically pinpoint the user's location within the 1.2 million-square-foot, 16-acre center and provide directions from that location. Users also can ask the app for directions, as well as select a destination and directions to it.

White used the Music City Center floor plan, lists of rooms and their attributes and even descriptions of art on the walls to create the app's abilities. It also can collect data for foot-traffic analysis, pinpointing when and where most people enter the convention center and where they're most likely to get lost. That could lead to signage changes and other adjustments to improve the facility.

White and a team of Vanderbilt students created Music City Center Wayfinder as part of a public-private partnership between the convention center and Vanderbilt's Institute for Software Integrated Systems. The wayfinding technology they developed prompted the launch of a startup company, White's Ziiio.

There was no payment by either side for the project. The center received the app, and White and his team gained the opportunity to demonstrate their technology in a convincing setting and on a national stage.

White said there are ample opportunities to use the app and iBeacons elsewhere, including airports, hotels and hospitals.

You'll know where you are if you have the Music City Center Wayfinder app on your phone. From left: Jules White and Nashville Mayor Karl Dean test the app.

# The Ultimate Alpha Tester

*Grad student has inside insight on paralysis*

The exoskeleton that mechanical engineering Ph.D. candidate Andrew Ekelem is programming could potentially impact the lives of an estimated 250,000–400,000 Americans living with spinal cord injuries or dysfunction.

Ekelem is one of them.

In 2010, he was a University of California, Berkeley, undergraduate enjoying a weekend of snowboarding near Lake Tahoe. Ekelem tried a resort's highest jump, landed on his back and found he couldn't move his legs. After two surgeries and rehabilitation, it became clear he never would walk again.

He explored spinal cord research but transferred his focus to devices that help paralyzed patients. He chose Vanderbilt for his doctoral studies so he could work on Professor of Mechanical Engineering Michael Goldfarb's exoskeleton.

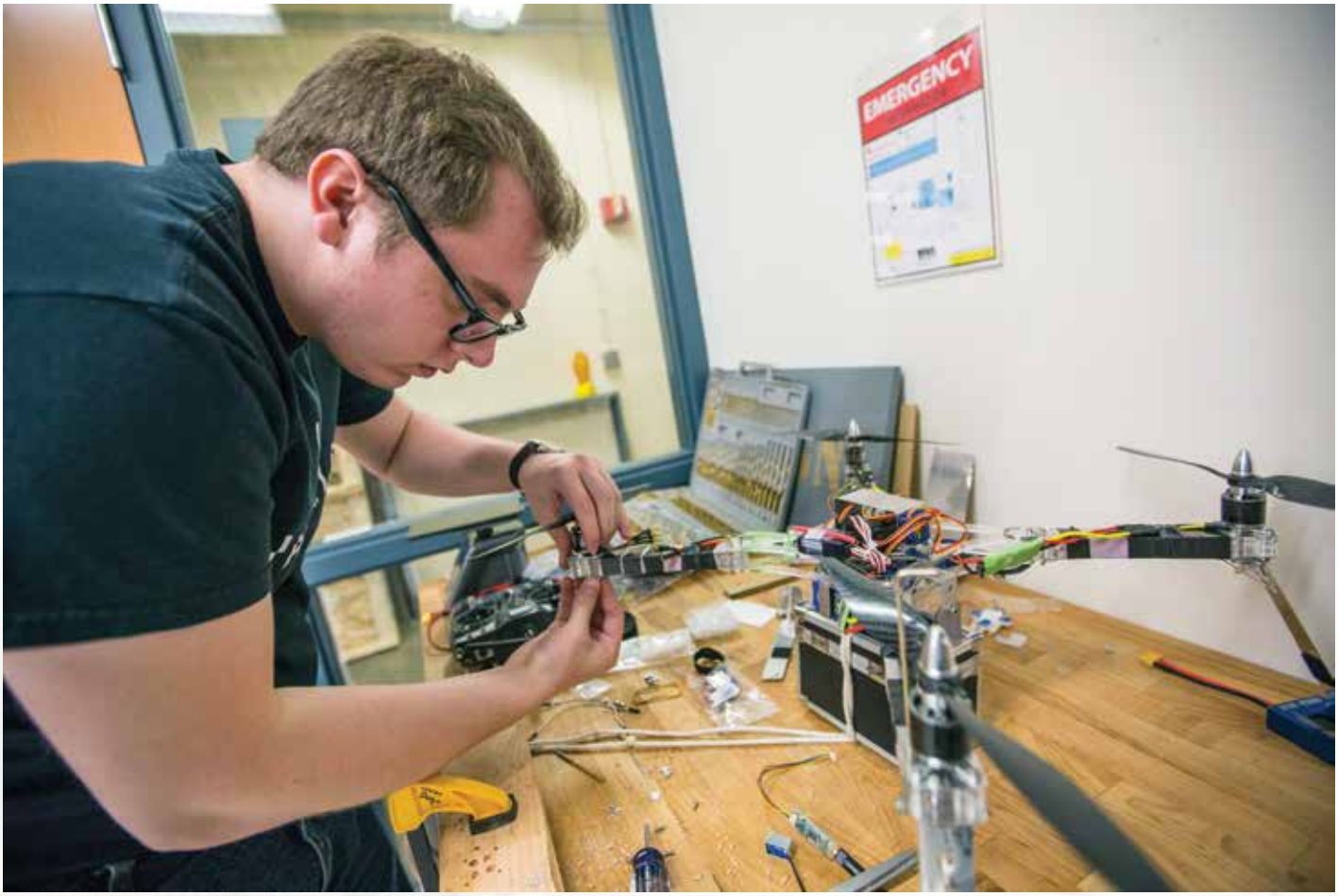
Ekelem's engineering background was ideal for the exoskeleton team, Goldfarb said, but his accident gives him a perspective few graduate students acquire.

"He's more highly motivated and has more insight about what we want to do," Goldfarb said. "We can do the engineering, but it's impossible to get the insight that Andrew brings."

Licensed as Indego, the exoskeleton weighs 26 pounds and breaks into five pieces that users can easily transport and put on by themselves. Ekelem and the rest of Goldfarb's team are working on an addition—sending electrical impulses to users' leg muscles, which encourages healthy movement and conserves the battery because motors would do less work.

The Indego technology is licensed to Parker Hannifin Corp. and is expected to have FDA approval and go on the market late this year. Ekelem is on track to earn his Ph.D. in 2018.

Andrew Ekelem uses 25 feet of wire and a laptop registering ascents, descents, walking and standby modes as he works with exoskeleton test subject Dustin Fleeman. Above, from left, Ekelem, Michael Goldfarb and Fleeman. Opposite page, from left, physician Gerasimos Bastas and Ekelem monitor Fleeman as he walks using the exoskeleton.




Vanderbilt has found that its students do better and are happier when they begin to "do stuff" in their first year.

# Getting Their Hands Dirty

*First-year students dive into hands-on learning*

Some engineering students arrive with a clear idea of their paths through college to future careers. Others know their strengths lie in math and science, but they're not sure of the best engineering major to fit their interests.

ES 140 Introduction to Engineering is a course for both.

For some, it reinforces a decision the students already made. For the others, it exposes students to specific topics of interest so they can settle on a major.

Christopher Rowe, associate professor of engineering management and director of general engineering, helped redesign the course a decade ago. He said that incoming students select three modules for their first semester, spending about four weeks in each. Thirteen faculty members from across the departments guide about 340 students through the course.

"The power of ES 140 and the way that it's structured is that it lends itself extremely well to hands-on design projects. That's important for first-year students—get them in a lab and get their hands dirty," Rowe said

For example, those who pick civil and environmental engineering as a module spend class at the Laboratory for Systems Integrity and Reliability designing, fabricating and testing wind turbine blades in a large wind tunnel. Students interested in biomedical engineering investigate using lasers to improve people's eyesight. A mechanical engineering module introduces students to the school's Design Studio, where they can learn how 3D printers work and use one to make their own projects. In all, students can pick three different disciplines to explore, each with a hands-on component illustrating the respective topics.

No matter what modules they choose, all students must work in teams to deliver a project at the end of each, and it doesn't end there. Presentations get them communicating effectively about their work.

# Better Healing with Nanotechnology

*Regulating the regulators*

Behind the pathology for a variety of painful and deadly diseases lies genes that aren't doing their jobs.

They may be blocking the healing process for foot wounds in diabetic patients or contributing to cancer by interfering with the dying off of mutated or damaged cells.

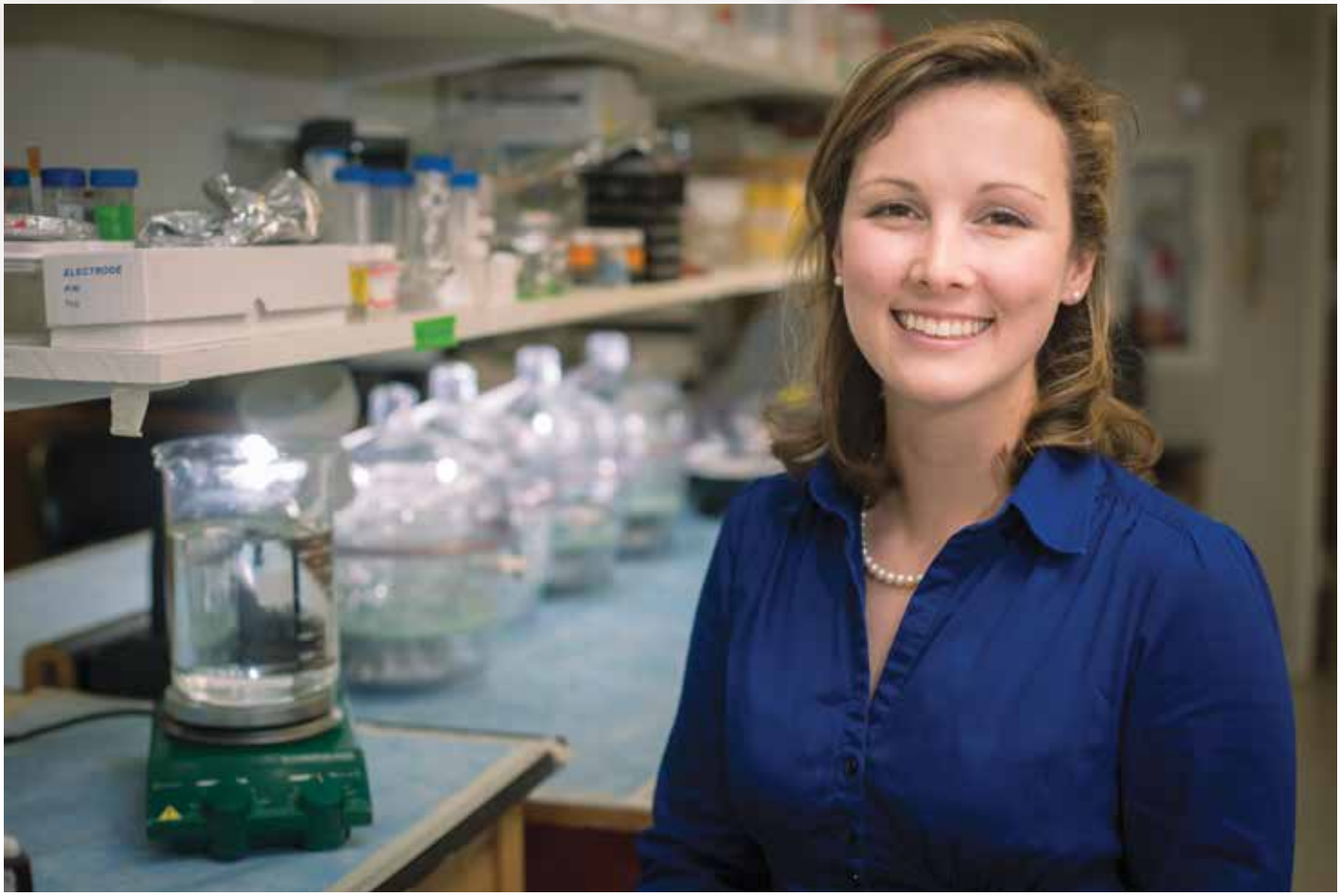
Kelsey Beavers, a Ph.D. candidate in interdisciplinary materials science, is exploring how inserting engineering into those biological processes can lead to a healthier society. She works with Assistant Professor of Biomedical Engineering Craig Duvall in developing nanotechnology that could deliver drugs for a broad range of treatments.

Beavers and Duvall work with microRNA. This "master puppeteer" of gene networks is a regulatory molecule that, if overactive, can be devastating for patients because it may turn off genes vital to maintaining healthy tissue. Regulating overactive microRNA could result in faster skin healing or regeneration of damaged bones, kidneys and livers.

In the case of diabetic foot wounds, Duvall and Beavers have already demonstrated that turning on a transcription factor that controls a whole group of genes—rather than using a single protein growth factor—could result in more robust healing.

Designing an extremely targeted drug carrier is also a high priority, as only microRNAs in diseased tissue should be regulated and only for a certain length of time.

That kind of work is what drew Beavers to Vanderbilt, allowing her to design her own interdisciplinary course of study in materials science and focus on nanomaterials. She is co-mentored by Sharon Weiss, associate professor of electrical engineering.



Kelsey Beavers won Vanderbilt's graduate student 3-Minute Thesis competition this year by explaining her work simply, vividly and in just three minutes.

# Use the Husk, not the Corn

*Developing more efficient biofuels*

The work that graduate student Sonia Brady does with Matthew Lang involves reaching out trans-institutionally at Vanderbilt.

Nature exquisitely engineered a way to produce fuel from organic matter. The process resides in decaying leaves on the forest floor or a backyard compost pile and the tiny amounts of energy those produce.

Without understanding how enzymes work to break down organic matter on the molecular level, human engineers can't apply the process to untold areas of research, including the significant promise of efficient and plentiful biofuels.

Matthew Lang, professor of chemical and biomolecular engineering, and Sonia Brady, a Ph.D. candidate in chemical engineering, are beginning to decode the process.

Lang studied motor proteins, often in the context of medical applications, before coming to Vanderbilt University from MIT. When he arrived, faculty at Vanderbilt introduced him to cellobiohydrolase enzymes and how they break down cellulose, the most abundant organic polymer on Earth.

Through cross-disciplinary collaborations, Lang and Brady were able to take that process down to a single-molecule test.

Ethanol, derived from corn, provides a good context to explain Lang and Brady's research. It's simple to make because it converts starch in the corn itself into fuel. Brady and Lang now want to break down cellulose in the corn husks or from other feedstocks that can grow more quickly and pull fewer nutrients from the soil than corn.

Brady arrived at Vanderbilt in 2011 and won the Department of Chemical and Biomolecular Engineering's teaching assistant award her first year.


# Pumped about Bicycles

*Applying engineering to a classic*

Alumnus Josh Poertner combined a love of biking with engineering design to create these beautiful and functional bike pumps.

As a teenager, Josh Poertner, BE'00, raced bicycles in Europe. At 15, he paid $90 for his first black and pink Silca Super Pista bike pump.

Poertner came to Vanderbilt and earned a mechanical engineering degree while still traveling and racing. He says Vanderbilt's engineering machine shop saved him, but almost killed his GPA (although he graduated cum laude).

"It's where I learned that somebody actually has to make the things that engineers design. Often, we young engineers were designing stuff that could not be made," he says. After graduation, he joined Zipp Speed Weaponry's tech team, working on carbon-composite bike racing wheels.

Then, in 2013, Poertner flew to Italy to have dinner with Claudio Sacchi, the grandson of the founder of Silca, the classic Italian bike pump he treasured and that's been a favorite of racers since 1917. Poertner offered to buy the company, move it to Indianapolis, and honor the name. Sacchi said yes.

The new Super Pista floor pump is American-designed. Its pressure gauge is on the base to keep it safe. The pump handle of rosewood and stainless steel was inspired by Japanese cooking knives. A magnetic chuck snaps the nozzle onto the tire's valve. The air hose is a high-pressure brake line from a race car. "It's a three-millimeter inner diameter Teflon tube overbraided in stainless steel and then outer-jacketed in a beautiful red polyurethane," Poertner said.

The Silca Super Pista Ultimate Floor Pump costs $450. It won best in show for new products at the 2014 Interbike convention and trade show. The Super Pista Ultimate Artist Edition is $950. No two are alike. It's sold out.

"I know the price is high, but I'm confident that there will always be a market for a finely handcrafted tool that's beautiful, functional and built to last forever."

He still has his first Silca pump. "My kids use it to pump their tires."

# Thank you to our SPONSORS

Our sponsors generously support the Vanderbilt University School of Engineering's design program.
Thank you for providing your time, experience and financial support that help make our program a success.

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Rebecca Lisi

Sarah Englert

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Neonatal Intensive Care Unit

Vanderbilt University School of Engineering,
ASCE Student Chapter

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Vanderbilt University School of Medicine,
Cascio Laboratory

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# About Design Day 2015

The Vanderbilt University School of Engineering had a full house for Design Day 2015, April 20. This year's event featured projects with Camgian Microsystems, Metova, Nissan North America, Northrop Grumman, Philips Healthcare, the Surgical Clinic, United Launch Alliance and many other companies. The public sector was represented with projects benefiting entities such as Metro Nashville Public Schools and the Nashville Public Library. We thank all of our project sponsors and give special thanks to AT&T for its support of our design program and of the 2015 Innovation Awards.

Three innovation awards were given this year:

- First Place—Translational Imaging Using Telemedical Modalities for 3D Printed Medical Devices (p.17)
- Second Place—Hysteroscopic Surgery Simulator (p. 21)
- Third Place—JetStream Clean Hybrid Energy Scalable System (CHESS) (p. 35)

This year, Associate Professor of Chemical and Biomolecular Engineering Scott Guelcher and Assistant Professor of the Practice of Mechanical Engineering Tom Withrow joined the engineering design faculty team. Also new were video presentations of software engineering projects by computer science students under the direction of Jules White, assistant professor of computer science and computer engineering.

In Vanderbilt's design courses, students learn how to assess client needs, research existing designs and apply both creativity and engineering concepts to produce design solutions. They work in teams, upholding professional, ethical and business standards. By the end of the academic year, the teams produce a prototype, process design or virtual demonstration.

This year, one team went beyond and put its project to work in the field. The team, composed of members of the Vanderbilt Aerospace Club, designed and built a compact rocket and an autonomous ground support equipment system. The ASGE was designed to locate, retrieve and deposit in the rocket a sample as might be required for a mission to Mars. The team's system won first place, marking the school's third consecutive first place win in the NASA Student Launch competition, held near NASA's Marshall Space Flight Center in Huntsville, Alabama.

We are proud of all our students and their achievements. At Vanderbilt, Design Day is not only a showcase for our students but also a celebration of their engineering education. Key to the success of Design Day is the involvement of our industry sponsors. We value design projects sponsored by industry and invite project sponsors—industry representatives and entrepreneurs, as well as research and clinical faculty—to submit project proposals. This enriching experience allows you to work with Vanderbilt engineering seniors and discover what makes our students stand out. If you or your colleagues are interested in sponsoring a project, please contact me.

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The following is a reprint of the 2015 Design Day catalog.

# Contents



*AT&T Innovation Award Winner

# Contents



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 and Translational Research grant (UL1TR000011 from NCATS/NIH).

[1]Paul A. Harris, Robert Taylor, Robert Thielke, Jonathon 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.

# Remote-Controlled Oxygen Flow Regulator

**TEAM MEMBERS:**

Steven Arnst
Ketan Kulkarni
David Liao
Nicholas Ma

**ADVISER:**

Lisa Lancaster, M.D.

**SPONSOR:**

Vanderbilt University Medical Center, Department of Medicine, Interstitial Lung Disease Program

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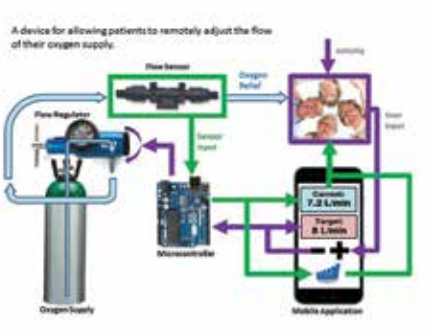



There is a need in the market for a device that allows patients with interstitial pulmonary fibrosis (IPF) to remotely adjust the flow rate of their in-home oxygen delivery unit. The current standard for oxygen delivery involves a manual flow regulator that must be adjusted by a dial on the oxygen source. This requires physical activity that may lead to patients receiving less oxygen than they need. The goal of this project is to create an oxygen delivery device that allows patients to adjust their flow rate through a mobile application on their Android smartphone. The design includes a Wi-Fi-enabled microcontroller and a flow sensor that collects data for ambulatory patient monitoring. Because the target users of the device are primarily elderly patients, the mobile application features a simple user interface that resembles the dial on current oxygen regulators, which minimizes the need to learn new technology. The device will reduce the need for IPF patients to physically exert themselves to adjust their flow rate, and allow them to use their oxygen delivery system more efficiently.

# A Multi-Contact Electrode to Identify the Origins of Seizures in Mouse Models of Epilepsy

**TEAM MEMBERS:**

Julia Dmowska
Benjamin Jacobi
Christopher Monsen
Mihir Odak
Tianwei Shen, BME/ChE
Azwan Zaman

**ADVISERS:**

Matthew Walker III, Associate Professor of the Practice of Biomedical Engineering

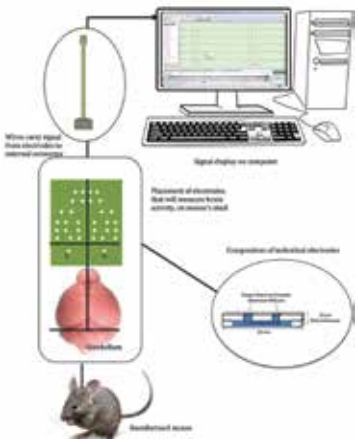
Martin Gallagher, Associate Professor of Neurology

**SPONSOR:**

Vanderbilt University Medical Center, Department of Neurology

VANDERBILT UNIVERSITY MEDICAL CENTER

The project's sponsor is studying how epilepsy begins and spreads throughout the brain in a mouse model. The multi-contact electrode he is using is too expensive to allow for the number of experiments he wishes to perform. It also does not cover the brain as adequately as the sponsor would like. The project's goal is to design an electrode that works as well or better as the one he is currently using, and can be made using in-house equipment at Vanderbilt for a fraction of the cost. The team designed the electrode layout after a model that had been previously used by other researchers. The new layout provides better cover of the overall mouse brain than the existing electrode. We also chose slight material changes to increase savings, such as changing the electrodes to copper. The team built a prototype by designing photomasks using electron beam lithography and used these masks, as well as various photolithographic techniques, to produce the electrode. We are testing it in vitro and in vivo, and revising the process as necessary. The final product covers more of the brain than previous electrodes while costing much less, creating a better and cheaper electrode.



**Schematic representation of our project. Copper wires carry signals to the display from copper electrodes.**

## MRI-Compatible Vibrotactile Stimulus Device

**TEAM MEMBERS:**

James Baker-McKee
Michael Bischoff
Robert Hanlin, CompE
Edward Ko
Jingxiao Wang
Yuan Xie

**ADVISERS:**

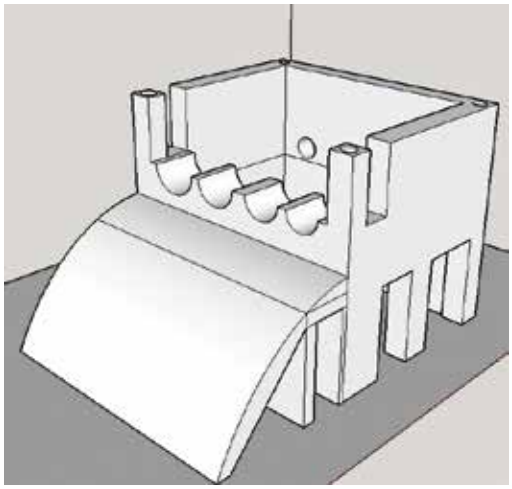
Carissa Cascio, Director of Cascio Laboratory

Lauren Bryant, Ph.D. Candidate, Cascio Laboratory

**SPONSOR:**

Cascio Laboratory, Vanderbilt University Medical Center
Kennedy Center for Research on Human Development

VANDERBILT UNIVERSITY MEDICAL CENTER



The current standard for autism diagnosis is qualitative, relying on specialists who assess patient behavior rather than the use of imaging and objective biological markers. Since research suggests that affected patients have hypo- and hypersensitivities to stimuli, researchers could use magnetic resonance imaging (MRI) of brain activity to determine reaction thresholds and sensitivities from tactile and auditory stimulation.

Our solution is a compact, modular and MRI-compatible device providing tactile, auditory and visual stimulation. A ceramic chip and MRI-compatible headphones provide tactile and auditory stimulation, respectively. An optional LCD screen provides visual stimulation for non-imaging sessions. A 3D printed housing attaches the ceramic chip to the patient's finger and holds the LCD screen. A Raspberry Pi computer and compact oscilloscope control all three of these devices. Researchers will input experimental parameters for the three types of stimulation into a graphical user interface (GUI). The GUI will communicate the parameters to the Raspberry Pi to carry out the experiment. Future research will use imaging data gathered during multisensory stimulation. The data will lay numerical groundwork for analyses of therapeutic efficacy and quantitative descriptions of disorders in the autism spectrum.

## 3D-Printed Clubfoot Casting Through Smartphone Imaging

**TEAM MEMBERS:**

Nathaniel Braman
Attiyya Houston
Melena Mendive
Simeng Miao

**ADVISERS:**

Matthew Walker III, Associate Professor of the Practice of Biomedical Engineering

Jonathan Schoenecker, M.D., Pediatric Orthopaedic Surgeon

**SPONSOR:**

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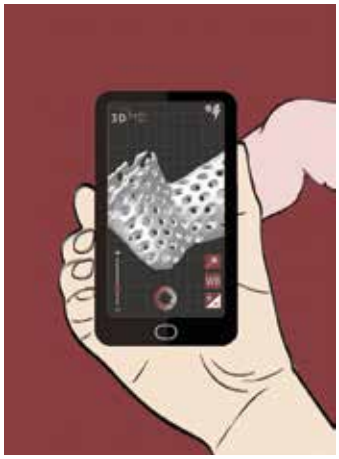

Clubfoot is a congenital deformity characterized by an inward twisting of the feet, affecting 1 in 1000 infants worldwide. Treatment begins with a series of castings to reposition the foot, requiring weekly visits to an orthopod. Despite the prevalence of clubfoot, relatively few healthcare providers specialize in its treatment, leaving young patients at risk of lifelong deformity and impaired mobility. We aim to narrow this treatment gap by developing a more accessible clubfoot casting protocol that capitalizes on the ubiquity of smartphones.

Our approach transforms the common smartphone into an intuitive diagnostic imaging device to guide clubfoot treatment. An app instructs parents to image their child's foot from key angles. An image processing platform extracts anatomical parameters used to predict and apply the next phase in correction to a 3D cast model. Models are sent to a 3D printer, delivering casts customized to patients' fit and therapeutic needs. This protocol improves upon current clubfoot treatment by reducing technical skill requirements. Additionally, our design empowers parents to take an active role in their child's treatment and offers enhanced comfort and convenience, while delivering efficacy on par with current standards.

## Pressure Mapping of Prosthetic Socket-Liner Interfaces

**TEAM MEMBERS:**

Jeremy Arkin
Devitt Frank
Zachary Pryor

**ADVISER:**

Aaron Fitzsimmons, CP, OT, FAAOP

**SPONSOR:**

The Surgical Clinic PLLC


Our goal is to determine differences in pressure between the socket and liner interface on a residual limb to enhance personalized prescription of prosthetic devices. Currently, the prescription of prosthetic devices has been governed by patients' qualitative feedback of whether or not their device feels "comfortable." Amputees often suffer from neuropathy; therefore, this qualitative feedback may not reliably confirm that the prosthetic is not imposing stresses that will result in tissue degeneration. We designed a removable pressure-mapping device to provide prosthetists with reliable force distribution information to optimize the customization of a patient's prosthetic device.

A casted elastomer strip containing force sensitive resistors is inserted into a patient's prosthetic device socket in a possible area of high pressure. An Arduino microcontroller gathers the sensor output and displays the location and degree of the associated forces. This output can be gathered during a stationary standing position, as well as during a full gait cycle for a better understating of the acting forces within a patient's prosthetic device. A prosthetist can then physically alter the device socket to alleviate identified areas of high pressure. The strip is a more mobile and cost efficient prescriptive tool than current mapping systems. It will additionally gather much needed data on the different pressure ranges associated with locations on residual limbs.

## Implementation of Real-Time Tracking in the Vanderbilt NICU

**TEAM MEMBERS:**

Kristin Barth
Megan Madonna
Houston Massey
Trenton Piepergerdes

**ADVISERS:**

Dan France, Research Associate Professor of Anesthesiology, Medicine and Biomedical Engineering

William Walsh, M.D., Pediatrics, Chief of Nurseries

Peter Grubb, M.D., Pediatrics, NICU Medical Director

David Cochran, Senior IT Consultant, Vanderbilt

**SPONSOR:**

Monroe Carell Jr. Children's Hospital at Vanderbilt, Neonatal Intensive Care Unit

The Neonatal Intensive Care Unit in Monroe Carell Jr. Children's Hospital at Vanderbilt houses 100 beds spread over a quarter mile and is managed among five physician teams. This requires meticulous organization by the providers to coordinate the logistics for infants and teams. Twice daily, providers meet to relay patient information, to confirm the location and the team assignment of each patient, and to communicate upcoming infant room changes. These meetings often last more than 30 minutes, which causes efficiency and safety concerns. Our goal is to aid clinician teams in making decisions about infants' locations and in responding to the patients' needs in an organized fashion.

We implemented AeroScout asset-tracking sensors to track babies, providers and key pieces of equipment throughout the NICU. We also created a mock-up map display system and Systems Requirement Document detailing how tracking technology can assist the NICU team in efficiently planning and coordinating operations. An electronic map display system differs from the current standard of written and oral communication by eliminating errors that may arise from paper transcription, by reducing time spent coordinating logistical information, and by providing a quick way to locate other clinicians and equipment in emergencies.

## Hybrid Prosthetic Socket

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**ADVISER:**

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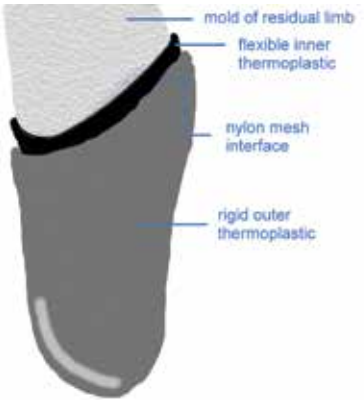
The Surgical Clinic PLLC




In the United States alone, there are currently more than 1.2 million people who have suffered the loss of a limb. Of these, about 18.5 percent are above the knee (transfemoral) amputees. The prosthetic socket is the component of a prosthetic that interfaces directly with the residual limb. Current sockets on the market tend to be either 100 percent rigid or 100 percent flexible, which can make them unsuitable for the range of motion involved in a normal day's activity. Sockets often dislocate or lose their fit while a patient is seated because the socket is too rigid to flex with the patient's leg, or the socket is too flexible to withstand forces of more rigorous activity.

To address these issues, the team used a unique nylon mesh interface to bind two thermoplastics together to make a transfemoral socket. The inner thermoplastic is flexible and offers comfort. The outer thermoplastic is rigid and able to withstand forces experienced while the patient is mobile, while still more flexible than materials (such as carbon fiber) used in current socket designs. The socket can simultaneously flex with a patient's residual limb and support a patient's weight during activity. This design is also easier, faster and cheaper to manufacture than current prosthetic sockets, reducing costs to both patients and prosthetics manufacturers.

## NICView: A Neonatal Case Simulator

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Medical residents in the neonatal intensive care unit face new work hour restrictions. As a result, residents today are less experienced than previous generations in decision-making and procedural knowledge. Therefore, a method of exposing residents to NICU scenarios outside of their work hour constraints is desirable to ensure that residents are broadly prepared to provide high-quality care.

NICView is an interactive 2D simulation game that mimics cases seen in the NICU. Through exposing residents to case simulations, the intent of our project is to increase decision-making speed and procedural competency in residents. The game begins with a clinical vignette. The resident will then use this vignette to make appropriate decisions and choose the appropriate medical instrument or procedure. Finally, the users will receive points based on the correctness and timeliness of their decisions.

Our project has several advantages compared to a simulation doll. The NICView is playable at home, less expensive and does not require a specialist. We hope to see decreased decision-making time and increased correctness in comparative skill set scenarios for residents who use the game, which will translate into the clinical setting by allowing residents to focus more on performing procedures more quickly and accurately.

## Hydraulic Knee Design

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Currently, there are an estimated 222,000 transfemoral amputees in the United States alone. While prosthetic knee options exist for walking, running and biking, no affordable knee is capable of performing all three activities effectively. Prosthetic knees range from $4,000 to $80,000, and most transfemoral amputees cannot afford to purchase different knees for various activities. Therefore, we designed a lightweight prosthetic knee capable of easily transitioning between walking, running and biking modes.

For walking, a rotary hydraulic unit built into a polycentric frame provides our knee with both stumble recovery and increased toe clearance. Additionally, an adjustable bumper locks at different angles to shortening the knee's backswing and decreasing overall knee extension time to improve high-speed running performance. Finally, for biking, our knee disengages the geometric locking of the polycentric frame and minimizes the damping of the hydraulic unit to allow for a smoother pedal. No currently available knee features a polycentric frame with stumble recovery, a polycentric frame with biking capabilities, or an adjustable bumper. These features offer active amputees a lightweight, versatile solution for high-level performance in multiple activities with a single prosthetic.

## Night Eyes

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Vanderbilt University Medical Center


Aging drivers struggle to differentiate objects during nighttime driving due to changes in eye characteristics such as lens and pupil properties, the number of rods or rod pigments, and eye muscle strength. These drivers need a solution that will improve their acuity at night by increasing visible contrast. Currently, no solutions exist that amplify the visible contrast entering the eye. We aim to create a wearable electronic device to enhance nighttime driving acuity.

Our design is an iteration of a legacy project from 2014. This design consists of a camera attached to a Raspberry Pi single board computer. The image received by the camera will be displayed on a transparent organic light-emitting diode (TOLED) screen. Code programmed on the Raspberry Pi will filter the image from the camera and detect edges of the objects in the camera's field of view. This will amplify the visible contrast of those objects. This system will be fitted into frames that will provide a user with a wearable solution.

## DICOM Assist Software

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**SPONSOR:**

Philips Healthcare

PHILIPS

Philips Healthcare is a prominent player in the health care industry, especially in regard to manufacturing and repairing imaging modalities. A Philips Field Service Engineer inspects machines at client sites and frequently concludes that the problem lies in the connectivity between the machine and the hospital's DICOM (Digital Imaging and Communications in Medicine) network. In this case, the FSEs do not have adequate tools or training to solve this communication issue. Currently, Philips is often forced to contact the original equipment manufacturer (e.g. Siemens, G.E.) of a particular machine to solve the network problems. Our objective is to develop a generic software interface that makes the process of identifying and solving this issue more efficient. This program will allow for on-site analysis of the connectivity issue between the medical imaging equipment from various original equipment manufacturers and the DICOM network of the hospital or medical office. It incorporates the seven operational layers of network communication and troubleshoots problems within each layer. The program, DICOM Assist Software, is runnable on a low-end Windows laptop, provides a means for solving these communication and connectivity issues, increases the effectiveness of Philips FSEs and, ultimately, reduces cost and machine downtime.


**Example of troubleshooting the settings within the Network layer of a GE LOGIQ Ultrasound machine.**

## Hysteroscopic Surgery Simulator

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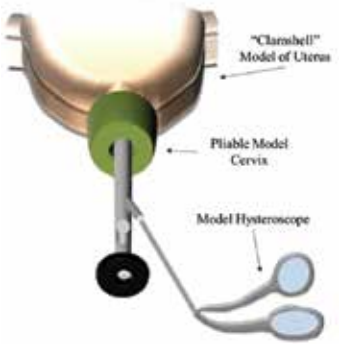
VANDERBILT UNIVERSITY MEDICAL CENTER

Hysteroscopy is a branch of laparoscopic surgery in obstetrics and gynecology plagued by complications such as uterine wall perforation or intra-operative hemorrhaging. Most complications are caused by surgeon error or inexperience, and 74 percent of these events are preventable. Our goal was to design a realistic hysteroscopic surgery simulator (HSS) at low cost that incorporates haptic feedback and quantitatively measures skill. It was designed to be adaptable to modification for various tasks or design changes. We designed a 3D-printed uterus to simulate the surgical environment and developed various tasks for a trainee to perform. The tasks assess surgical skills associated with common hysteroscopy procedures.




**The model illustrates a non-virtual, simulated uterine environment with tasks to measure surgeon competence and progress.**

Although hysteroscopic simulations do exist, they are almost entirely virtual. Current technology lacks a physical learning environment and haptic feedback, and they have no quantitative feedback to measure competency and progress. Additionally, they are very expensive, making them prohibitive to many hospitals and medical facilities. Our design is a more affordable alternative to current HSS systems. Medical residents will test and vet our design upon completion. It is the intent that this HSS will measurably improve the surgical skills of residents who train on the simulation and will reduce surgical errors and complications.

# Developing an Inexpensive Handheld Ultrasound Device for the Detection of Liver Fibrosis

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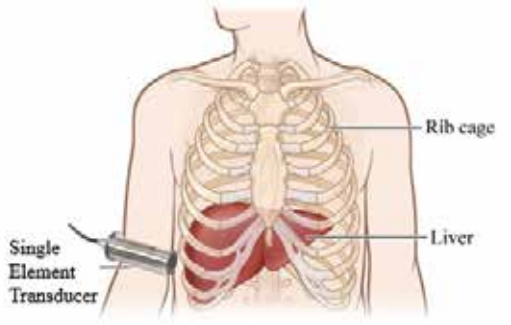


In developing countries, liver fibrosis resulting from alcoholism and hepatitis B and C is a major problem. Up to 500,000 people die each year from hepatitis C-related liver diseases alone. There are several diagnostic tests available, including a biopsy, which is invasive and prone to infection. Ultrasound is a less expensive option but it still presents a cost challenge in the developing world.

To minimize both cost and risk, a handheld ultrasound device implements a single element transducer, which is less expensive than the typical ultrasound array transducers. Instead of creating an image, the device calculates a stiffness measurement that corresponds to the stage of liver fibrosis by measuring the time it takes for a single wave to travel through the tissue. This non-traditional on-axis displacement method utilizes Acoustic Radiation Force Impulse imaging.

Our team designed and built a prototype of a single element ultrasound probe to generate radio frequency data, which the BEAM lab will use to create data tables relating the stiffness of the tissue to stages of liver fibrosis. The current design implements several filters and amplifiers to improve signal collection, and additional noise algorithms will be applied later. This device will increase accessibility for the diagnosis of liver fibrosis.

# Alarm Level Assessment for Risk Modification of ICU Delirium (A.L.A.R.M.)

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The intensive care unit is characterized by noise resulting from alarms, slamming doors, talking, moving carts, and other distractions. Alarm sources include infusion pumps, mechanical ventilators, intra-aortic balloon pumps, and patient monitors. Alarm noise can result in alarm fatigue for clinical staff. More importantly, ICU noise can result in delirium and post-traumatic stress disorder for patients. The incidence of new PTSD at 12 months post-ICU discharge is up to 10 percent.

An alarm system is needed that can respond to current ICU noise levels with appropriate volume and tone to minimize negative effects on patients while maximizing clinical performance accuracy. Our objectives include determining desired alarm conditions via psychoacoustic analysis and studies in an anechoic chamber, and implementing these conditions in a dynamic prototype.

Psychoacoustic analysis on alarm recordings characterize current systems and attempt to parse out noise components that contribute to PTSD. In an anechoic chamber, clinicians perform a simulated drug administration task in response to alarms of varying signal-to-noise ratios relative to hospital background noise. The desired SNR and alarm characteristics determined form the basis of our dynamic alarm prototype. Device manufacturers can use this proof-of-concept to implement this technology into existing products.

# Design and Implementation of Mobile Application for Pharmacy Medication Verification

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**SPONSOR:**

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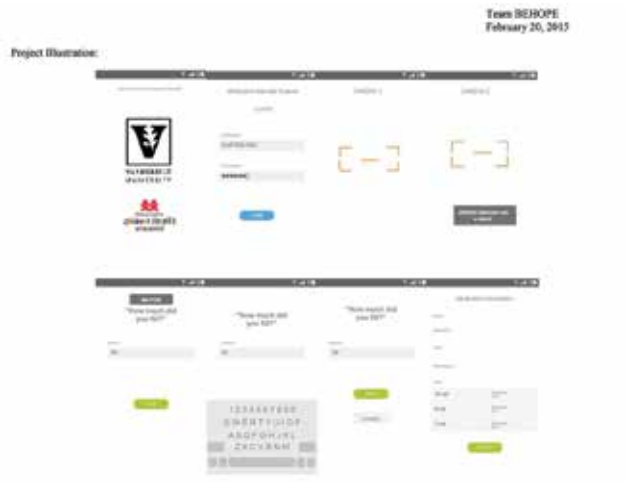


Errors can occur in medication dispensing when pharmacy technicians and pharmacists either select an incorrect medication or dispense an incorrect amount of medication. These errors have the potential to harm patients and be costly to the pharmacy. Our goal is to improve medication safety by creating a system to decrease the medication dispensing error rate. We designed and implemented a mobile application that utilizes barcode scanning technology and additional unique features to verify that the medication selected and amount filled matches the medication and amount prescribed.

The mobile application is designed to notify the user to rescan when the user selects and scans an incorrect medication. After the application verifies that the user selected the correct medication, it prompts technician users to enter the amount of medication that he or she filled. If the user is a pharmacist checking prescriptions that technicians already filled, the application will instead prompt the user to mark off which amount he or she is checking.

The unique aspects of our design, including its portability and the amount filled feature, allow it to be implemented in settings that cannot use completely automated medication dispensing machines due to logistical concerns or a lack of resources.

# Multifunctional Prosthetic Knee

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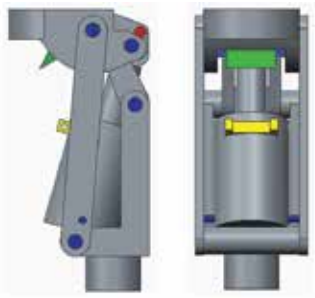

Currently, there is no prosthetic knee available to transfemoral amputees that has combined functionality for running and cycling. Most available knee prostheses solve certain problems but still have major limitations in other areas. For instance, some of the best choices available are too tall for most users or require the use of bulky additions to achieve normal running gait. Amputees are inconvenienced by these problems in that they must purchase and switch between multiple knees to engage in different activities. Our goal is to create a single knee that allows an amputee to run, bike, and walk more naturally while remaining at a desirable height for most users.

We designed a knee that allows for different modes of operation that will, in turn, give transfemoral amputees the capabilities they desire. Our frame design incorporates a mechanism to allow for a free swing mode (biking mode) that provides users the ability to run and bike on the same knee. We also integrated a flexion limiter into the frame so that athletes using our knee can run with a more natural gait cycle. This design differs from existing technology in that it allows for a greater breadth of activities, while remaining within a desired height range.

## Design of the Next Generation Fermentation Lab with Scale-up Modeling

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Fermentation is widely used in the pharmaceutical, food and beverage industries and is similar to biological wastewater treatment. The purpose of our project is to design a three-week fermentation lab for the next generation – one that's based on the chemical engineering concepts learned in our sophomore and junior courses. This simple, yeast-based fermentation experiment gives students an introduction to bioprocessing and the monitoring and control of a small-scale, fed-batch reactor. The experimental procedure incorporates a Vernier ethanol sensor and carbon dioxide sensors along with our newly designed fermentation reactor. The experiment also focuses on the factors that affect the fermentation rate: types of sugars, concentration of sugar solution and operating temperature. In alcohol fermentation that is anaerobic (without oxygen), the sugar is converted into two 3-carbon sugars known as pyruvate. The pyruvate is then converted into ethanol through the formation of acetaldehyde and carbon dioxide. We have developed the important components of the lab module, including selection of equipment and raw materials, incorporation of LoggerPro software and Vernier sensors, procedures for a three-week experiment, scale-up, economic modeling and safety analysis. Our design offers a new yeast fermentation-based module that utilizes readily available sensors and allows introduction of a modern topic not yet covered in the laboratory. In addition, it provides an opportunity for students to explore real-world application of fermentation.

## Visual Interface and Data Collection System for the ChBE Unit Operations Laboratory

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This design project takes the Chemical and Biomolecular Engineering Laboratory to the next level by upgrading the technology and designing new visual interfaces using LoggerPro, MatLab and LabVIEW software. The project involves the incorporation of 10 new 65-inch monitors on which visual interfaces will be displayed for the different unit operations labs. New systems are also developed for the monitors to be used for prelab lectures and poster presentations using wireless streaming technology. They will allow more flexibility in future ChBE lab and design course instruction and execution.

## A Chemical and Polymer Product Safety Center at Vanderbilt University

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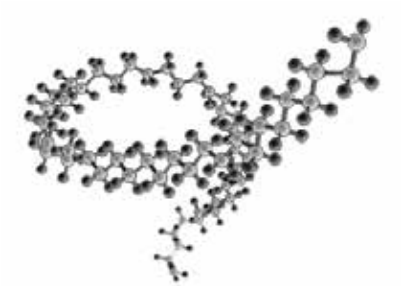

Polymers are commonly used in a diverse range of products, including medical devices, automotive and aircraft components and household items. Many of these products have polymer components that are critically important to the overall safety of the product. Failure in certain polymer products can lead to death, serious injuries, lawsuits, financial losses and negative public perception of companies. Our new Polymer Product Safety Center aims to identify and prevent these failures before they occur.

The focus of the center will be education and expertise. First, it is vital to educate businesses to enable them to design safe polymer products. The center will offer safety classes for companies, a graduate degree in safety engineering and a safety analysis curriculum within any graduate degree that contains a polymer product design component. The center will interact with other safety organizations nationwide to expand resources. The education component will be enhanced at the university and medical center setting due to the multidisciplinary expertise that would otherwise be unavailable to companies.

The second focus of the center is expertise. Small and medium-sized companies will interact directly with the center for prototype testing and multidisciplinary risk assessment of polymer products. The center will offer guidance on key safety tests to perform on prototypes, provide direction on where and how the tests can be conducted and house a library of case studies for reference purposes in order to reduce failures during prototype design and manufacture.

Increased safety education and expertise offered to businesses will result in improved polymer design that will decrease injuries and deaths, create a positive perception of companies, reduce legal consequences and lead to more sustainable businesses.

## Medical Shipper Testing, Modeling and Optimization

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Medical shipping containers can contain extremely valuable products that are temperature sensitive, such as pharmaceutical drugs. Preventing of these products from freezing or overheating while being shipped across various conditions in the United States and abroad is crucial to preserving their original function. As a result, there is a demand for shipping solutions that will maintain the temperature of these products within desired specifications during transport. Our group interfaced with a shipping company that specializes in the manufacturing, testing and distribution of advanced shipping solutions.

Our goal is to develop a model for the shipping company that includes analysis of thermal loads, heat transfer and package thermal resistance. Thermal conductivity of the makeup materials of the package is determined experimentally. Model testing involves temperature monitoring of the package located inside a thermally isolated chamber. Analysis and data processing are conducted to extract the details of the package performance. We expect the completion of our design to aid in shipping container design.

## Phosgene-Free Route to Polycarbonates

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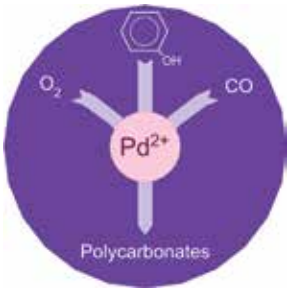


Polycarbonates are plastics used in a variety of applications ranging from medical devices to cell phones. Traditionally, polycarbonates are manufactured in a process that uses phosgene, a highly toxic gas that gained notoriety in World War I as an agent of chemical warfare. Phosgene presents a clear safety hazard to chemical plant operators and public health. Our project aims to design an inherently safer industrial polycarbonate plant that eliminates the use of phosgene by utilizing a novel synthesis method.

This novel synthesis pathway uses oxidative carbonylation of phenol with a palladium catalyst. Phenol reacts with carbon monoxide and oxygen under high pressure to form diphenyl carbonate (DPC), a monomer of polycarbonates. In addition to eliminating phosgene, this reaction scheme avoids the traditional use of a carcinogenic solvent (dichloromethane), greatly reduces wastewater production and offers a higher purity product. We present this novel chemical plant design as a safer, greener and economically viable alternative to traditional polycarbonate production.

## Multi-Product Brewing

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Beer's role as a dietary staple for several millennia has prompted development of engineering processes around increasing and improving its production. In the spirit of those endeavors, our team is proposing alternative, grassroots brewery designs for the production and distribution of 13 craft beers at a minimum annual capacity of 50,000 total barrels (or 1.5 million gallons). Our team immersed itself in the world of craft brewing. Through our diligent research and analysis of the brewing process, we modeled our process, scheduled detailed brewing cycles, and conducted economic feasibility, safety and environmental impact analyses. Meeting and working with both brewmasters and Nashville brewery owners, we developed relationships with ingredient and equipment suppliers to establish real cost projections for capital and operating expenses over the next five to eight years.

# A Mobile Wastewater Treatment Process for Hydraulic Fracturing Wastes

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Hydraulic fracturing is the process of pumping water into gas wells over a mile beneath the surface at high pressure in order to create fissures in the formations and recover oil and gas. The fracturing fluid is primarily made up of water with several chemical additives, including surfactants, friction reducers, gelling agents, antiscalants, buffers, corrosion inhibitors, biocides, clay stabilizers and sand. It is estimated that 15-80 percent of this fluid comes back to the surface as flowback water and produced water—a mixture of what was pumped into the ground and several naturally occurring chemicals that are in the earth. Currently, these products are being trucked to other states, such as Texas and Pennsylvania, where they are disposed of in deep-injection wells.

The goal of our project is to design a mobile treatment system for the hydraulic fracturing wastewater so that it may be reused in subsequent fractures. The wastewater will be stored in separate containment bladders based on the composition of flowback water at the various stages of the well's production. From there, the wastewater will go into the mobile treatment system to remove any constituents harmful to the functionality of the fracturing fluid and then be combined with fresh water for reuse in subsequent fracturing jobs.

# Hydraulic Fracturing Waste Treatment System

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Hydraulic fracturing utilizes millions of gallons of water that are pumped at high pressure into gas wells miles below the surface. The high demand of water for hydraulic fracturing may result in water crises in the vicinity. Approximately 15-80 percent of the injected fluid flows back to the surface as flowback fluid, which contains a high concentration of minerals. The minerals in the flowback fluid can be harmful to the environment. Our objective is to design a mobile waste treatment system to treat this waste stream so it can be reused as fracturing fluid. This would reduce water usage for the overall hydraulic fracturing process.

We segregated the flowback fluid into three different periods, each with different flow rates and concentrations of the components. The flowback fluid is treated using technologies such as reverse osmosis, membrane distillation and capacitive deionization, depending on their initial concentration. The flowback fluid is treated to a target concentration that will not interfere with the performance of the additives in the fracturing fluid.

## Natural Gas to Aromatics

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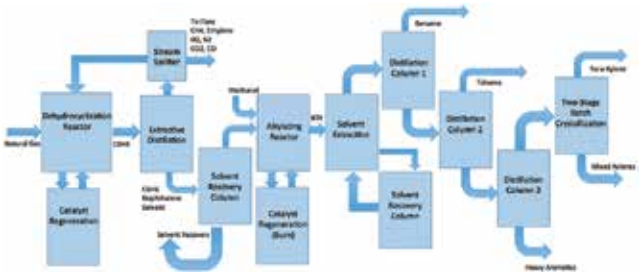

Ninety-five million metric tons of benzene, toluene and xylene (BTX) are commercially produced worldwide each year. The vast majority comes from two methods: catalytic reforming of naphtha and steam cracking of naphtha. Both methods require crude oil as a starting material. Our design circumvents the use of crude oil by using modified zeolite catalysts to produce BTX from cheap, readily available natural gas.

Our design is based on U.S. patent 8,138,384 assigned to Exxon/Mobil. It converts natural gas to BTX through a two-step process: dehydrocyclization followed by aromatic alkylation. The dehydrocyclization step uses a modified zeolite catalyst to produce benzene directly from methane. The aromatic alkylation step reacts the benzene with methanol to produce BTX with a high selectivity toward para-xylene.

Our two-step process results in a BTX product containing a higher fraction of para-xylene than conventionally produced BTX. Para-xylene is valuable because it is a raw material in the production of polyethylene terephthalate (PET) saturated polyester polymers. To maximize the profitability of the process, a separation process isolates the para-xylene. The entire process results in two product streams: the first a mixture of benzene, toluene and mixed xylenes; and the second a high-purity stream of para-xylene.

## A Testing Program to Certify Nutrition Supplement Integrity

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In the United States, nutrition supplements are regulated as a food product, and therefore, the standards for nutrition supplements are not as rigorous as standards for pharmaceuticals. Regulations stemming from The Dietary Supplement Health and Education Act of 1994 and other legislation require manufacturers of finished product supplements to follow current Good Manufacturing Processes (GMP). This requires testing of identity, strength and contamination for all ingredients, as well as some testing for finished products. Despite these regulations, it is estimated that 12 percent of supplements have been linked to safety concerns or product quality issues. Recent studies have found that many "all natural" supplements contain fillers and steroids that are not listed in the ingredients, as well as traces of heavy metals. This can cause many health problems in consumers, including allergic reactions, positive drug testing for steroids, and with prolonged or excessive use, heavy metal poisoning.

We designed a profitable business model for a third party to verify quality and purity variations in nutrition supplements. Our model not only includes an in-depth breakdown of the variety of tests and services that are offered to manufacturers, but also includes a detailed economic analysis from a consumer and investment standpoint. Our proposed testing procedures determine if the samples obtained from manufacturers contain metals, fillers and/or steroids. A certificate of analysis from this testing is provided to the manufacturer that can be referenced on their product. In addition, part of our model is to provide assistance with GMPs, if needed.

# Brine Concentration Systems Analysis for a Chlor-Alkali Plant

**TEAM MEMBERS:**

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Monica Sowers
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Chemical Engineering Design Advisory Board

Caustic soda (NaOH) and chlorine gas (Cl2) are almost exclusively produced by an electrolysis process in which sodium chloride is decomposed into chlorine on the anode side and caustic soda and hydrogen on the cathode side. This process also produces a spent brine stream containing unreacted sodium chloride, as well as small amounts of sodium chlorate, sodium sulfate and silica. This stream could be recycled to the electrolysis unit, but it must first be treated to increase the concentration of sodium chloride and decrease the concentration of other components in the stream.

Recycling streams is an important part of designing chemical plants. The ability to reuse the spent brine stream may not only reduce supply costs, but also cut down on environmental waste from the plant. The goal of our project is to design a process that combines various technologies to bring the spent brine stream to the specifications required in order for a stream to be fed to the electrolysis unit. These technologies may include reverse osmosis, crystallization, mechanical vapor recompression and nanofiltration. Ultimately, we created a cost-effective design for recycling the spent brine stream, as well as provided information regarding the economics and environmental impact of our design.

# Design and Optimization of a Chlor-Alkali Brine Concentration Process

**TEAM MEMBERS:**

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In the chlor-alkali process, a brine solution undergoes electrolysis to produce chlorine, caustic soda and a hydrogen gas byproduct. While mercury and diaphragm-based methods are the most common ways to accomplish this in industry, membrane methods are preferred in new plants because they require less capital investment, have smaller operating costs and are safer and more environmentally friendly. Treatment of the dilute brine exiting the membrane process has become a primary concern to reduce waste and raw material costs as current desalination methods are expensive and still produce large amounts of waste products.

Our team has designed a reconcentration process to bring effluent from a membrane-based process up to a reusable concentration. This process reduces operating costs and decreases the discharge of brine waste to the environment. Using ASPEN chemical modeling software, and after consultations with industry experts regarding current best practices, we evaluated multiple process options on a basis of energy efficiency and the cost per unit of brine solution produced. Technologies including multiple effect evaporators, reverse osmosis systems and commercial salt addition were considered alone and in combination to determine the optimal design. Our final design includes process design specifications as well as economic and environmental considerations to provide the optimal solution for waste brine reconcentration within an existing membrane-based chlor-alkali process.

# Biopharmaceutical Process–Contract Development Organization: Startup–Early Stage Assets

**TEAM MEMBERS:**

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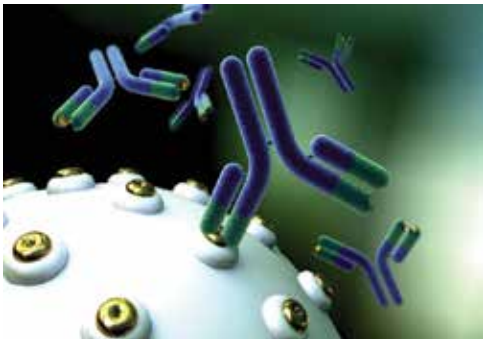
Chemical Engineering Design Advisory Board

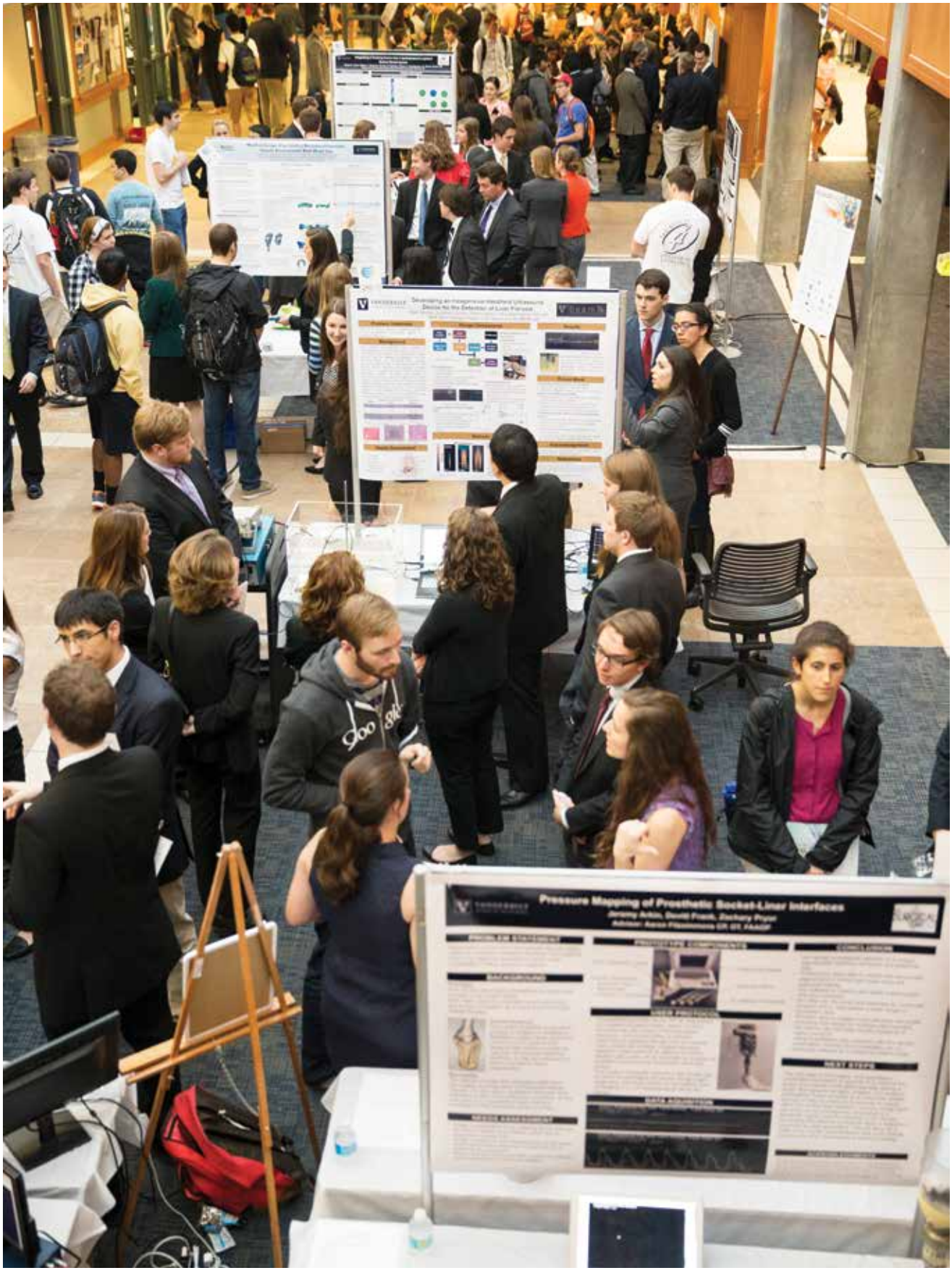


**Monoclonal antibodies bind to specific target sites, making them selective agents useful as therapeutic technologies.**

Monoclonal antibodies have recently moved to the forefront of therapeutic biochemical technologies. By taking advantage of their inherent specificity, antibodies can be engineered to bind to many different target sites, making them superb candidates for improved diagnostic assays or advanced treatments for various types of cancers or autoimmune diseases. Recognizing the increasing market demand for this type of therapy, our group's goal is to design a facility capable of manufacturing new monoclonal antibodies that may not fit the current product pipeline offered by large pharmaceutical companies.

Our team aims to develop streamlined processes for cell line selection and cell culture, optimization and implementation of the bioprocess, and downstream purification of the product–all while maintaining product quality and adhering to CGMP regulations. Process evaluation includes cost analysis, an investigation of product turnover rate and process flexibility studies. Additionally, to keep up with current industry trends in the biopharmaceutical field, we consider the use of disposable bioreactors as an alternative to traditional stainless steel drums. Ultimately, we expect our design to return a high titer and consistent product quality while being flexible enough to meet our customer's demands.

**Teams of seniors devoted two semesters to solving design problems before presenting more than 60 projects on Design Day.**




**Design Day presentations allow recruiters and other industry representatives to view a student's work and how students communicate and present themselves.**

## Franklin, Tennessee, Civil Engineering Design Project

**TEAM MEMBERS:**
Daniel Awogbemila
Zach Elliott
Cherrelle Jarrett
Kelsey Simmons
Betsy Timbers

**ADVISER:**
Adam Crunk, P.E., Principal

**SPONSOR:**
Crunk Engineering

A developer who acquired a 13.7-acre property on Liberty Pike in Franklin, Tenn., wants to maximize the office space that can be built there, taking into consideration the site's constraints and the City of Franklin's development requirements. The outcome of this project will be a site plan showing the proposed office space, along with required parking, drive aisles and access roads to the surrounding street network.

The project team will research the city's building codes related to buffer, setback, landscaping and tree preservation. Deliverables will include a grading plan detailing the proposed finished floor elevation of buildings and the stormwater drainage plan. The grading plan will show contour elevations at 1-foot intervals based on the assumption that no grading will be permitted beyond the property boundary. It also will include a storm sewer system that routes the increased stormwater runoff to a proposed detention pond designed for 2-year to 100-year storm events. Additionally, a utility plan will be completed showing a proposed gravity sanitary sewer system, along with domestic water and fire water pipes designed to serve the demands of the proposed office buildings.

## Office Building Site–Franklin, Tennessee

**TEAM MEMBERS:**
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Crunk Engineering

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## Venture Construction–Office Building Site Design

**TEAM MEMBERS:**

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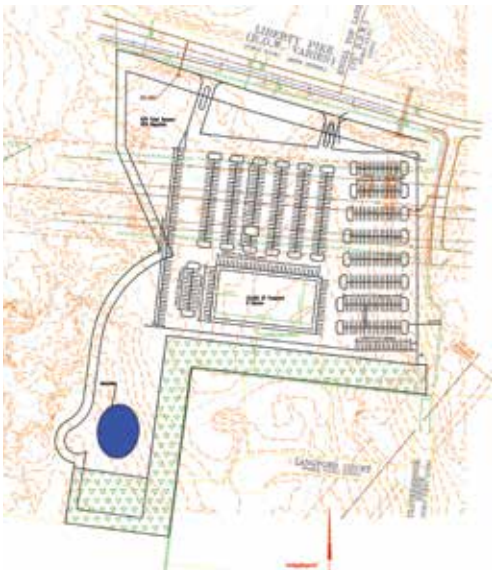
Crunk Engineering



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## ASCE Steel Bridge Competition

**TEAM MEMBERS:**

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Marisa Kelly
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**ADVISER:**

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**SPONSOR:**

Vanderbilt University

The 2015 Vanderbilt Steel Bridge Team was asked to design, fabricate and weld a steel bridge for the American Society of Civil Engineers/American Institute of Steel Construction competition. The bridge must be designed and fabricated by the student team and then built in a timed competition. Each bridge component must be fewer than three feet long. Many other criteria make this design challenge similar to real-world construction. Students compete against 25 Southeastern universities to determine who constructed the lightest and strongest bridge the most quickly. The top bridges advance to the national competition.

This year's bridge is especially light due to the overhead truss design and the use of aircraft chromoly steel. The team fabricated and welded all the parts of the bridge in the civil engineering lab. Each section requires exact measurements and cuts, extensive surface treatment and a well-designed jig before it is ready to be assembled to form the complete bridge. This competition is realistic in that, during construction, a river is assumed to flow underneath. No builders may step in this area. Students must think creatively and intelligently about how the bridge will be constructed in order to excel at the competition.

# Artiphon

**TEAM MEMBERS:**

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**ADVISER:**

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**SPONSOR:**

Artiphon

The Artiphon digital multi-instrument is designed to mimic a guitar, bass, violin, piano and drum machine, all in one compact package, that provides both experienced and beginning musicians with a versatile tool for music creation. The instrument has built in speakers, can be played in various positions, and can interface with applications such as Garage Band on a smartphone. The core feature of Artiphon's revolutionary instrument is the virtual string interface, and the key technology behind the interface is pressure and touch sensitive sensors.

The instrument's behavior must be consistent to assure that Artiphon provides high quality instruments when they go to market. This relies on completely characterizing the behavior of the tactile sensor and its sensing circuit's response. Our project aims to develop better force sensing technologies for Artiphon's multi-instrument in order to completely capture the subtle human gestures as efficiently and accurately as possible.

As part of this goal, we tested the current circuits and developed a computational model that predicted these responses. We built a rig that automatically performs a force sweep and collects data, and provided it to Artiphon for future use. Additionally, our team optimized the sensing circuits to correctly capture the data and translate intuitive movements and musical intent into high quality music. Our development of the testing rig, computational model, and optimization of sensing circuits provides a solution that will help Artiphon as it continues to produce high quality, retail-ready versions of its instrument.

ELECTRICAL ENGINEERING & COMPUTER SCIENCE

# Egburt On Wheels

**TEAM MEMBERS:**

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**ADVISER:**

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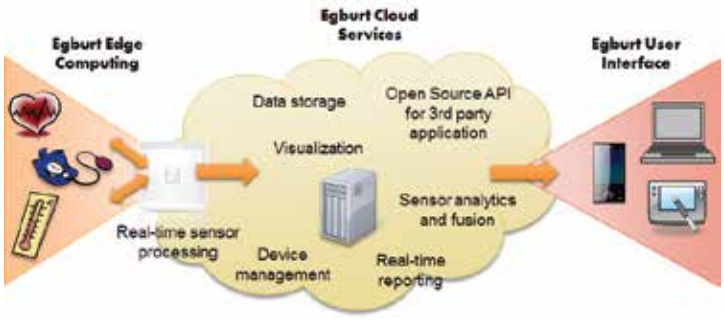
**SPONSOR:**

Camgian Microsystems




Immobility often accompanies many health conditions especially in elderly populations. In hospitals and elder-care facilities, patients are often wheelchair bound or bedridden, making it dangerous for the patients to move around without supervision. It also is expensive to hire staff for the sole purpose of monitoring patients. The goal of our project is to design a mobile system that can be attached to a wheelchair or to a bed to monitor a patient's major health status (pulse, temperature, oxygen saturation, muscle contraction, location, and blood pressure), and to deliver alerts on detection of anomalies to specified health care providers.

Our team is working with Camgian Microsystems' award-winning Internet-of-Things platform: Egburt. The sensors are interfaced with Egburt and the data are uploaded and processed to the cloud, where a health care provider can monitor a patient in real time. If a sensor records an abnormal value, the health care provider will be alerted. This system differs from existing devices due to its mobility, minimal setup, real time alerts, and its ease of use as an all-in-one platform for wireless environment monitoring.

## JetStream's Clean Hybrid Energy Scalable System (CHESS)

**TEAM MEMBERS:**

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Hanum Hanafi
Alyssa Jaffe, ChE
Asma Mohd Sidik
Benjamin Sturgeon

**ADVISERS:**

Steven Cornelius, CEO, JetStream Energy Systems

Mike Myers, Research Scientist, Adjunct Assistant Professor of Civil Engineering and Computer Science

**SPONSOR:**

JetStream Energy Systems

As Earth's nonrenewable fuels become scarce, there is a worldwide need for providing clean energy solutions. This is the third Vanderbilt School of Engineering Senior Design Team to partner with JetStream Energy Systems CEO Steven Cornelius to produce the company's first Clean Hybrid Energy Scalable System (CHESS) prototype. Throughout the year, our team integrated the solar, wind and generator systems into a working prototype while preparing a detailed assembly and operation manual. Previous teams had gathered most of the required parts and wrote some of the code necessary to run the system. However, the components were never complete enough to truly test. Now that JetStream is completing system details to commercialize its product, it was imperative for our team to produce a working prototype, which will allow the company to share a feasible design with potential investors in June 2015. While competing companies currently offer wind and solar energy solutions, JetStream's innovative Master Control Unit has been programmed to optimize the use of its three components based on the surrounding environment. There are many user requirements of this system and the CHESS team has approached them all to produce the high-quality system our client desires.

## Metova's Augmented Reality System (MARS)

**TEAM MEMBERS:**

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Ian Simonson
Ben Taylor
Mahyar Varasteh
Matthew Volz

**ADVISER:**

Richard Alan Peters, Associate Professor of Electrical Engineering and Computer Science

**SPONSOR:**

Metova

The MARS Project (Metova's Augmented Reality System) is a proof-of-concept application designed to showcase the capabilities of modern-day augmented reality technology. The goal of this project is to provide a prototype of a game that uses a camera to view real world objects placed on a table. The physical objects are augmented on a virtual game board on a smartphone or tablet, and any player who views the virtual board sees the same objects, including their position and relative size in the same places on the virtual board.

The main elements of this application are the Qualcomm Vuforia mobile vision platform, used to superimpose three-dimensional models on unique objects, and the Unity game engine, used to simulate and animate the models into an augmented reality tower defense game. The augmented reality technology present in this application allows for a variety of viewpoints for the player(s) and an entirely new gaming experience when compared to existing tower defense smartphone games. The result is to create a tower defense application that will be available on the Android platform and to provide Metova with a number of software components from our project to be utilized in other applications.

## Millennium Space Systems Team

**TEAM MEMBERS:**

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Matt Collum
Will Kay
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Brian Stanley, BME/EE

**ADVISER:**

Robert Reed, Professor of Electrical Engineering

**SPONSOR:**

Millennium Space Systems, Inc.

**The National Instruments embedded computer**

As demand for inexpensive satellite systems increases, satellite providers are looking to provide the best functionality at the best price. One of the key systems of any spacecraft is the bus controller. These systems act as the brains of the spacecraft, controlling the many other subsystems. Ideally, they are inexpensive, flexible, small in size, and low power. The National Instruments embedded computer excels in all of these categories.

To fly in space, however, systems must also tolerate the hazardous radiation of orbital environments. The team evaluated the system to determine whether it will stand up to total ionizing dose radiation. The team also characterized some of the components of the system individually to identify failure points. The team irradiated the system and four components with a Cesium-137 gamma ray source. The team will make recommendations on the space hardiness of the system based on its findings.

## SFEG Little Box

**TEAM MEMBERS:**

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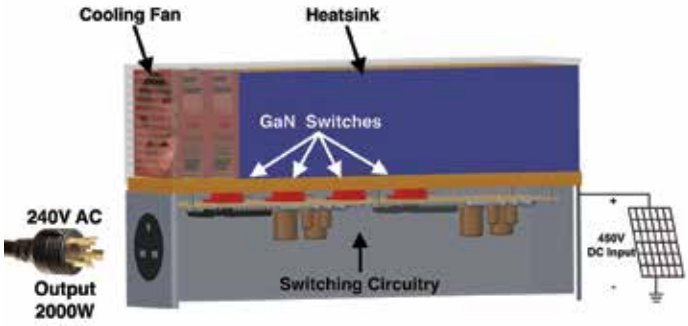
Erin Hall
Gianfranco Scipioni, ES
Brendan Stallard, ME
Michael Wurm, BME
Da Ying

**ADVISER:**

Arthur Witulski, Research Associate Professor of Electrical Engineering

**SPONSOR:**

Scott Fetzer Electrical Group




High-power inverters that convert solar-panel DC power to consumer usable AC power are bulky and relatively inefficient. The Google Littlebox Challenge asks participants to design a smaller, more efficient power inverter within tight electrical and mechanical constraints. The goal is to create a 2kW micro-inverter that could be deployed directly onto solar photovoltaic arrays, providing 240V AC power to a home, and minimizing the space and energy lost to inversion. The inverter must fit within 40in3 (about the size of a half-liter bottle of water), have no surface temperature above 140ºF, operate above 95 percent efficiency with minimal voltage and current ripples, and obey FCC limitations for high frequency emission and conduction at radio frequencies.

Our design will utilize high frequency pulse width modulation of new Gallium Nitride (GaN) semiconductor devices that will function as high frequency switches. This increase in switching frequency compared to current designs will increase efficiency, but also decrease margin for error when timing switching intervals. We anticipate a prototype that switches at ~800kHz and 95% efficiency, and will be tested on a variety of 2kVA loads (hairdryer or washing machine) at a .3–.7 power factor, both inductive and capacitive.

# Power Factor Correction Circuit Design for Motor Control

**TEAM MEMBERS:**

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Ziyue Song

**ADVISER:**

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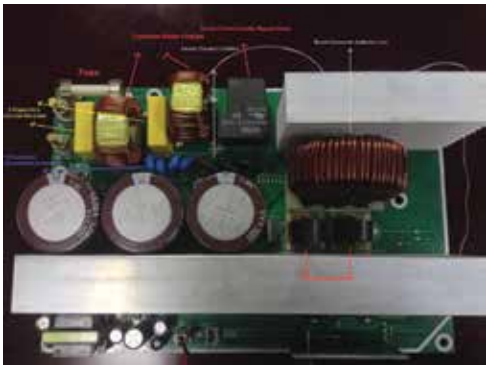
Scott Fetzer Electrical Group



In an electric power system, a load with a low power factor draws more current than a load with a high power factor for the same amount of useful power transferred. In the case of a switched-mode power supply for motor control, a boost converter is inserted between the bridge rectifier and the main input capacitors to correct the power factor in order to deliver more useful power and reduce the amount of reactive power. The Power Factor Correction senior design project aims to simulate testing and evaluation for the PFC circuit both online and offline with rapid prototyping, online simulation testing, and offline prototype testing.

The design of the PFC circuit includes multiple stages. An input AC voltage ranges from 120 VAC to 240 VAC with a frequency of 50/60 Hz. An EMI filter suppresses common-mode noise. A bridge rectifier converts AC signal. A boost converter further attenuates the high frequency harmonics in the AC signal. A voltage regulator at the end delivers a steady DC bus output voltage. The end product should be cost-effective for mass production and be suited for DC motor control.

# Portable PCA Pump

**TEAM MEMBERS:**

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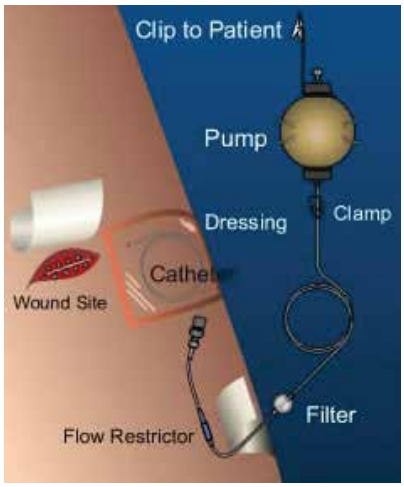
Colleen Kerr
Jayme Kravitz, ME
Tate Travaglini

**ADVISER:**

Darrin Taormina, M.D., Anesthesiologist

**SPONSOR:**

Vesalius Dynamics




Our project is to design and build a portable analgesia infusion pump. We are working with Vesalius Dynamics to create a new, reasonably priced electromechanical pain pump that can deliver accurate dosages. After a major surgery such as a knee or hip replacement, the patient will need a local analgesic delivered through a catheter to the surgery site. This catheter is connected to a pain pump where a physician adjusts a dosage level. A portable pain pump provides advantages to both patients and hospitals, including allowing patients to leave a hospital sooner.

Currently there are several different pain pumps on the market. However, these pain pumps rely solely on elastic mechanical components to pump the local analgesics, which results in inconsistent dosage amounts. Our pump provides a higher degree of precision and reliability in dosages for the same price as devices currently on the market. Our main improvement to the current portable pain pump system is the addition of electrical components to regulate flow rate and a dosage capsule that provides accurate measurement of the analgesics.

# Ideal

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**SPONSOR:**
Vanderbilt University

VANDERBILT UNIVERSITY

For many people, what we wear matters and how we look matters. Ideal is a social network similar to a digital photo album or Pinterest-style application that allows users to create the wardrobes they prefer for an ideal partner, or that express their own style through the fashions they post. Users create their 'ideal' by sharing apparel they find online, and by snapping photos of outfits they see worn by others and adding those to their profile, too. Users may also browse friends' profiles and add items they might like.


ELECTRICAL ENGINEERING & COMPUTER SCIENCE

# Large-scale Analysis of Software Engineering with Massively Open Online Course Assignments

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**SPONSOR:**
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Presently, it is difficult to analyze the code practices of software developers and engineers due to the various styles and methods with which people program. Therefore, there is not much opportunity to fix common errors in coding patterns or even improve specific areas. Further, it is difficult to compare programs because of the various applications people strive to solve problems for; akin to comparing apples and oranges.

MOOC courses are taken by a large, diverse group of programming professionals. This provides a great common code base to begin looking at for any patterns or anti-patterns or other metrics within their submission. We must look at these patterns and extract significance from them. Why are they important? What can be inferred from this information? And what can be done with this information?

This project focuses on analyzing code samples submitted by about 2,000 students to a MOOC. The information includes the students' code, forum comments, country, education level, age, employment status, course scores, and IP addresses. We hope to find code clones or certain patterns not only within the code, but also across demographics or other divides. We also can check for the code's safety, any frameworks used, or their final scalability.

# PickUpSports

**TEAM MEMBER:**
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**SPONSOR:**
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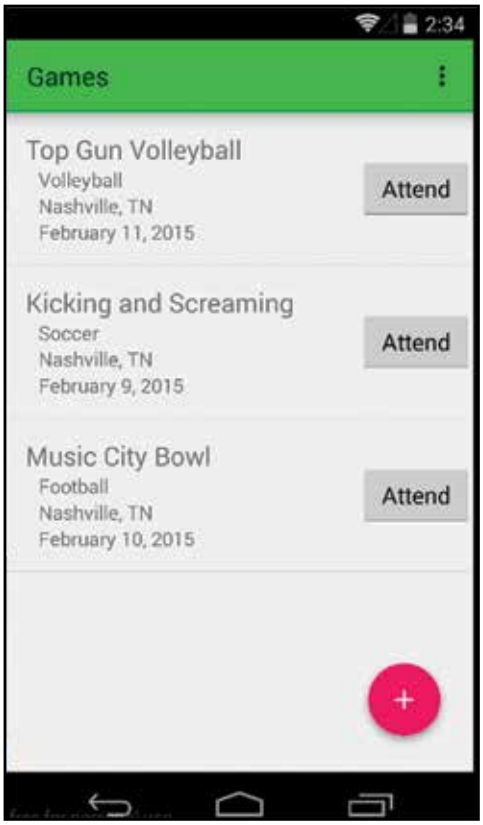
Many students around the world participate in collegiate athletics or intramural sports.

Time spent participating in school sports or intramural teams with friends and classmates helps develop healthy habits and behaviors, and promotes camaraderie and friendship. However, after the school year ends, it often becomes difficult to find activities and people to play sports with, and this cornerstone of many young people's lives tends to fall by the wayside.

This application is designed to synchronize the athletic events of friends and neighbors specifically pertaining to the timing, location, and attendance of an event. Users are able to sign up with an account and link with their friends so they are able to create athletic events for people to attend, either publicly or privately, and attend other people's events.

By providing a central interface for communication tailored specifically for sporting events, this application will allow amateur sport teams and individuals to involve themselves more easily in their local community. Users will see the activities of others in their area and join in with schoolmates, friends and new people who share similar interests in athletic competition.




# Coffee Rec

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Vanderbilt University

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Across different industries, our preferences are being used to generate recommendations of products we like. Amazon recommends goods we might like based on our past purchases, and Netflix recommends movies based on our watching histories. These recommender/filtering systems make it easier for consumers find new products matched to their tastes.

This project seeks to implement a system for recommending coffees. Without any large store of coffee data, an alternative solution will need to be used to generate the initial data for the recommendations. Mining Twitter and correlating mentions of different coffees to the user who posts the tweet can generate this data store. By monitoring the tweets users make about different coffees, we will create an initial database of coffee preferences that can be used to generate recommendations

There are a huge number of coffee roasters and different coffees from which to choose. This application will allow a user to track past coffees they have tried. The data will be compared with other users' histories, along with information from several other data sources to generate recommended coffees for a user. The recommendations will be integrated into an iOS mobile app to allow users to track coffees and view recommendations.

# Bazaar

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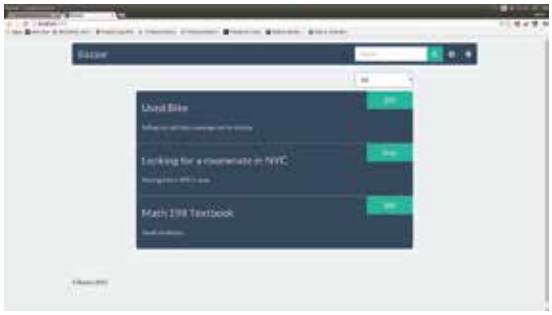

Among college students today there is no easy and safe way to connect with their peers across schools for buying, selling or interacting. In current products, there can be a lack of trust between users, such as with Craigslist, or the inability to interact with students from other universities, as with Facebook, or too broad of a scope, as with eBay or Amazon.

Bazaar, a simple, open source marketplace and community, solves this problem by connecting students to each other across universities in the same area. By keeping interactions local and exclusively for students, there is a greater sense of community, making the experience rewarding and simple. Bazaar aims to create communities of students, allowing them to interact in ways we have yet to anticipate.

# Student Attendance Management Application

**TEAM MEMBERS:**
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Peng Zhang
Qishen Zhang

**ADVISER:**
Jules White, Assistant Professor of Electrical Engineering and Computer Science

**CLIENTS:**
Metro Nashville Public Schools
Nashville Public Library
Metro ITS
Metro Parks and Recreation


Nashville AfterZone Alliance is a coordinated system that allows after-school providers countywide to deliver high-quality programs that support student success. It shares with its closest partner, Metro Nashville Public Schools, the same three key benchmarks of success: school attendance, school behavior and grades. MNPS and NAZA secured funding to build an evaluation model that triangulates student participation levels and program quality with the three benchmarks. Preliminary analyses shows clear evidence of the importance of quality on student outcomes. Tracking students and their participation is foundational to NAZA's model, its targeted instruction and program evaluation. However, the original web attendance app is obsolete and virtually impossible to maintain, so they need a new, secure, low-cost, and more structured application to launch in fall 2015.

Our project is composed of a web application and cross-platform mobile applications that will allow all NAZA-affiliated after-school providers to track student participation. Attendance information flows back into the MNPS data warehouse on a daily basis. The applications will interface with an existing student management system and securely access the student database. Based on permission levels, users of the applications will be able to create and update attendance rosters, track student participation and performance, as well as report interesting statistics via graphics/charts.

# Coursaic

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**ADVISER:**
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**SPONSOR:**
Vanderbilt University

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Students often have a difficult time knowing what material is important when preparing for exams. Our solution is an app that allows students to collaborate on exam preparation. Coursaic is an app that allows users to take practice exams that are constructed from other users. The idea is simple: navigate to a course (i.e. CS 101), create practice questions, and take exams containing questions by other users.

As an incentive for students to create questions, there is a minimum number of questions that a user must create before they are allowed to take any practice exam. All questions are organized by topics specified by the user who creates the question. The idea is that over time, course material produces many questions that can be re-used and taken by students who are new to the course. To prevent poorly constructed questions, each question can be flagged by other users, bringing it to the attention of professors and allowing them to disable the question. We believe that this tool will make studying a more productive experience where students can share course material and test one another in an exam-like setting.

# Task List

**TEAM MEMBERS:**
Sahil Panjwani
William Pascucci

**ADVISER:**
Jules White, Assistant Professor of Electrical Engineering and Computer Science

**SPONSOR:**
Vanderbilt University

VANDERBILT UNIVERSITY

Traditional time planners are interfaces that capture information regarding your tasks and availability of time, ultimately requiring you do all the planning. Task List aims to provide a smart, automated and easy-to-use system to solve this problem. Ease of use will be achieved through a UI that minimizes the number of user actions to update, edit, delay, or complete a given task, utilizing push notifications and a page in the app dedicated to task modifications. Tasks will be sorted in a number of views such as simple list, calendar, or category form. Different categories will be built around various criteria such as the nature of the task in terms of its goal (health/fitness, chores/errands, academic, work related, etc.) and in terms of its timing (fixed deadline, can be delayed, daily task, one-time task, etc.). Users also will be able to modify/create certain fields and categories.

The app is based on time scheduling using the Simplex method to optimize overall utility. By using the categories of the task combined with its importance, the app will sort the tasks and send suggestions about which task merits attention. The app will keep track of productivity and efficiency by prompting user for estimated time required and actual time spent. Furthermore, the app will take into account a user's behavioral tendencies, time of day, etc. to further enhance the suggestion system. The app has the potential to combine location criteria such as distance to a task to add to the suggestion engine as well.

# Artiphon Instrument Overlay Analysis

**TEAM MEMBERS:**

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Daniel Corona
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Revanth Sanne

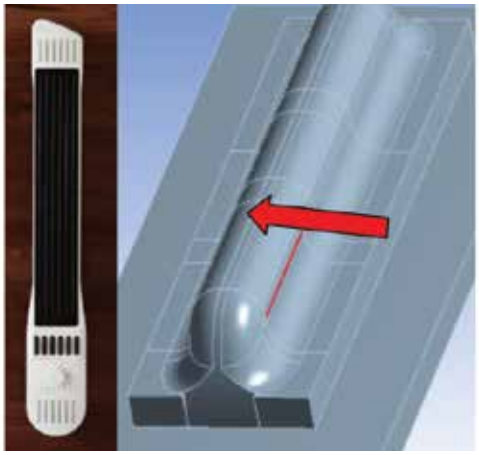
**ADVISER:**

Ryan Wrenn,
Chief Technology Officer

**SPONSOR:**

Artiphon

Artiphon is a music technology startup in Nashville that has created a consumer electronic device with which musicians control software instruments using conventional instrument techniques. Players apply force with plucks and presses to rubber-like surfaces which replicate strings. These surfaces lie on a force sensor array. Material properties and geometric parameters of these overlays affect how accurately the device can sense the forces applied. Our team was asked to determine which overlay design parameters affect sensor accuracy the most.



**Force response model of simulated string surface**

To achieve this goal, the team developed computational models simulating plucks and presses on the overlays. We used these models to hypothesize which parameters have the greatest effect on force transmission. The team then fabricated physical overlays to test these hypotheses by applying known forces to match those simulated in the computational model. In this way, the group also determined specifically how these parameters affect force transmission. We stored confirmed data from the models in a software database, supplying a graphical user interface to make the information easily accessible. As a result, Artiphon is able to utilize the database to anticipate the effects of design changes on overlay performance rather than manufacturing multiple overlay prototypes to test design parameters.

# Engineering Enhanced Pointe Shoes

**TEAM MEMBERS:**

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Amaranth Unangst
Adrienne Zwiener

**ADVISERS:**

Rebecca Lisi
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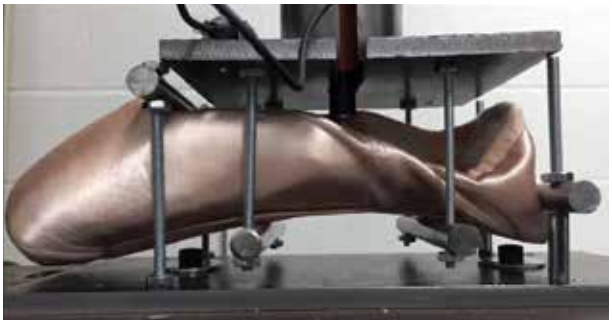
**SPONSOR:**

Vanderbilt University
School of Engineering

VANDERBILT School of Engineering

Today, traditional ballet pointe shoes last approximately 10 hours for a professional dancer and cost as much as $100. Intermediate ballet dancers may go through a pair a week, making the cost prohibitive for a dancer not already in a professional company. Our goal for this project is to demonstrably extend the life of traditional pointe shoes, thereby reducing the overall cost of pointe shoes for a dancer.



The main structural components of the pointe shoe are the shank and the box, which are made with composites of leather, cardboard and papier mâché. These materials break down over time due to the impact of repeated flexing motions and exposure to moisture in the form of sweat.

The team's solution to this problem is our Primas, which was inspired by shoe trees for men's dress shoes. Their purpose is two-fold: to draw moisture out of the shoe and to preserve the shape without causing damage to the shoe.

## Violin Support System

**TEAM MEMBERS:**

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Brittany van Gelder

**ADVISER:**

Tracy Silverman, Electric Violinist and Composer

**SPONSOR:**

Tracy Silverman

Thirty-five percent of violinists and violists experience prevalent neck and shoulder pain from the standard playing position. If not treated properly, this pain could develop into long-term injury and even end professional careers. The project goal is to design a support system for acoustic violins that alleviates this pain.

The device supports the violin completely without aid from the violinist's head or hand. The design has two main components: a neck strap that the violinist wears and a chest mount that attaches to the bottom of the violin. The neck strap places the violin in the proper playing location, and the chest piece moves the pressure of the instrument from the shoulder to the chest. Together, the device can hold a full-scale violin without the support from the violinist. Since the violinist does not need to hold the violin with his or her head, the neck and shoulder muscles are less strained while playing.

## Denso Manufacturing Plasma Torch Auto-Exchange

**TEAM MEMBERS:**

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**ADVISER:**

Robert Ridley, North American Production Engineer

**SPONSOR:**

DENSO Manufacturing Tennessee Inc.

DENSO


Denso uses a robotically manipulated plasma welder on its manufacturing lines. Every four hours, the torch must be removed from the robot and serviced. Because the welding stage is the bottleneck of the line, the entire line must be shut down for 10 minutes while line workers remove the torch and install a freshly serviced one. Denso charged us with designing a tool changer that will allow the torch to be changed quickly and autonomously.

Our solution is a tool changer equipped with quick-disconnecting couplers. This tool changer comes in two halves—one that attaches to the robot and one that attaches to the torch—that attach and detach using a pneumatically-powered coupler. With the quick couplers, the supply line connections can be made and broken in a matter of seconds with virtually no loss of gas or fluid. This rapid torch changer will save Denso significant time and money on its manufacturing lines and will increase safety by not requiring workers to handle the plasma welder by hand.

## Mobile Phone Device Charger for Use in Remote Locations

**TEAM MEMBERS:**

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**SPONSOR:**

Griffin Technology

While mobile device adoption is rapidly growing in developing regions, inadequate power infrastructure can present a serious roadblock to speedy and sustained growth. According to *The Economist*, about 1.5 billion people, or more than a fifth of the world's population, have no access to electricity, and a billion more have only an unreliable and intermittent supply. Unfortunately, these are the same regions with residents who are ready to leapfrog into the smartphone age, propelled by the economic and technological demands of globalization and development. Current solar-powered solutions on the market right now are often slow to charge or out of this market's price range.

This project seeks to design, fabricate and test a cost-effective, convenient and durable charger that allows users to charge mobile phone devices via standard power cables. The charging unit will be required to generate and store charge as needed to support multiple devices. The device can also be used by travelers and outdoorsmen and for disaster relief when power is not readily available.

Our solution incorporates multiple power sources (solar, kinetic and grid) to provide the utmost flexibility and reliability into an all-in-one design that meets U.S. military standards for durability.

## MAX Mobility Power Wheelchair

**TEAM MEMBERS:**

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**ADVISERS:**

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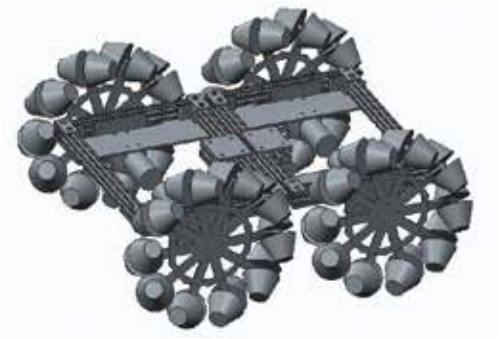
**SPONSOR:**

MAX Mobility



Wheelchairs provide users a way to stay mobile, but they are severely limited in their ability to overcome obstacles such as curbs. While ramps help alleviate this problem, the fact remains that wheelchair users cannot easily navigate steps that rise over a few inches. Our overall goal for this project is to eliminate this hindrance completely. In order to accomplish this, we designed a motorized wheelchair that is not only highly maneuverable, but it can also safely climb curbs of up to 7 inches.

The simplest way to climb a curb is to approach it with a big wheel. While typical wheelchairs have two small caster wheels as front wheels, our wheelchair incorporates four 20-inch mecanum wheels, each powered by its own motor. Mecanum wheels feature angled rollers along its circumference that allow for multidirectional movement as the wheels spin independently. Additionally, our design includes a central pivot, which keeps all four wheels in contact with the ground at all times. Unlike other power wheelchairs, our design is maneuverable and functional in various terrains.

## Nissan Guided Vehicle System (GVS)

**TEAM MEMBERS:**

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**SPONSOR:**

Nissan North America

Nissan's Vehicle Assembly Plant in Smyrna, Tenn., produces over 600,000 cars annually. As cars are assembled in the plant, parts are consistently brought on carts to the main assembly line to replenish the parts already installed by workers. To accomplish this, parts for each vehicle assembly line are selected from bins and placed on the carts in "pick areas" throughout the plant. The goal of our project is to automate the movement of these carts throughout the pick areas. Automation will reduce workload and ensure that the proper parts are placed on each cart.

Our solution is the GVS, or Guided Vehicle System. GVS is an Arduino-based, magnetic-line-following robot that will pull carts through pick sections. Housed in a custom steel chassis, GVS is powered by Nissan Leaf Li-ion batteries and will be able to integrate with Nissan's existing Andon quality management system. GVS can maneuver within any current or projected floor layout and can be adjusted easily by Nissan engineers. Our goal is to produce GVS at half the cost of the automated carts used in some areas of the plant currently. Testing in Nissan's facility is ongoing.

## Portable Military Quadcopter

**TEAM MEMBERS:**

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Michelle Kao, Information Technology Manager

**SPONSOR:**

Northrop Grumman

During field operations, military personnel use radio devices to communicate when they need assistance. However, mountainous terrain or urban structures can sometimes block these radio signals, resulting in unheard distress calls. Our goal is to create a device that allows wireless communication regardless of landscape, which could prevent these dangerous situations. We designed a compact quadcopter that improves communication by carrying a relay to a sufficient height in order to establish line-of-sight communication.

The individual user can fold the arms of the quadcopter for storage in a backpack by removing quick-release pins. During flight, the user can select a preset position based on GPS waypoints or use a transmitter to manually control the quadcopter. We performed testing verification and cost analysis for all engineering aspects of the quadcopter to optimize performance within cost constraints. The folding frame, preset functions and parachute, which can be deployed manually or automatically in the event of a battery failure, render this quadcopter ideal for military use.

# Automated Pill Dispenser

**TEAM MEMBERS:**

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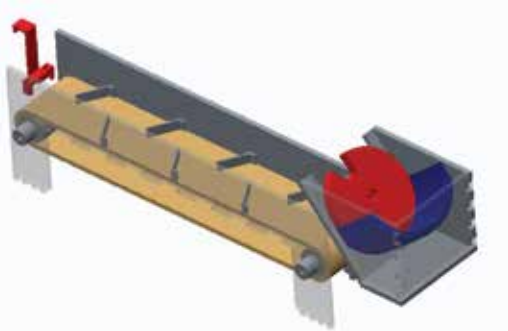
Connor Strickland, BME
Ilman Ziat

**ADVISER:**

Lie Tang, Ph.D., Control Specialist

**SPONSOR:**

Quality Manufacturing Services Inc.



As online pharmaceutical sales continue to grow, so does the need for more accurate and efficient methods to count and dispense pills. Our group is designing an automated pill dispenser for QMSI to accomplish this task. An automated pill dispenser is a device that counts a specific number of pills from a large quantity and dispenses them into pharmaceutical pill bottles. It should be able to handle any size pill or capsule with no changes to the system, other than calibrating the speed of its motors.

Our design consists of two stages. The first stage, the "hopper," is a device that holds a liter of pills and dispenses them onto a conveyor. The second stage is a linear sorting conveyor with a counting photo eye. Our system provides a solution to the problem of bringing automatic pill dispensing to a small scale. This is an untapped area of pharmaceutical industry that our sponsor would like to explore. Our goal is to give our client a device that makes no errors in counting and dispensing pills and that they can use with their current products.

# Support Structure for Gulfstream G-450 Wing Panel

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**ADVISERS:**

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Joe Warise, Senior Industrial Engineer

**SPONSOR:**

Triumph Aerostructures

Triumph Aerostructures - Vought Aircraft Division

Triumph Aerostructures, Vought aircraft division, is a Nashville company that manufactures airplane parts. The company's manufacturing process for the G-450 wing panel currently utilizes a fixture which was initially designed for a different wing panel, and, as such, it has major ergonomic and safety issues. To reduce the risk of falling and repeated stress injury, we were approached to design and implement a new support structure custom made for the G-450 wing panel.

The design consists of three safety-tested steel poles, fitted with custom slides, clamps and latches. These ensure the workers can reach every square inch of the wing panel with minimal strain. Our design holds the wing a level distance from the floor and allows factory workers to access both sides of the panel via scissor lift. Once implemented, this will be a marked improvement from Triumph's current fixture, which holds the wing at an angle and requires workers to climb onto an elevated platform to complete their work. Overall, the new support system will allow for more efficient, ergonomic and safer operation on Triumph's factory floor.

## Cryogenic Fluid Optimization

**TEAM MEMBERS:**

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Jevaugn Shabazz
Supriyadi Tasim

**ADVISERS:**

Marcus Arnold, Human Launch Services, Propulsion Systems

Peter Wilson, Human Launch Services

**SPONSOR:**

United Launch Alliance

Cryogenic fluid is a vital component used in rockets. It is not only used for cooling the system, but also as a propellant after it cycles through the rocket. Due to the extreme conditions rockets may travel through and the heat generated by the rocket flames, it is of great importance that the cryogenic fluid remains at its starting, cold temperature.

United Launch Alliance, a company which provides reliable and cost-efficient space launch services for the U.S. government, is tasking our team with collecting data on how the temperature of cryogenic fluid changes as various parameters are changed. Our goal is to find an optimal setup to achieve low-cost, low weight and high thermal efficiency with the result that the cryogenic fluid temperature fluctuation remains small.

Our primary research parameters were: insulation material, insulation thickness, pipe material, ambient environment temperature and composition of ambient environment gas. Analysis of our testing device was done by utilizing theoretical heat transfer equations, COMSOL simulations and experimental testing.

## Shunt Tunneling Device

**TEAM MEMBERS:**

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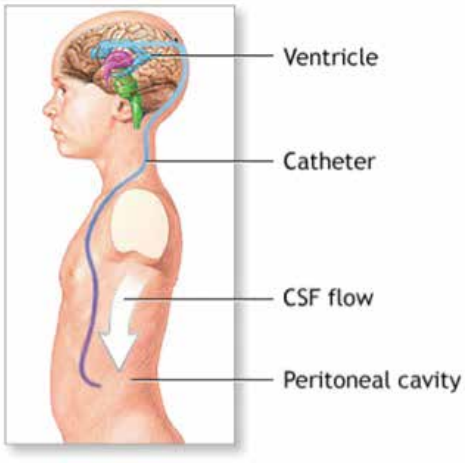
**ADVISER:**

Robert Naftel, M.D., Assistant Professor, Neurological Surgery

**SPONSOR:**

Vanderbilt University Medical Center, Department of Neurological Surgery




Hydrocephalus is a disease characterized by an excessive accumulation of cerebrospinal fluid in and around the brain. The current treatment involves installing a shunt system that regulates the drainage of excess CSF from the brain to the peritoneal cavity in the abdomen. The goal of this senior design project is to improve the shunt tunneling device.

The current shunt tunneling device is a rigid stainless steel rod, which is usually bent by the surgeon to better navigate around the tricky curvature of the human body. Navigating the instrument from behind the ear to the top of the skull is difficult because of the rigidity of the rod. The difficulty of this maneuver, coupled with the amount of force required to tunnel, can often lead to an accidental extra incision that exposes the patient to potential infection.

To increase the functionality of the tunneling device, our prototype focuses on improving navigation. This was accomplished by developing a bending mechanism at the tip to better navigate the curvature of the skull. Overall, our prototype increases the ease of use and control while also decreasing the risks associated with the shunt tunneling procedure.

# Anatomic Laser Metrology

**TEAM MEMBERS:**

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Orion Michael Phillips

**ADVISERS:**

Ray Lathrop, Postdoctoral Fellow

George Wanna, M.D., Associate Professor of Otolaryngology, Associate Program Director, Neurotology Fellowship

**SPONSOR:**

Vanderbilt University Medical Center, Department of Otolaryngology

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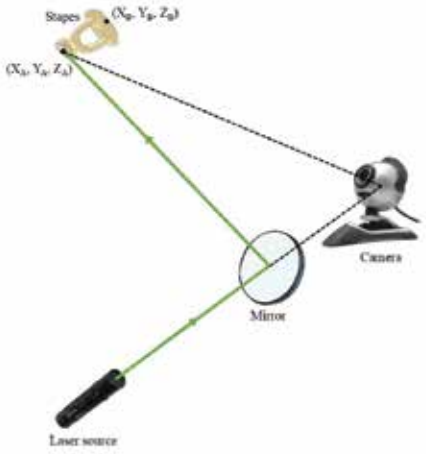

A set up of laser measuring device

Middle ear surgery commonly involves the implantation of prosthesis. To obtain the correct size of prosthesis, the surgeon makes an appropriate distance measurement on the small auditory bones in the middle ear, which requires an accuracy of near 0.1 mm. Currently, the surgeon uses a measurement rod which has an accuracy of 0.5 mm to perform the measurement. Using an inappropriate size of implant may cause the prosthesis to not stay in place and contribute to severe hearing problems. Our goal is to build a measuring device with higher accuracy by applying laser metrology technology.

The surgeon moves the laser onto one endpoint by changing the orientation of a mirror placed outside of the ear. A camera placed at a distance from the mirror captures the laser position. This position, with the mirror and camera, makes the shape of a triangle. By using basic trigonometry and image processing, the XYZ position of the endpoint is obtained. The surgeon then measures the XYZ position of the other endpoint and calculates the distance between them. The advantage of this laser measuring device over the measurement rod is higher accuracy—up to 0.2 mm. The process is applicable for other types of surgery as well.

# NASA Mini Mars Ascent Vehicle

**TEAM MEMBERS:**

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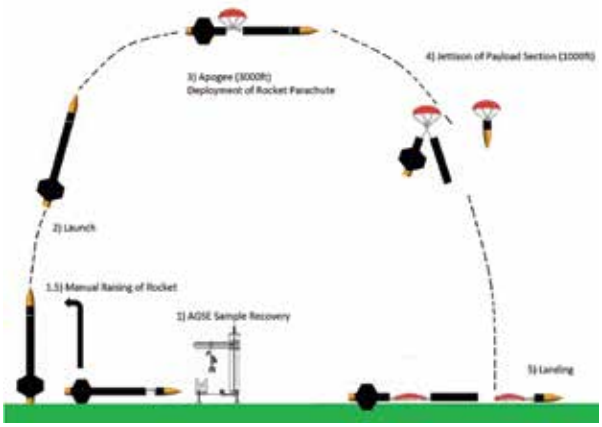
Christopher Lyne
Jacob Moore
Cameron Ridgewell

**ADVISER:**

A.V. Anilkumar, Professor of the Practice of Mechanical Engineering

**SPONSOR:**

NASA




Every year, NASA sponsors a national rocketry competition, inviting universities across the country to enter, and each year the Vanderbilt Aerospace Team, composed of six mechanical engineering seniors, competes in this challenge. This year, the challenge models a Mars sample-recovery mission. The team is tasked with building Autonomous Ground Support Equipment, which must locate and retrieve a small sample from the ground without human interaction. Furthermore, the AGSE must safely deposit the sample into a team-designed rocket compartment. The entire rocket, containing the sample, is launched to reach an altitude of 3,000 feet before deploying the payload in an independent section of the rocket at 1,000 feet.

Throughout the year, VU Aerospace has focused on designing a reliable and durable rocket and robotic AGSE system. Using camera-based object recognition, the AGSE is able to locate and plan trajectories to both retrieve and securely deposit the payload in the rocket from anywhere in its workspace. Additionally, as minimizing weight and wasted space is critical in aerospace design, the team has optimized a compact rocket design that seeks to maximize space efficiency and reduce the need for a larger motor while maintaining the reliability and innovation of other designs.

# Design and Project Faculty

We take great pride in recognizing these faculty members for their outstanding contributions and excellence as instructors, advisers, and mentors in our senior design and project courses represented at Design Day 2015.

**JOEL BARNETT**
Associate Professor of the Practice of Mechanical Engineering

**RALPH BRUCE**
Professor of the Practice of Electrical Engineering

**KENNETH DEBELAK**
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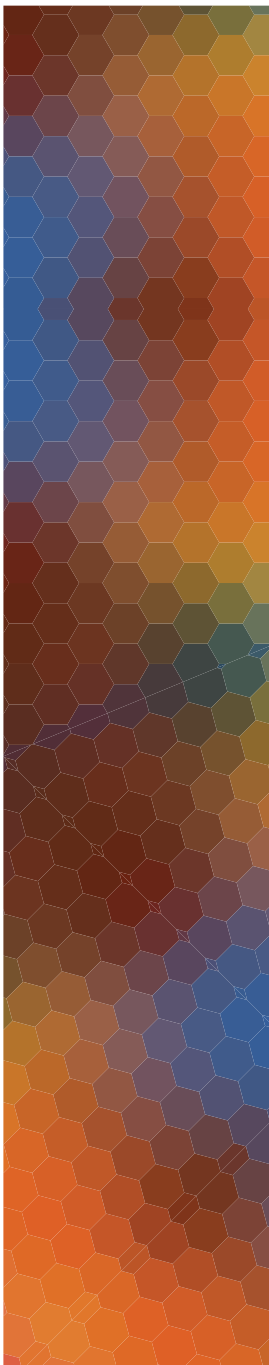

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