DESIGN DAY VU

School *of* Engineering

MONDAY, APRIL 24, 2023

Thank you to our sponsors

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

Airport Cooperative Research Program

American Society of Civil Engineers, Vanderbilt University Student Chapter

Aurora Water

Barge Design Solutions, Inc.

BASF

Booz Allen

Boxing Resource Center

Carolina Stalite

Civic Design Center

Civil-Military Innovation Institute Inc.

Cumberland River Compact

Dominion Water & Sanitation District

Gresham Smith

Healing Innovations, Inc.

Irving Materials, Inc.

KCI Technologies Inc.

KPFF Consulting Engineers

NASA

Nashville Zoo at Grassmere

Naval Surface Warfare Center, Panama City Division

Nissan North America

Norchem Corporation

PaintJet

Polymer and Chemical Technologies, LLC

Sterling Ranch

StudyCommon

Tennessee Concrete Association

Tennessee Department of Environment and Conservation, Division of Water Resources

The Product Development and Management Association

TM TKO, LLC

TrakRx

Utility Global

Vanderbilt University
- Facilities Department
- Transportation and Mobility Office
- Office of Immersion Resources

Vanderbilt University School of Engineering
- Digital Fabrication Laboratory
- Duvall Advanced Therapeutics Laboratory
- Locke Biosensing Laboratory
- Wilson ImmunoEngineering Laboratory
- Vanderbilt Aerospace Design Laboratory
- Vanderbilt Institute for Surgery and Engineering

Vanderbilt University School of Medicine
- Department of Pharmacology

Vanderbilt University Medical Center
- Department of Anesthesiology
- Department of Cardiology
- Department of Cardiac Surgery
- Department of Neurology
- Department of Plastic Surgery
- Department of Radiology
- Department of Thoracic Surgery
- Department of Orthopaedic Surgery
- Division of Kidney & Pancreas Transplantation

Cover designed by Mary Alice Bernal, Finn Partners Southeast.

Preface

On behalf of the School of Engineering, we would like to share the 54 senior design engineering capstone design projects for 2023. We had capstone projects completed in partnership with sponsors including Nissan North America, BASF, NASA Marshall Space Flight Center, Gresham Smith, Sterling Ranch Development Company, Booz Allen Hamilton, Vanderbilt University Medical Center, and many more. We thank all of our project sponsors, advisers, and mentors for their support of our design teams and the entire program.

Senior design courses provide students with experience working on real-world projects that involve design constraints, budgets, reviews and deadlines. All the teams, sponsors, mentors, and everyone involved have experienced a year that created a challenging environment for collaborative design. They will remember the adaptability and hard work to keep working from all corners of the globe.

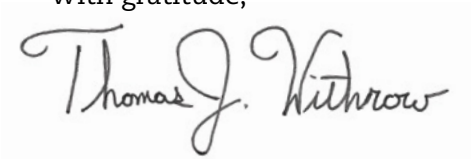
Students learned about professionalism, teamwork, entrepreneurship, and above all resilience. As their projects take form, student teams interact with their industry and faculty advisers, hold meetings, write formal documentation and present their work. By the end of the academic year, the teams produce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

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

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

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

With gratitude,



Thomas J. Withrow
Assistant Dean for Design
Associate Professor of the Practice of Mechanical Engineering
514 Olin Hall
615.322.3594
thomas.j.withrow@vanderbilt.edu

Contents

Departments and Programs

APRIL 24

19
ELECTRICAL AND COMPUTER ENGINEERING

FACULTY ADVISER

Walter Collett, Professor of the Practice of Electrical and Computer Engineering

ECE-1
Portable demonstration device for digital system concepts

ECE-2
IEEE 2023 SoutheastCon robot design

ECE-3
Few-shot image classification for low-resource sickle cell disease diagnosis

ECE-4
Optical wet paint thickness heat map

ECE-5
AI compound term decomposition

ECE-6
Automating international trademark data acquisition

22
ENGINEERING SCIENCE

FACULTY ADVISER

Courtney Johnson, Assistant Professor of the Practice of Technical Communications

ES-1
Airport management design competition

ES-2
Campus HVAC control strategy

ES-3
Conversion of water quality state operating permit paper application to an electronic system

ES-4
Focus groups and expansion of the StudyCommon EdTech application

ES-5
Global Student Innovation Challenge powered by PDMA

ES-6
Semi-autonomous distributed mesh framework for versatile drone usage

ES-7
Smart pill bottle cap for tracking medication adherence

26
MECHANICAL ENGINEERING

FACULTY ADVISERS

Thomas Withrow, Assistant Dean for Design and Associate Professor of the Practice of Mechanical Engineering

Jason Mitchell, Assistant Professor of the Practice of Mechanical Engineering

Ranjana Sahai, Assistant Professor of the Practice of Mechanical Engineering

ME-1
Nissan hose clamp automation project

ME-2
Light-based target training tool

ME-3
Low-cost autonomous modular submersible

ME-4
Mechatronic design/build of a hydrogen generation spray machine

ME-5
Firehose ungulate enrichment device for the Nashville Zoo

ME-6
Primate food delivery and enrichment device for the Nashville Zoo

ME-7
Tree conveyor system to deliver 500,000 trees

ME-8
Vanderbilt modular and portable underwater vehicle for NAVSEA

ME-9
Stroke rehabilitation device for upper extremity patients

ME-10
Timing system for Boxing Resource Center

ME-11
United States Army fast rope insertion gloves

ME-12
Rocket with autonomous camera payload for RF command imaging

BIOMEDICAL ENGINEERING
BME-1

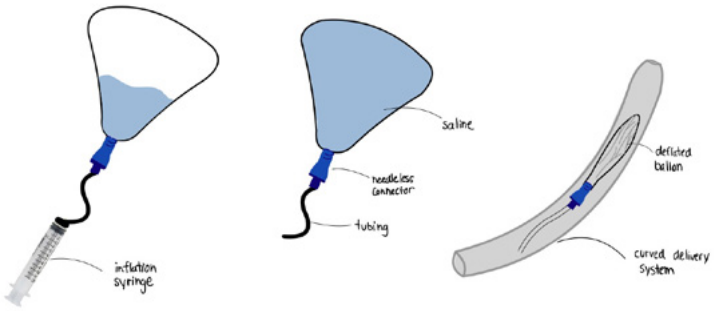
TEAM
Beatty Fann, BME
Lauren Elias, BME
Reethi Padmanabhan, BME/CSET
Samantha Mallahan, BME

ADVISER
Professor Marc Moore, BME
David Austin Schirmer, M.D., Department of Obstetrics and Gynecology, Emory University School of Medicine
Sabrine Bensouda, M.D. Candidate, Emory University School of Medicine

SPONSOR
Vanderbilt University School of Engineering

Uterine balloon for preventing intrauterine adhesions

The goal of our project is to prevent the formation of intrauterine adhesions following uterine adhesiolysis procedures, specifically to treat Asherman's syndrome. Our team has designed a silicone, uterus-shaped balloon with a curved delivery system that enables the balloon to be seamlessly delivered through the cervix and into the uterine cavity. The balloon is then inflated with saline causing it to mold to the inside of the uterine walls, preventing them from touching and forming adhesions. The balloon will remain in the uterus for one week and then be removed by deflating the balloon and pulling on the tubing extending into the vaginal canal. We aim for the final design to contain small enough components that no cervical dilation is necessary for insertion. The balloon will be made by dip molding silicone and the tubing will be connected to the balloon using a needleless connector that will prevent backflow of the saline under everyday uterine and abdominal pressures. Given that there is currently no balloon on the market designed to fit the uterine cavity or designed with a delivery system, our device will be the first of its kind.



This illustration shows the balloon inflated with saline, the placement of the needleless connector, the tubing that will extend into the vaginal canal, and the curved delivery system used for the insertion of the balloon.

VANDERBILT
School *of* Engineering

BIOMEDICAL ENGINEERING
BME-2

TEAM
Aaron Guo, BME
Eva Gbur, BME
Hongkai Jiang, BME
Tiffany Le, BME
Vignesh Chennupati, BME

ADVISER
Joseph Schlesinger, M.D., Department of Anesthesiology, VUMC

SPONSOR
Vanderbilt University School of Engineering

Mitigating ICU alarm fatigue by integrating visual and auditory notifications

Our project seeks to redesign alarms in the Intensive Care Unit (ICU) to be more informative of patient condition and to reduce alarm fatigue among clinicians. We have developed a heads-up display (HUD) that attaches to glasses to visually represent changes in three patient vitals—heart rate, blood pressure, and blood oxygenation—and their relative severity. The HUD casing is 3D-printed to fit an Arduino microcontroller, an organic light-emitting diode (OLED) display, a lens, and a mirror. This design reflects the graphical vital display onto a piece of semi-translucent glass in front of the user's eye. The visual display is paired with modified auditory icon alarms that better convey changes in blood pressure and the relative severity than previous versions. The multisensory design of the alarm system aims to decrease clinician response time to emergency situations and improve accuracy in emergency identification.

Integration of a custom heads-up display (HUD) with commercial bone conduction headphones that deliver improved auditory icons into a multisensory alarm system. Only one side of the headphones is shown for clarity.

VANDERBILT
School *of* Engineering

TEAM

Lauren Babb, BME
Morgan Butts, BME
Jordyn Herrington, BME
Addison White, BME
Qinzhe Xing, BME

ADVISERS

Rachel Forbes, M.B.A., F.A.C.S, Division of Kidney & Pancreas Transplantation, VUMC
Professor Marc Moore, BME

SPONSOR

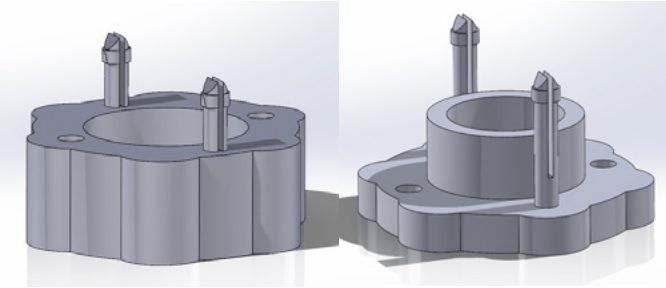
Vanderbilt University School of Engineering

BIOMEDICAL ENGINEERING

BME-3

Renal anastomosis quick-connect device

With the rising prevalence of end-stage kidney disease (ESKD) and its precursors, there exists an increased need to optimize the efficiency of kidney transplantations. Current modes of failure in kidney transplants are largely rooted in the limitations of the surgical procedure itself. Namely, the longer the implantation process, the more cellular damage to the donor kidney, and the higher the risk for long-term complications in the patient. To accelerate this process, we have designed an anastomotic quick-connect device, enabling a faster connection between the donor kidney vessels and the recipient's vessels than is currently possible through manual suturing alone. Our design consists of two independent rings to quickly grasp each respective vessel and latch the two together via complementary prongs and slots. Drawing on inspiration from gastrointestinal staplers and microvascular couplers, our team hopes to adapt existing technology for renal anatomy in order to improve the efficiency and success rate of kidney transplantations.



The illustration shows the end-vessel connection piece (left) and the side-vessel connection piece of the device (right). The holes and spikes on each piece lock to the corresponding features on the other piece.

VANDERBILT
School *of* Engineering

TEAM

Rose Herdejurgen, BME
Brianna Jacobson, BME
Kathryn Lee, BME
Alexis Whitby, BME/EE

ADVISERS

Luke Benda, Healing Innovations, Inc.
Ben Taylor, Healing Innovations, Inc.

SPONSOR

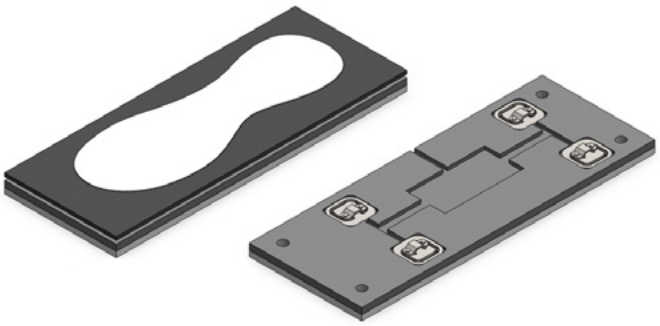
Healing Innovations, Inc.

BIOMEDICAL ENGINEERING

BME-4

Footplate force sensor for a gait rehabilitation machine

Healing Innovations developed the Rise&Walk InClinic, a robotic rehabilitation device that provides body weight-supported therapy to patients with neurological injuries and gait impairments. Clinicians expressed a desire for the Rise&Walk to provide metrics related to patient biomechanics to improve rehabilitation intervention. Two footplate force sensors were developed to be integrated with the Rise&Walk footplates. Each footplate force sensor consists of four load cells in the corners of the footplate, embedded in 3D-printed housings and protected between top and bottom layers of aluminum and steel. The readings from the right and left footplates are compared to determine bilateral body weight distribution. The readings from the anterior two load cells and posterior two load cells of a single foot are each averaged to determine the body weight loading on the toes and heel, respectively. This is used to identify instances of successful steps–steps in which over half of the body weight is transferred from heel-to-toe. Multiple gait rehabilitation machines exist, but none provide this degree of real-time gait metrics to clinicians. This device is expected to provide reliable body weight distribution and successful step indication metrics, leading to more informed and personalized rehabilitation care.



The footplate force sensor consists of a rectangular steel baseplate, a layer of 3D-printed plastic with cavities to hold the four load cells, a layer of aluminum to distribute the load, and a top layer of traction rubber.

HEALINGINNOVATIONS

BIOMEDICAL ENGINEERING
BME-5

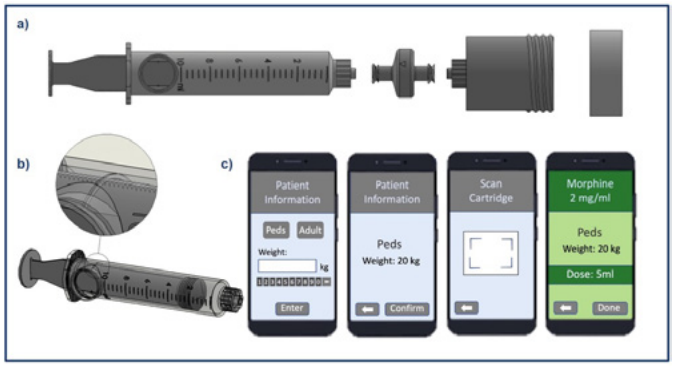
TEAM
Namrah Ajmal, BME/Math
Westin Bate, BME
Jessica Handwerker, BME
Hannah Kirkham, BME
Ally Questell, BME/SOC

ADVISERS
Kiersten Brown-Espaillat, DNP, Department of Neurology, VUMC
Stephen Gallion, Nurse Manager, Department of Neurology, VUMC

SPONSOR
Vanderbilt University Medical Center

Novel medication administration device

In emergency transport settings, it is often challenging for emergency medical technicians (EMTs) to administer the correct drug and dose. The goal of this project is to design a novel medication administration device that improves accuracy and precision of drug administration while decreasing drug waste given recent supply shortages. Our design incorporates a two-part solution consisting of a physical device and an app. The physical device is a modified 10 mL syringe with a serrated plunger that clicks against a ridge on the barrel in 0.1 mL increments. A magnifying bulge enlarges the numbered dose printed on the plunger, enabling EMTs to more precisely administer medication. The syringe draws medication through a one-way duckbill check valve from a sterile cartridge. The cartridge, with the one-way valve on its outlet and 0.2 μm filter to allow sterile air into its inlet, will reduce waste by keeping drug stock sterile across multiple uses. Our app, compatible with tablets used by EMTs, allows personnel to input patient metrics. After scanning a drug-specific code found on the cartridge, the app displays the drug's name and the patient-specific dose on a color-coded screen, helping to increase accuracy of medication administration.



a) The physical parts of our drug administration system from left to right: the 10 mL syringe with 0.1 mL precision clicks, the one-way check valve, the zero-waste 20 mL drug cartridge, and the 0.2 μm filter cap. b) The serrated plunger interfaces with a ridge on the barrel to click at 0.1 mL increments to allow for increased dosing precision compared to current methods. c) The app first asks the emergency medical technician if the patient is a pediatric (peds) or adult patient and allows for input of the patient's weight. A verification screen is shown followed by a prompt to scan a drug-specific code on the cartridge. The app then calculates the patient-specific dose and displays the dose on a color-coded screen specific to the drug type.

VANDERBILT UNIVERSITY MEDICAL CENTER

BIOMEDICAL ENGINEERING
BME-6

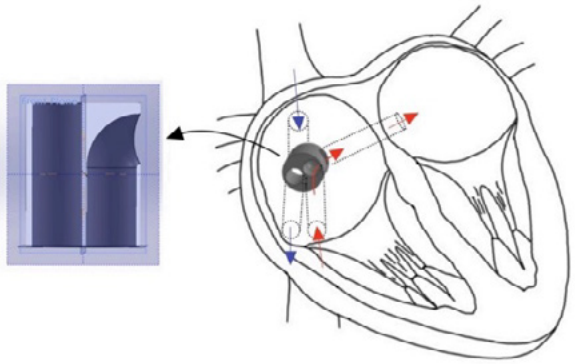
TEAM
Faith Bradley, BME
Jeremiah Johnson, BME
Joel Odeyemi, BME
Hannah Stepp, BME

ADVISERS
Professor Marc Moore, BME
Matthew Bacchetta, M.D., M.B.A., F.A.C.S., Department of Cardiology, VUMC
Carl Johnson Jr., M.D., Ph.D., Department of Cardiology, VUMC
Rei Ukita, Ph.D., Department of Cardiac Surgery, VUMC

SPONSORS
Vanderbilt University School of Engineering
Vanderbilt University Medical Center, Department of Cardiac Surgery

Novel cannula design for central access veno-arterial ECMO

End-stage lung failure is the most severe phase of chronic pulmonary diseases and is characterized by impaired ventilation in the alveoli. Extracorporeal membrane oxygenation (ECMO) machines facilitate gas exchange and effectively replace the function of irreversibly damaged lungs. Additionally, ECMO substantially prolongs the lives of patients on transplant lists–an essential intermediary role given the dearth of viable donor lungs. However, many current ECMO designs lead to discomfort and significantly limit patient mobility. Such decreased ambulation results in increased weaning complication rates and unfavorable patient outcomes. Therefore, there is a need for a novel cannula configuration to improve patient ambulation and recovery rates following ECMO procedures. Our design accomplishes this via a consolidated veno-arterial central cannulation approach consisting of conjoined single-lumen cannulas directed by a 3D-printed cap residing (via suture) in the right atrium. The cap's curved inner channel sufficiently guides the return cannula across the pre-perforated atrial septum into the left atrium. This design enables improved patient mobility and a concise ECMO configuration via a single external entry incision while maintaining a similar oxygenation efficiency and hemodynamic profile to traditional ECMO systems.



Our 3D-printed cannula cap allows for a single external incision to direct blood through two cannulas (dotted lines). One cannula brings deoxygenated blood (blue arrows) to an extracorporeal membrane oxygenation (ECMO) pump from the right atrium, while the other cannula redirects oxygenated blood (red arrow) across the atrial septum into the left atrium.

School of Engineering

VANDERBILT UNIVERSITY MEDICAL CENTER

TEAM
William Bryant, BME
Caitlin Grogan, BME
Aiden Kunkler-Peck, BME
Emma Wheat, BME

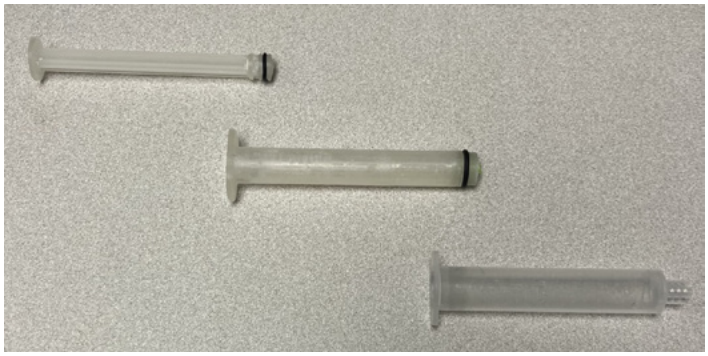
ADVISER
Nicholson Chadwick, M.D., Department of Radiology, VUMC

SPONSOR
Vanderbilt University Medical Center

BIOMEDICAL ENGINEERING
BME-7

Concentric barrel syringe for sequential administration of injectate

Our project addresses the loss of syringe needle visualization in patients receiving joint pain management injections under ultrasound to ensure steroid administration into the desired joint space. We developed a concentric barrel syringe design that will combine a 3D-printed syringe and plunger inside of a standard syringe. The inner syringe also acts as a plunger, creating two distinct barrels in one syringe. This allows for the sequential injection of anesthetic and steroid into the joint space without switching syringes mid-procedure. Our final design will feature a 3D-printed polylactic acid modified syringe with a one-way duckbill valve and plunger that will fit within a standard 10cc medical syringe. The anesthetic within the 10cc syringe will be administered first using the modified syringe body as a plunger. Then, the steroid within the inner syringe will be administered using the innermost plunger design. The use of a one-way duckbill valve in the inner syringe will ensure that no undesirable mixing of injectates occurs throughout this process. This design will allow physicians to perform sequential injections using a single hand, allowing them to maintain continuous visualization of the joint space under ultrasound.



The syringe design is composed of a 3D printed inner syringe with a one-way valve (middle) and plunger (top). The inner syringe fits inside a standard 10 cc syringe (bottom) to form a syringe with two distinct, concentric compartments.

VANDERBILT UNIVERSITY MEDICAL CENTER

TEAM
James Metz, BME
Phia Pannullo, BME
Cameron Pirozzi, BME/CS/Math
Macy Scott, BME

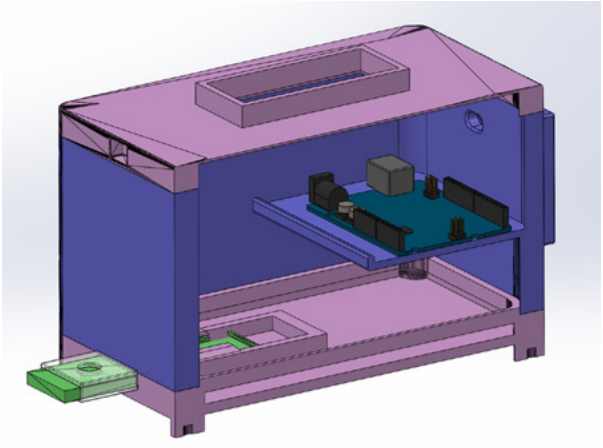
ADVISER
Professor Andrea Locke, BME

SPONSOR
Vanderbilt University School of Engineering

BIOMEDICAL ENGINEERING
BME-8

A point-of-care test for diagnosis and management of sickle cell disease

The goal of our project is to create a low-cost point-of-care diagnostic device for sickle cell disease that can operate in resource constrained environments. We have developed a portable imaging box and easy to operate assay procedure coupled with a machine learning model from the ECE department to function diagnostically in the field. Our design uses common materials such as resin, a Raspberry Pi, and an LCD screen. Our final design will incorporate a sliding tray to push the sample into the box holding a Raspberry Pi camera that will image the sample. The image will be analyzed by the ECE team's machine learning model and the result is displayed on the LCD screen mounted outside the box. Our current focus is to continue streamlining the hardware, create readable instructions for the procedure, and provide samples to the ECE team working on the machine learning model. We hope that this device can be implemented in low-resource settings to provide quick analysis of sickle cell disease samples.



An assembly of the imaging box, including the sample tray and the mount for the Raspberry Pi camera.

School of Engineering

BIOMEDICAL ENGINEERING
BME-9

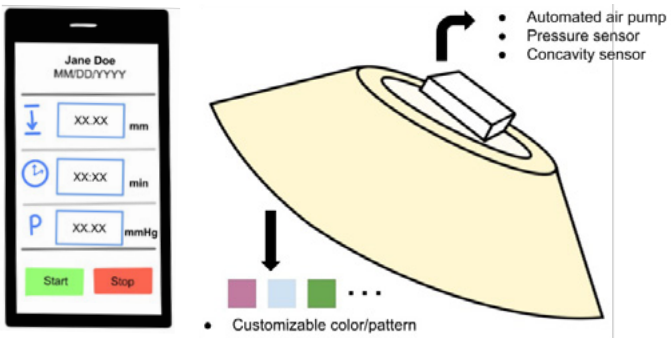
TEAM
Thomas Dean, BME
Sarah Reilly, BME
Jasmine Su, BME
Victoria Tung, BME

ADVISERS
Caitlin Demarest, M.D., Ph.D.
Christine Nasri, NP

SPONSOR
Vanderbilt University School of Engineering

Vacuum bell modifications for pediatric pectus excavatum

A current popular treatment for children with pectus excavatum, a congenital chest wall deformity, is a vacuum bell that provides a pressure chamber to pull the concave chest and breastbone forward. However, it has limitations in that it is not child friendly, and it does not provide metrics to quantify the use of the bell and concavity improvement. Our team's goal was to design a more effective and patient friendly non-operative treatment option for pediatric patients. The team's solution is a version of an existing vacuum bell device with added features and a customizable appearance to appeal to a young patient. This modified version of the vacuum bell allows for quantification of the duration that the bell was worn, the pressure inside the chamber, and the concavity depth from the bell to the chest. The team also anticipates integrating a Bluetooth automation function so the user can set the pressure in the chamber to a specified value as well as log the use of the bell.



The vacuum bell includes a rechargeable lithium battery and automated pressure sensor, air pump, concavity measurement, and duration of use enabled through a Bluetooth Arduino.

School of Engineering

BIOMEDICAL ENGINEERING
BME-10

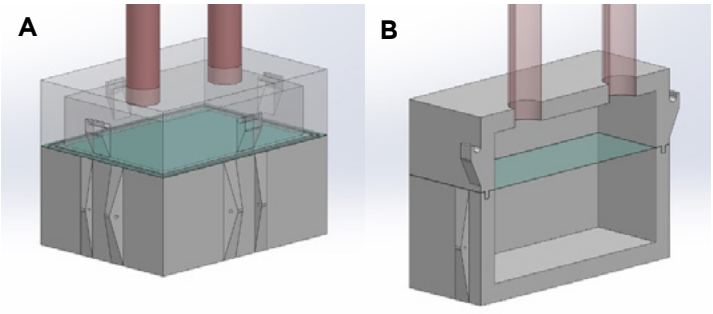
TEAM
Jeremy Langsam, BME
Julia Sullivan, BME
Hank Golding, BME
Wade Emrich, BME
Vidhya Shunmugasundaram, BME

ADVISERS
Professor Jeffry Nyman, BME
David Harrison, M.D., Department of Pharmacology, VUMC
Elizabeth Hennen, Ph.D. Candidate, BME

SPONSOR
Vanderbilt University School of Engineering
Vanderbilt University School of Medicine, Department of Pharmacology

Bioreactor that induces pressure without shear stress

Our goal is to design a bioreactor that applies pressure invariant to the shear stress applied to the cells. This will help researchers identify mechanotransduction pathways arising only from pressure, as opposed to pathways triggered also by shear stress, in turn aiding hypertension research. Variable pressure bioreactors are currently unable to divorce pressure from shear. Our final design consists of an upper and lower compartment, separated by a thin rubber membrane. The upper compartment features two access points for plastic tubing for compressed air entering and exiting the chamber. When compressed air enters the upper compartment, the buildup in pressure causes the rubber membrane to compress downward into the lower compartment. This decrease in volume in the lower compartment results in an increase in pressure. The endothelial cells are cultured atop a hydrogel membrane on a plastic insert, which mimics the vessel thickness and prevents the hydrogel from stretching, thus controlling for shear stress. The membrane prevents turbulent airflow from disrupting the surface of the culturing solution. Pressure sensors (not pictured) are placed in the lower compartment to validate the conditions applied. The pressure application is further validated through VEGF staining and IMAGEJ modeling.



(A) shows the bioreactor with a transparent upper chamber, while (B) shows a section view of the bioreactor. The gray parts will be constructed using a bio-friendly resin printer. The red tubes are used for air intake and outtake (solenoids to control intake and outtake aren't shown). The green sheet between compartments is the rubber membrane.

School of Engineering

VANDERBILT UNIVERSITY MEDICAL CENTER

TEAM
Jonathan Dwiyono, BME/EE
Stephan Gorgey, BME
Kush Hari, BME/EE
Madison Veliky, BME/CompE

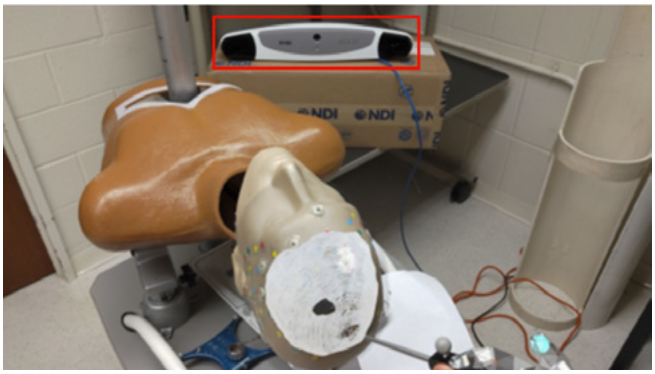
ADVISER
Professor Michael Miga, BME

SPONSOR
Vanderbilt Institute for Surgery and Engineering

BIOMEDICAL ENGINEERING
BME-11

Augmented reality for surgical guidance and training

The high cost of image guidance systems prevents medical students from having unlimited access to them for training. To better facilitate training, the team developed an augmented reality app for surgical instruction using a Microsoft HoloLens 2 and NDI Polaris Vega VT Tracker. With the app, users can scroll through 3D MRI data, visualize brain shift and anatomical obstacles relevant to the operation, and watch video-guided lessons regarding craniotomy planning. While other surgical training apps may include similar 3D rendered information, this app leverages augmented reality to allow use physical tools to interact with the neuroanatomy holograms inside the physical head. With this immersive simulation, neurosurgery students can potentially improve their spatial awareness by simultaneously viewing and interacting with physical and image space. To verify the efficacy of the app, a user perception study will be conducted with current residents and neurosurgeons.



Using the Microsoft HoloLens 2 and an optical tracker (indicated by the red box), the virtual brain and tumor models of a craniotomy case were projected onto the physical head as if the user had X-Ray vision.

VISE VANDERBILT INSTITUTE FOR SURGERY AND ENGINEERING

TEAM
Jeremiah Egolf, BME
John Abbott, BME
Hayden McMillion, BME

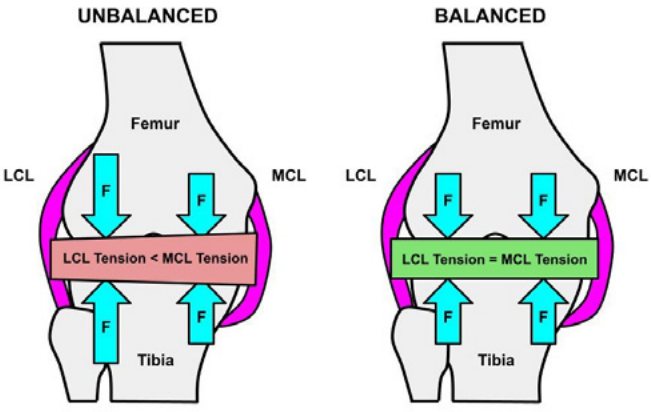
ADVISER
Ryan Martin, M.D., Department of Orthopaedic Surgery, VUMC

SPONSOR
Vanderbilt University Medical Center

BIOMEDICAL ENGINEERING
BME-12

Digital gap balancer for robot-assisted total knee replacements

Total knee arthroplasty (TKA) is key to the orthopedic market, with 800,000 TKA procedures taking place annually in the US. Knee implants must be revised when the implant loosens or wears over time, which often arises due to improper implant sizing. Revision rates are concerningly high despite advances in surgical technology and are often attributed to the invariable inconsistency in surgeons' sizing technique. Accurately balancing the tension in soft tissues around the tibiofemoral compartment is essential to sizing and can be standardized using digital instruments to reduce overall revision rates. Our digital gap balancer can approximate ligamentous tension by measuring the bicompartmental contact forces between the tibia and the medial/lateral femoral condyles. Our user-friendly device is intended to integrate with the VELYS robot-assisted surgery system from DePuy Synthes, which is used to perform TKA at the VUMC, and augment the surgical procedure by providing quantitative measures of implant fit.



When the tibiofemoral gap is properly balanced, our device will measure equal tibiofemoral contact forces in the medial and lateral compartments.

VANDERBILT UNIVERSITY MEDICAL CENTER

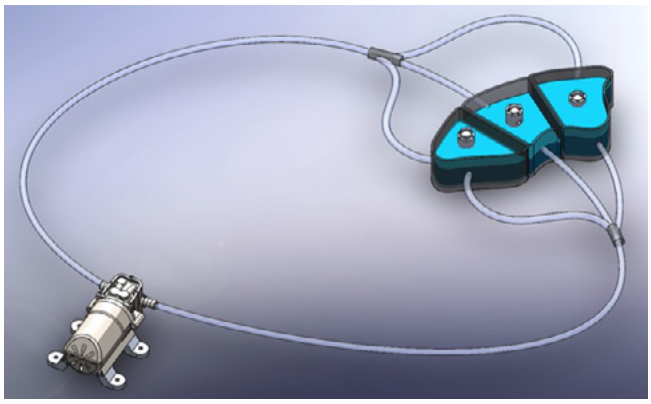
BIOMEDICAL ENGINEERING
BME-13

TEAM
Alba Minxha, BME
Sara Morice, BME
Lilianna Thrower, BME
Katherine Xie, BME

ADVISERS
Professor Marc Moore, BME
Matthew Smith, M.D., Ph.D., Department of Radiology, VUMC
Jared Grice, Ph.D., Department of Radiology, VUMC
William Livingston, BME Ph.D. student

SPONSOR
Vanderbilt University School of Engineering

Lung phantom to calibrate fluoroscopy technique for pulmonary embolism



The lung phantom consists of 3 compartments each with adjustable blockages. The pump creates a closed system with branched tubing entering and exiting each compartment, simulating blood flow through the lung.

Pulmonary embolism is a life-threatening cardiovascular disease. A patient must be quickly scanned so physicians can determine the severity of blockages. Existing imaging techniques require radiation injections and extensive preparation. VUMC radiologists proposed using a faster, non-invasive fluoroscopy machine. We are developing an anthropomorphic lung phantom that will calibrate and validate this fluoroscopy technique to diagnose pulmonary embolism. The phantom is composed of three compartments that mimic the right lung. These compartments are connected to a pump via input and output tubing. The tubing will have flow sensors to help in future testing. The blockages will be stimulated by a 3D printed cylinder that can be manually adjusted to mimic different levels of stenosis. This phantom will anthropomorphically resemble a lung, including the flow rate and occasional stenosis. When imaged with a fluoroscopy machine, the location and severity of blockages should be apparent based on a color difference from normal fluid flow. A perfusion map of the flow through the phantom would resemble that of a real lung as well. Overall, if the fluoroscopy machine can detect intentional stenosis of fluid flow through a phantom lung, then it can be used to detect pulmonary embolisms.

School *of* Engineering

TEAM

Blake Christiansen, ChemE
Samuel Leville, ChemE
Melanie Marszal, ChemE
Amy Pang, ChemE

ADVISERS

Professor Scott Guelcher, ChemE
Professor David Florian, ChemE

SPONSORS

Vanderbilt University Office of Immersion Resources

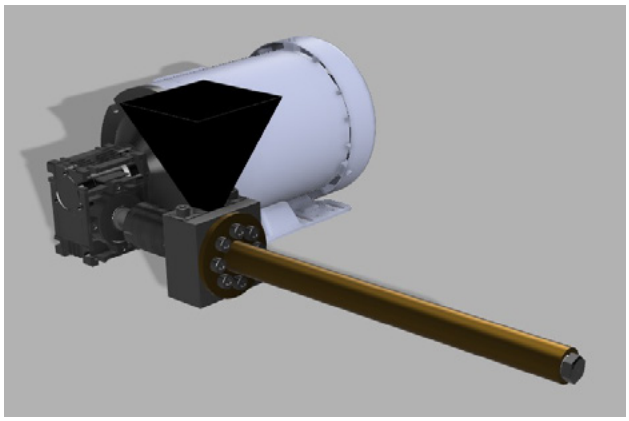
Digital Fabrication Laboratory

CHEMICAL AND BIOMOLECULAR ENGINEERING

ChBE-1

Building a filament extruder for optimized PET recycling

Plastic bottles are one of the highest contributors to waste in the United States. Fortunately, they can be recycled for a variety of purposes. Our team partnered with Vanderbilt recycling to utilize plastic bottle waste from students to supply 3D printing (3DP) labs across campus with recycled PET filament. Many extruders can process specific types of plastics and produce strands of filament that can be 3D printed. However, the extruder group aims to design an extruder that is optimized for processing granulated plastic bottles into filament. The team is using machinery in the Digital Fabrication Lab to granulate bottles from Vanderbilt recycling, applying simulation software to determine optimal extruder parameters for regrind, using computer-aided design (CAD) to design and assemble the extruder digitally, and building the extruder from purchased and fabricated components. They aim to use the prototype extruder to create a circular plastics economy at Vanderbilt in which students manufacture filament from recycled bottles to supply 3DP printing labs and makerspaces on campus.



The assembly of key components of the PET extruder: motor, gearbox, coupler, flange, barrel, screw, die, and hopper.

IMMERSION VANDERBILT

DIGITAL FABRICATION GUELCHER LAB

TEAM

Youssef Mohamed, ChemE
Akhila Ramgiri, ChemE/BME
Julia Van Epps, ChemE/BME

ADVISERS

Professor Scott Guelcher, ChemE
Professor David Florian, ChemE
Professor John Wilson, ChemE

SPONSORS

Digital Fabrication Lab

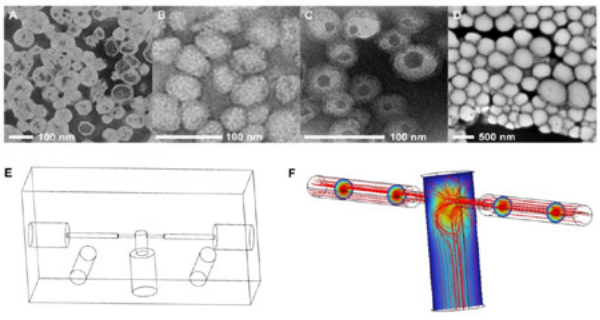
Wilson Lab

CHEMICAL AND BIOMOLECULAR ENGINEERING

ChBE-2

Optimization of a flash nanoprecipitation device for valuable therapeutic cargo

Flash NanoPrecipitation (FNP) is a process used to produce nanocarriers at a high yield, which has important applications in the pharmaceutical field. The Wilson Lab currently uses a commercial FNP device to develop nanoparticles to encapsulate therapeutic cargo. This device comprises a confined impinging jet mixer in which two inlet streams undergo a turbulent mixing process, thereby forming nanoparticles within a mixing chamber. However, the commercial device has two major limitations: increased holdup of expensive reagents within the device and lack of standardized mixing conditions. The objective here is to modify the current FNP device to overcome its limitations without compromising the size distribution and efficacy of the nanoparticles. We used CAD modeling and COMSOL Multiphysics Computational Fluid Dynamic simulations to optimize the current dimensions of the device, identify improvements to the overall process, and simulate fluid flow to confirm turbulent mixing. The digitally optimized design was 3D printed using stereolithography and validated using the commercial device as a control. This functional prototype FNP device implements more efficient nanoprecipitation by optimizing device geometry and fluid flow to reduce waste and control mixing.



Transmission electron microscopy (TEM) images show nanoparticles formulated by the FNP device (A-D). Optimized CAD prototype of the functional FNP device (E) that is further characterized by fluid flow simulations in COMSOL (F).

DIGITAL FABRICATION GUELCHER LAB

IMMUNOENGINEERING LABORATORY

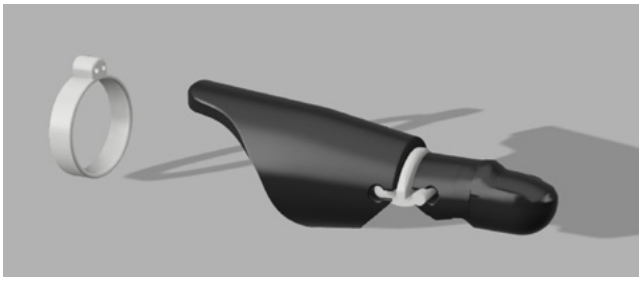
CHEMICAL AND BIOMOLECULAR ENGINEERING
ChBE-3

TEAM
Molly Friedman, ChemE/Chem
David Ong, ChemE/Chem
Noah Reckhorn, ChemE/Chem
Sianna Xu, ChemE/CS

ADVISERS
Professor Russell Dunn, ChemE
Alan Crawford, P.E., Independent Chemical Engineering Consultant
David Steckler, P.E., Impact Technology Development
Richard Baud, P.E., Baud Engineering, LLC

SPONSOR
Polymer and Chemical Technologies, LLC

Design and optimization of a 3D-printed prosthetic finger



This final finger design incorporates a ring to anchor the finger, a comfortable and conductive sleeve, a kinetic joint, and a SmartScreen-compatible fingertip.

Growing technological applications have created the potential for more affordable prosthetics. One option takes advantage of accessible and reusable 3D printers to print prosthetics at a small fraction of the cost. This project builds upon a previous design group's product, ideally upgrading functional and qualitative features of the design. Feedback was collected and broad goals were established: FAME (functionality, accessibility, marketability, expandability). Functionality focuses on design improvements in motor control, dexterity, strength, and durability of the prosthetic finger. Accessibility improvements address the prominent issues driving this project, in ways of availability and affordability. Prosthetic Evaluation Questionnaires specific to the printed prosthetics were created to collect quantitative and qualitative data to enable more personalized prosthetics. Marketability makes heavy engineering aspects translatable to consumers and stakeholders. This goal was to ensure prosthetics are user friendly and easily customizable from home. Expandability focuses on the potential of future development with the knowledge and applying aspects of this project to other prosthetic devices.

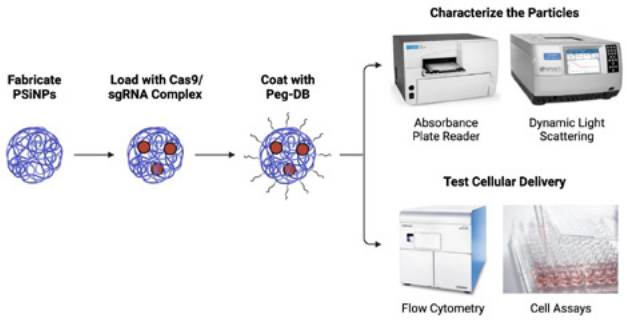
CHEMICAL AND BIOMOLECULAR ENGINEERING
ChBE-4

TEAM
Anastasia Shostak, ChemE
Daniel Shade, ChemE
Jacob Lumpkins, ChemE
Michael Weirich, ChemE

ADVISERS
Professor Russell Dunn, P.E., ChBE
Brian Babcock, Polymer Chemistry and Coatings, LLC
Karl Schnelle, Ph.D., Chemical Engineering Consultant

SPONSORS
Polymer and Chemical Technologies, LLC
Duvall Advanced Therapeutics Laboratory

Porous silicon nanoparticle drug delivery platform for cancer gene therapy



Schematic of the porous silicon nanoparticle (PSiNP) experimental workflow. First, PSiNPs are fabricated. Next, they are loaded with therapeutic cargo (Cas9/sgRNA Complex) and coated with a polymer stabilizer (Peg-DB). The finalized therapeutic nanoparticles are then characterized to evaluate loading properties and tested for efficacy and safety in vitro.

Nanoparticles have recently shown promise in targeted and efficient drug delivery to living systems due to their size, scalable production, and unique physicochemical properties. However, optimization of the various types of nanoparticles is necessary for successful therapeutic delivery with limited side effects to allow for commercial use. Our team uses porous silicon nanoparticles stabilized with the cationic polymer DB-Cy5 and coated with polyethylene glycol (Peg-DB) to deliver a GFP plasmid to cells. The performance of this model as a therapeutic modality is evaluated using various techniques including fluorescence and absorbance readings, dynamic light scattering measurements, live-dead cell assays, and flow cytometry. These findings will inform nanoparticle loading decisions with therapeutically relevant cargo, such as cancer therapeutics, and will allow for commercialization. We will be conducting an initial costing estimate of a pilot-plant-scale process with a schematic and considering revenue and profitability projections as well as IP protection, marketing, and operations of the eventual startup venture.

TEAM
Michael Gonsalves, ChemE
Maddie McKinney, ChemE
Glen Varghese, ChemE

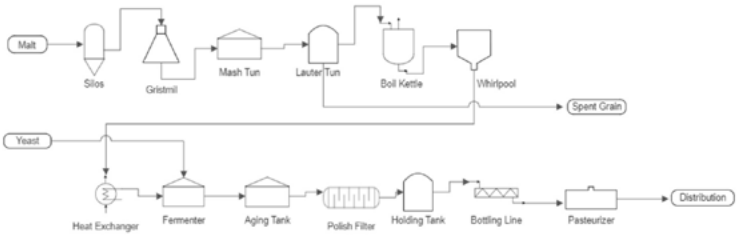
ADVISERS
Professor Russell Dunn, ChemE
Professor Bryan Beyer, ChemE
Tony Davis, Chemical Engineering Consultant

SPONSOR
Polymer and Chemical Technologies. LLC

CHEMICAL AND BIOMOLECULAR ENGINEERING

ChBE-5

Plant design and economic analysis for multi-product brewing



This figure shows the process flow diagram for large scale brewing.

Beer has evolved in many regions over thousands of years into countless styles and flavors. Today, from brewpubs to global producers, brewing is both a studied science and an artform. This project intends to determine the viability of a line of beers within a microbrewery with a total output of 100,000 beer barrels per year. By outlining the chemistry of brewing, equipment requirements, raw material and utility costs, our group will design a plant capable of producing the desired output. In addition, the plant to be designed will implement a variety of process improvements to reduce emissions associated with traditional brewing, such as utilizing carbon dioxide released during fermentation in carbonation. The final steps in this project consist of compiling a complete economic analysis and comparing the return on investment for a grassroots plant approach to that of contract brewing.

Polymer & Chemical Technologies, LLC

TEAM
Andrew Astre, ChemE
Lisa Nahyeon Kim, ChemE
Grace Labore, ChemE

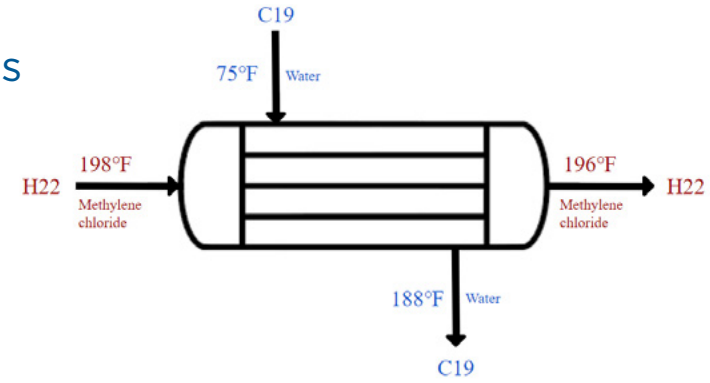
ADVISERS
Professor Russell Dunn, P.E., ChBE
Professor Brian Beyer, ChBE
Tony Davis, Chemical Engineering Consultant

SPONSOR
Polymer and Chemical Technologies, LLC

CHEMICAL AND BIOMOLECULAR ENGINEERING

ChBE-6

Detailed heat exchanger network design and cost analysis for a polycarbonate plant



Addition of strategic heat networks to integrate hot and cold streams within the resin facility (such as the one shown) allows for multimillion-dollar annual operating cost savings.

The goal of heat exchange network (HEN) creation is to decrease cooling water and steam utility usage by matching pairs of hot and cold streams, which is known as heat integration. The team obtained process flow diagrams of several plants within a polycarbonate production facility. Focusing on a resin plant, heat integration began by mapping out the phases of each stream before and after each heat exchanger, noting all associated heat duties. We then created a composite curve, which shows the total heat duty that can be integrated and proceeded to match hot and cold streams together. After compiling several designs of heat exchange networks, a most efficient solution can be determined by evaluating the economics of each. To improve cost performance of networks, the team is evaluating designs that integrate only the highest heat duty streams to avoid excessive capital expenses on less relevant stream matches.

Polymer & Chemical Technologies, LLC

CHEMICAL AND BIOMOLECULAR ENGINEERING
ChBE-7

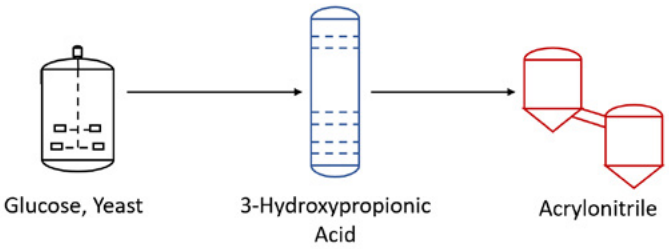
TEAM
Cade Burton, ChemE
Dahsong Lee, ChemE
Susanna Moore, ChemE
Alex Stoneman, ChemE/Chem

ADVISERS
Professor Russell Dunn, ChemE
Professor Jamey Young, ChemE
Karl Schnelle, PhD, Chemical Engineering Consultant
Brian Babcock, MS, Chemical Engineering Consultant

SPONSOR
Vanderbilt University School of Engineering

Environmentally sustainable biological production of acrylonitrile from sugars

Acrylonitrile (ACN) is a polymer with applications in carbon fiber, nylons, and rubbers. Its current method of production consumes fossil fuels and generates dangerous byproducts, posing widespread environmental risks. The goal of this project was to design an alternative method of ACN production from biomass-derived sugars, producing 2000 lbs/hr of product. The process goes through three main phases. First, metabolically engineered yeast cells convert glucose to 3-hydroxypropionic acid in a staggered batch bioreactor. Following purification, the acid reacts to form ethyl acrylate in a reactive distillation column, then the desired ACN via nitrilation in a riser reactor. The process also incorporates efficient waste management and a heat exchange network to minimize utility costs associated with heating and cooling. This represents a major potential improvement from current ACN production. It does not involve fossil fuels, which are finite resources, and it could have higher theoretical yields and be an overall safer process. Furthermore, as metabolic engineering strategies improve, the process could become even more economically advantageous.



A batch of yeast converts glucose into 3-hydroxypropionic acid, which undergoes reactive distillation and nitrilation to be converted into acrylonitrile.

School of Engineering

CHEMICAL AND BIOMOLECULAR ENGINEERING
ChBE-8

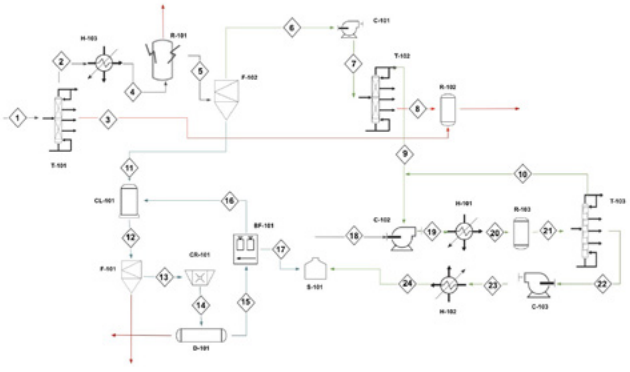
TEAM
Samuel Bogdanov, ChemE
Maxwell Byram, ChemE
Allison Cannati, ChemE
David Liption, ChemE

ADVISERS
Professor Russell Dunn, ChemE
Alan Crawford, Independent Chemical Engineering Consultant
David Steckler, Impact Technology Development
Richard Baud, P.E., Baud Engineering LLC

SPONSOR
Vanderbilt University School of Engineering

Decarbonization of natural gas from flared gas

Natural gas, which is composed of methane and other hydrocarbons, is a common byproduct of oil refining. Usually, natural gas is flared from refineries to control process pressure, resulting in the release of carbon dioxide (CO2) and unnecessary waste of high value hydrocarbons. The current industry standard for alternative methane use is steam methane reforming (SMR), which converts methane into hydrogen and CO_2. This process, however, is environmentally detrimental and accounts for 1% of annual CO_2 emissions globally. The project goal is a new process that can convert 3 MMscfd of methane feedstocks sourced from refineries into its atomic components with minimal environmental impact and a 20% rate of return on the initial investment (IRR). We chose to pursue plasma pyrolysis, which utilizes electric arcs to pyrolyze methane into elemental carbon-black and hydrogen gas. Plasma pyrolysis provides a 97% reduction in CO_2 emissions when compared to SMR. Our process design integrates an ammonia production facility; ammonia produced from hydrogen gas will be sold. The anticipated results are a minimum processing rate of 3 MMscfd of methane and a minimum IRR of 20%.



The Process Flow Diagram exhibits process section starting with the plasma pyrolysis of methane feedstock. The produced process gasses are separated from the generated carbon-black and sent to respective processing facilities. In the carbon-black facility, carbon-black nanoparticles are separated from atmospheric gasses, pelletized, dried, then sent to storage. Produced hydrogen is separated from undesired tail gasses and sent to the ammonia production facility. Pure nitrogen and hydrogen can react at low temperatures and high pressures to form ammonia with high conversions via the Haber-Bosch process. The produced ammonia is then sent to storage.

School of Engineering

TEAM
William Bell, ChemE
Samantha Nichols, ChemE
Tyler Oddo, ChemE

ADVISERS
Professor Russell Dunn, P.E., ChemE
Professor Bryan Beyer, ChemE
Tony Davis, Chemical Engineering Consultant

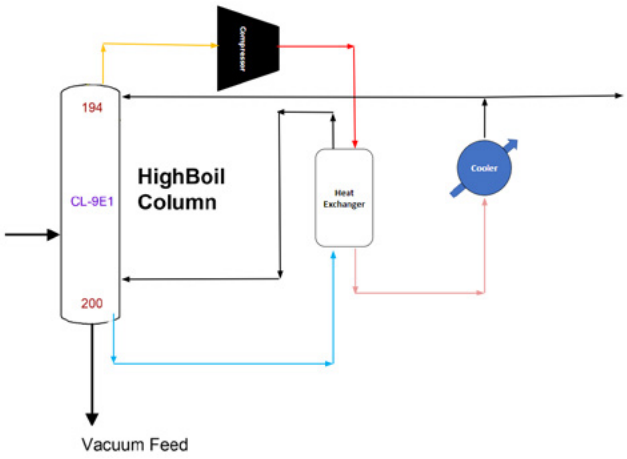
SPONSORS
Polymer & Chemical Technologies, LLC

CHEMICAL AND BIOMOLECULAR ENGINEERING

ChBE-9

Heat exchanger network design for improved plant savings

Most chemical plants require extensive heating and cooling duty for various processes, including distillations, reactions, and heat exchange operations. Utility costs are particularly high. To minimize utility (steam and cooling water) needs, heat integration via the implementation of a heat exchanger network is a good practice. The project goal is to reduce utility costs as much as possible for a PVC manufacturing plant by using heat exchangers to take advantage of heat already existing in process streams. Traditionally, heat exchanger networks are designed by matching streams with similar heat duties and thermodynamically valid temperature differences. To increase heat integration opportunities and savings, the team used heat pumping, pressure manipulation, reboiler feed preheating, and in-plant steam creation with the traditional network. The design recommendations can be implemented separately or in sum but are restricted due to retrofitting of the PVC plant. Anticipated utility savings using these heat integration methods range in the multimillions and offers long-term savings with minimal upkeep.



Schematic for a heat pumping project with the high boil column of an EDC Cracking plant. Heat pumping is optimal when applied to a distillation column where the distillate and bottoms streams have a small temperature difference. A compressor is used to increase the temperature and pressure of the distillate vapor to exchange heat with the bottoms stream rather than having the traditional reboiler and condenser. The cooler is required to finish cooling the distillate to its temperature specification. For this project alone, over 30 MMBTU/h of heat are integrated leading to approximately $1.2 million in annual savings from utility costs.

TEAM
Nick Lowe, ChemE
Jenna Phillips, ChemE
Eve Shanahan, ChemE

ADVISERS
Professor Russell Dunn, P.E., ChemE
Professor Paul Laibinis, ChemE
Professor Shihong Lin, CE, ChemE

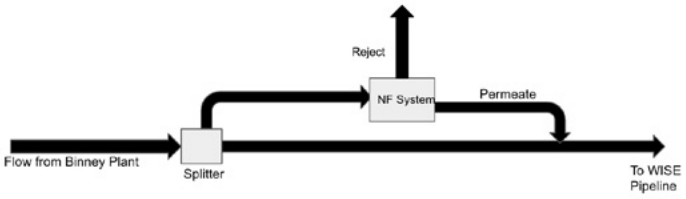
SPONSORS
Sterling Ranch
Dominion Water & Sanitation District
Aurora Water

CHEMICAL AND BIOMOLECULAR ENGINEERING

ChBE-10

Reducing source water TDS for Sterling Ranch

Sterling Ranch is a community in Douglas County, Colorado that is growing rapidly and needs an additional water source to meet their demands. They receive water from Dominion Water & Sanitation but are hoping to also use water from the WISE pipeline that runs through the Denver area. Water fed to this pipeline for Sterling Ranch's use comes from the Binney water treatment plant in Aurora, Colorado. This water has a total dissolved solids (TDS) level that sometimes exceeds the 700 ppm limit for entry into the WISE pipeline. The Binney plant is currently blending treated water with a pure stream from Denver Water to meet the TDS requirements, but a more permanent solution is needed. The design team suggests nanofiltration as that solution due to its combined effectiveness and energy efficiency. Lab-scale nanofiltration results are being used to model filter performance. This data, in conjunction with manufacturer information and process economics, will allow the team to suggest the best filters and the percentage of influent streams to be treated to most effectively reduce TDS.



This flow diagram shows the process for nanofiltration to reduce TDS entering the WISE pipeline.

CIVIL AND ENVIRONMENTAL ENGINEERING
CEE-1

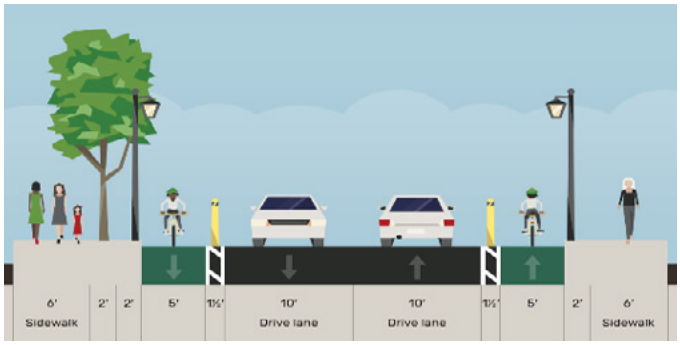
TEAM
Gracie Gumm, CE
Samuel Lee, CE
Sarah Paik, CE
Andy Sevilla, CE

ADVISERS
Michael Briggs, AICP, Vanderbilt Director of Mobility
Todd Serbent, P.E., KCI Technologies Inc.

SPONSORS
Vanderbilt Transportation and Mobility Office
KCI Technologies Inc.

Multimodal design to improve pedestrian and cyclist safety on 25th Avenue

Our project's goal is to improve mobility and safety for all users on Nashville's 25th Avenue, not just for those in vehicles. First, the team will improve pedestrian safety and mobility by making crosswalk improvements and adding a buffer zone between roadway users and sidewalk users. Second, improvements target cyclists. Preliminary traffic analysis showed that removing 25th Avenue's center turn lane is feasible, providing additional width to create separated and buffered bike lanes. Third, we will improve vehicular traffic flow, particularly for special-event parking, and find improvements to suboptimal curbside access for residents of Greek Row and Zeppos and Rothschild residential colleges. Finally, we will improve the aesthetics of 25th Avenue as a flagship entrance to campus that may include changing the sidewalk and road material to ones similar to the Walk and Roll Loop, increasing the amount of greenery, and adding lamp posts and banners.



Design along 25th Avenue removes the center turn lane to create room for bike lanes.

CIVIL AND ENVIRONMENTAL ENGINEERING
CEE-2

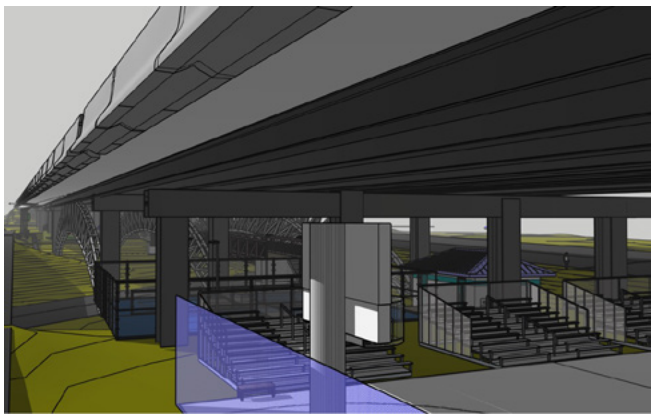
TEAM
Baker Harrington, CE
Alex Holzke, CE
Katie Reed, CE
Rachel Roberts, CE

ADVISERS
Mary McClendon Vavra, ASLA, AICP, Barge Design Solutions, Inc.
Drew Hardison, P.E., Barge Design Solutions, Inc.
Joseph Mayes, Civic Design Center

SPONSORS
Barge Design Solutions, Inc.
Civic Design Center

Breaking down social barriers I-40 imposes on marginalized communities

The placement and construction of the Interstate Highway System has profoundly impacted marginalized and lower socio-economic communities. Neighborhoods find themselves hemmed in by walls of concrete and round-the-clock traffic–isolated from friends, family, services, and opportunities. By reclaiming a small section of an Interstate underpass for public use, providing safe passage for all travel modalities and repurposing unoccupied space, our team is leveraging engineering solutions to mend broken ties and facilitate new ones. A crucial element is the complete overhaul of pedestrian safety and promotion of alternative transportation at and around the site. To encourage community engagement and interaction, the team designed a plaza for food trucks, a pedestrian walking bridge, basketball court, pickleball courts, and a restroom facility. Also, improvements to lighting, sound pollution, and urban blight will further transform a barren underpass into a functional, active gathering space. Our goal is to present a well-thought-out design that either inspires construction of the proposed solution or furthers research toward a more favorable, equitable outcome.



Lafayette Heights basketball court with bleachers (foreground), pickleball court and bathroom (middle ground) and pedestrian bridge crossing Lafayette Avenue (background).

TEAM
Jillian Flynn, CE
Chris Keller, CE
Alyssa Kerscher, CE/Arch
Alexa Mora, CE
Emily Zeller, E.I., CE

ADVISERS
Professor Curtis Byers, CE
Mike Hunkler, P.E., Gresham Smith
Remi Lynch, Civic Design Center
Don Williams, Consultant

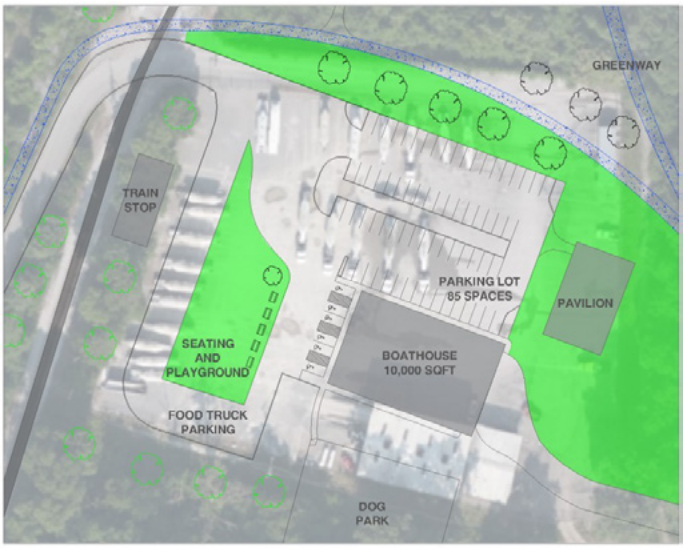
SPONSORS
Gresham Smith
Civic Design Center

CIVIL AND ENVIRONMENTAL ENGINEERING

CEE-3

Wharf Park site design

The Wharf Park project is a 25-acre site south of downtown Nashville zoned for public use and community development. This project is a planning effort designed to redevelop the city-owned vacant plot along the Cumberland River into a usable park space for the surrounding community. It possesses extensive acreage, a unique topography, and shares the remarkable riverfront views characteristic of Nashville's most iconic public spaces. The focus of the design was initially inspired by the lack of river access for recreational rowers. As such, Wharf Park is equipped with a boat house and visitor's center, a boat launch, and a scenic overlook. A scarcity of public spaces influenced the addition of various multiuse recreational facilities such as hard courts, a dog park, trails, and an amphitheater. The technical components of the design were complicated by the drastic elevation changes and the site's location in a floodplain. As a result, the focus was to design the critical components of a steel and concrete structure to connect the elevated pedestrian walkway with the lower portion of the park, the stormwater management systems, and the site grading.



Initial site plan for the park. The development includes a boat house, river access, green spaces, and recreational areas.

TEAM
Lucas Brooks, CE
Kiana Eastman, CE
Lindsey Siebe, CE
Nicole Witherell, CE

ADVISER
Nathan Grosser, P.E., KPFF

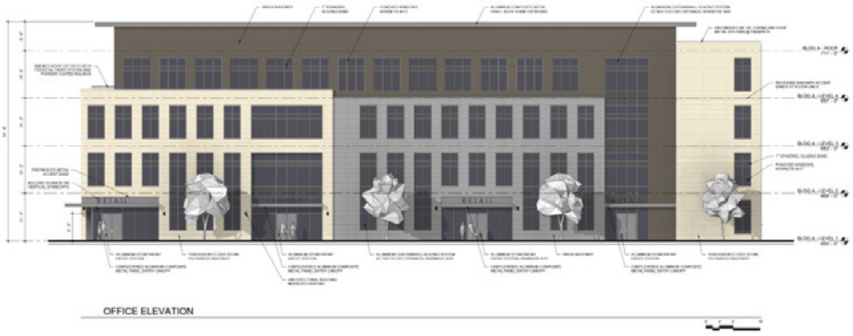
SPONSOR
KPFF Consulting Engineers

CIVIL AND ENVIRONMENTAL ENGINEERING

CEE-4

Steel framed retail and office building

The team created spreadsheets and used structural design software to determine loadings and design structural members for a four-story, steel-framed office building in Mt. Juliet's business district. By using both self-created and professional software, the team was able to compare results and become more familiar with the structural design process. This project helped the team further understand building design from start to finish and the capabilities of structural design software, which is helpful as the members prepare to enter the industry. The team designed the superstructure of the building in accordance with Nashville building codes ASCE 7-16 and IBC-18. The team used the codes and building location, purpose, and surrounding geographic features to determine the gravity and live loads applied to the structure. The loads were used to choose economical and sustainable beams, columns, base plates, and foundation elements. The team compiled calculations for each of the building elements. The goal was to balance material used in the structure and ease of construction to arrive at an economical solution.



Architectural rendering of four-story, steel-framed office building in Mount Juliet, Tennessee.

CIVIL AND ENVIRONMENTAL ENGINEERING

CEE-5

TEAM

Chelsea Middleton, CE
Arman Moazampour, CE
Tonio Reid, CE
Zac Smith, CE
Madi Wilson, CE

ADVISERS

Professor Ghina Absi, CE
Rich Teising, Staff Engineer, CE

SPONSORS

American Society of Civil Engineers, Vanderbilt University Student Chapter
BASF
Carolina Stalite
Irving Materials, Inc.
Norchem Corporation
TN Concrete Association

ASCE Concrete Canoe competition

The Vanderbilt Concrete Canoe team designed a canoe following the requirements of the American Society of Civil Engineers (ASCE) Concrete Canoe competition. The team's main goal is to design and build a canoe that meets minimum competition requirements and earn first place in racing and at least third place in the design category at the 2023 ASCE symposium. For the concrete mix design, the team tested numerous mixes and chose one based on density, strength and workability. The construction process consisted of building a male mold from wood, which mimicked the canoe's exterior shape, and a female mold from burlap and rockite, which covered the male mold. When female mold was removed, three layers of ¼" thick concrete, two layers of basalt mesh, and two foam sections were laid inside. Next steps include 28 days to cure, demolding, sanding, and sealing the canoe, and applying aesthetic finishes. The hull width decreases gradually, allowing for a flatter bottom that will make paddling in a straight line easier as well as improve balance and increase speed, maneuverability and stability.

The concrete canoe in female mold curing with three concrete layers reinforced with two layers of basalt mesh.

ASCE STUDENT CHAPTER Vanderbilt University

CIVIL AND ENVIRONMENTAL ENGINEERING

CEE-6

TEAM

Andrew Pittman, CE
Alphonse Oh, CE

ADVISERS

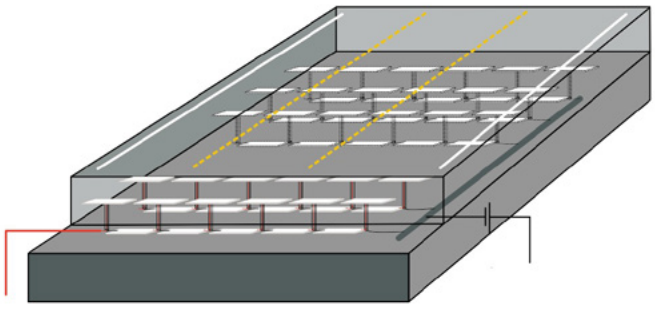
Professor Alan Bowers, CE
Rich Teising, Staff Engineer

SPONSOR

Vanderbilt University School of Engineering

Embedded thermoelectric generator for asphalt pavement

Urban landscapes often experience the worst case heat scenarios due to dark pigmentation and high thermal capacity of asphalt, resulting in waste heat radiation from pavement and structural elements and higher urban temperatures compared to less urban surroundings. It is proposed to reduce asphalt surface tempatures by converting some of the heat absorbed by the asphalt into electrical energy to dissipate the heat and recover useful product, i.e. electrical energy. Conceptually, it is sought to optimize a thermo electric generator (TEG) configuration for paved surfaces. While others have attempted to use the Seebeck effect in this context using prefabricated TEGs, we aim to improve generation rates by increasing the depth differential and heat absorption surface area of the configuration. Thus, with greater generation efficiency, the TEG will remove more heat from paved surfaces and generate electrical energy. Some economic issues faced by the first generation prototype is anticipated. However, we plan to use the most suitable materials available to test the 'best case scenario' for efficiency. Additionally, this will permit data collection and analysis and a comparism to other configurations.



3D cross section of embedded thermoelectric generators in asphalt

School of Engineering

TEAM
Jack Evans, ECE
Benjamin Fahrenkrug, EE
Kenneth Huff, EE
Marina Qian, EE
Nicholas Simpson, EE
Stuart Wodzro, EE

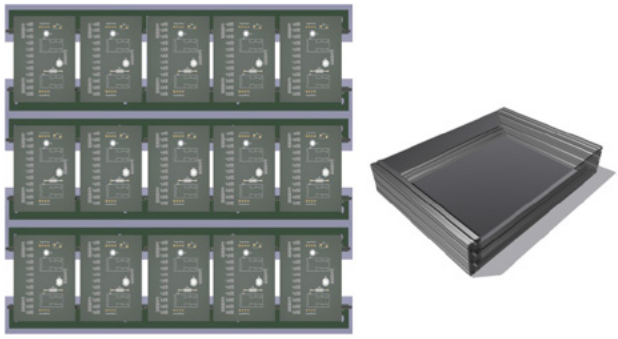
ADVISER
Professor Walter Collett, ECE

SPONSOR
Vanderbilt University School of Engineering

ELECTRICAL AND COMPUTER ENGINEERING
ECE-1

Portable demonstration device for digital system concepts

Digital Systems is a required course for ECE and CS majors where students often encounter learning difficulties due to the microscopic size of digital circuits. Our project realizes core concepts of combinational and sequential logic at a macroscopic scale. This facilitates learning by improving the visibility of digital logic concepts. Our device is a portable enclosure that is visible for an entire class, using relay logic to meet visibility requirements. The enclosure hosts a power delivery system for reconfigurable gate printed circuit boards (PCBs) designed with relay logic. The device allows users to create digital circuits to demonstrate sequential and combinational logic by connecting PCBs via jumper cables. We designed a control PCB that contains switches and buttons for inputs and LEDs and a buzzer for outputs. Additionally, we designed two types of gate PCBs. The first is a universal gate PCB that allows one to create Inverter, NAND, NOR, and XNOR gates by configuring jumper connections. The second is a D-Flip-Flop PCB for creating sequential circuits. Both boards contain LEDs, safety fuses, and input and output connections.



Left, an initial prototype rendering of gate module PCBs plugged into the power rail system. Right, a 3D view of the CAD design for the enclosure that will house the power rail system and gate PCBs.

School of Engineering

TEAM
Carter Bell, ECE
Dylan Geiger, EE
Kristi Kim, ECE
Daniel Negash, CompE
Trenton Singleton, EE

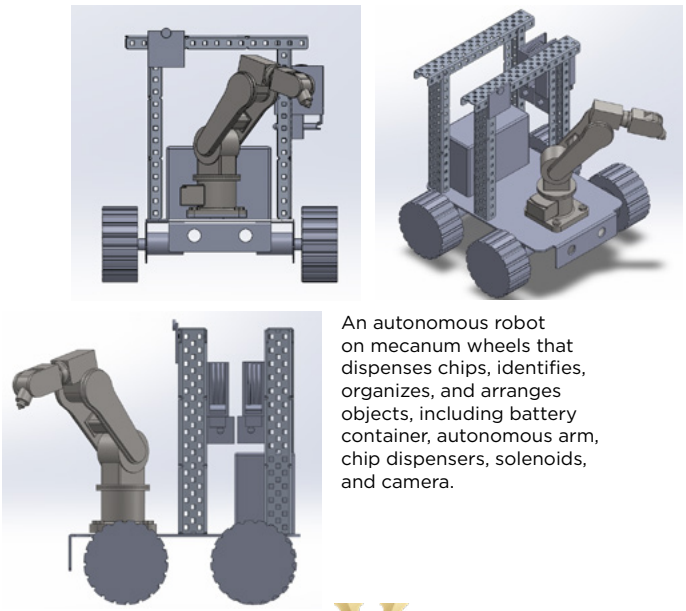
ADVISERS
Charles Gerrity, ECE
Professor Walter Collett, ECE

SPONSOR
Vanderbilt University School of Engineering

ELECTRICAL AND COMPUTER ENGINEERING
ECE-2

IEEE 2023 SoutheastCon robot design

The Institute of Electrical and Electronics Engineers (IEEE) holds a SoutheastCon Hardware Competition annually for university teams. This year, teams are to create an autonomous robot capable of completing multiple tasks in a timely manner. Our robot will be placed in a playing field simulating a theme park recently hit by a hurricane. The robot will need to move stranded rubber ducks back to their pond, dispense food in various sections of the park, recycle debris, and activate a virtual fireworks display all within 3 minutes. The robot will receive a score based on how many tasks are completed. Our team created a high-level robot design following an in-depth look at the competition specifications and scoring system. On the hardware side, various components, such as a robotic arm and chassis, are being constructed and integrated into one cohesive robot. On the software side, a computer vision model is being developed to allow the robot to navigate the playing field. Additionally, each robot's component is being programmed to complete the tasks.



An autonomous robot on mecanum wheels that dispenses chips, identifies, organizes, and arranges objects, including battery container, autonomous arm, chip dispensers, solenoids, and camera.

School of Engineering

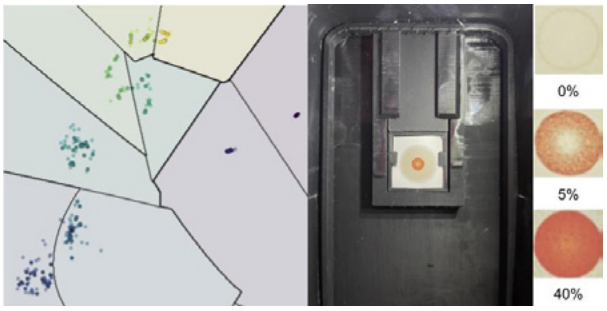
ELECTRICAL AND COMPUTER ENGINEERING
ECE-3

TEAM
Axel Irikungoma, ECE
Laurent Lochard, EE
Abdullah Nassar, ECE
Zachary Ritholz, ECE/Hist
Ben Van Sleen, ECE/Econ

ADVISER
Professor Andrea Locke, BME

SPONSOR
Locke Biosensing Lab,
Vanderbilt University
School of Engineering

Few-shot image classification for low-resource sickle cell disease diagnosis



The algorithm discriminates between different percentages of sickled blood after taking a raw image and cropping out casing to leave only the blood sample.

Sickle cell disease is a debilitating blood disorder affecting over 4 million people, predominantly in developing nations. The team designed a machine-learning model and Android application that, when combined with a separately developed physical device, can determine the proportion of sickled hemoglobin in an individual with high accuracy at extremely low cost. This diagnostic can be used to determine if a patient has symptomatic sickle cell disease or is a genetic carrier. The algorithm takes a raw image from the device, crops it to contain only the region containing the blood sample, and performs a novel image processing pipeline to dramatically reduce dimensionality (while retaining much of the variance) before making final predictions using a support vector machine. Unlike state-of-the-art deep learning approaches, this form of image-based machine learning can be trained with just a couple hundred domain-specific images (instead of millions). We predict this model architecture can achieve a classification accuracy 94% to 97% in production. The model will be deployed in both an Android application and in a Raspberry Pi. Better still, because the model is not demanding of hardware; there remains opportunity to significantly reduce production costs through the use of smaller microcontrollers.

School *of* Engineering

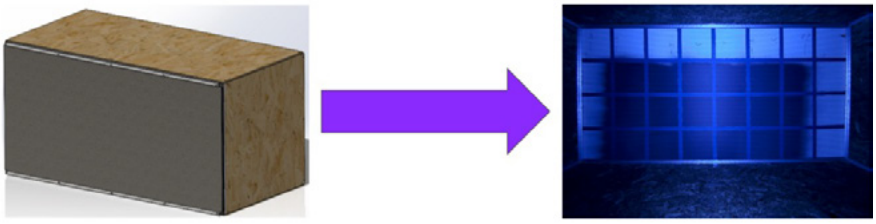
ELECTRICAL AND COMPUTER ENGINEERING
ECE-4

TEAM
Ben Shani, EE
Conrad Jensen, EE/Math
Lionel Tesi, ECE

ADVISER
Nick Hegeman, PaintJet

SPONSOR
PaintJet

Optical wet paint thickness heat map



A capture from our test rig showing the UV intensity used for data normalization.

Paint thickness currently is measured manually using special metal cards, which is laborious and requires thousands of samples to achieve meaningful resolution. Our goal is to measure wet paint thickness by taking photographs under special lighting conditions. The images are taken and analyzed as paint is applied to determine thickness in real time. This provides an automated way to verify paint has been applied to paint manufacturer specifications and to correct any mistakes. To create a correlation between an image and paint thickness, a data set of wet paint images with known thicknesses is collected. This data is gathered in the controlled environment of our test rig under similar conditions to the practical application. We expect to be able to measure paint thickness +/- 0.005" within 5 seconds of taking a photo.

PAINTJET

TEAM
Edwin Campbell, CompE
Alexandre Dixneuf, ECE/Math
Bryan Nicholson-Dews, CompE

ADVISERS
Matt Schneller, TM TKO
Alex Durgin, TM TKO

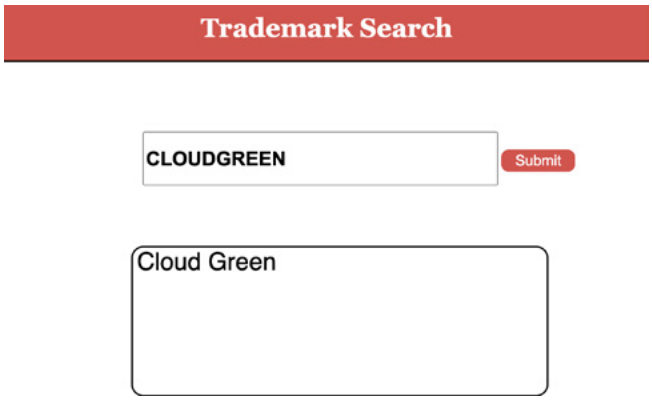
SPONSOR
TM TKO

ELECTRICAL AND COMPUTER ENGINEERING

ECE-5

AI compound term decomposition

TM TKO provides easily accessible trademark research tools. TM TKO is looking for alternative ways to evaluate whether terms in marks are "compound" terms that should be split (e.g.CLOUDGREEN into CLOUD and GREEN) or intentional misspellings or neologisms that should not be split. The team is developing a new algorithm to find the most probable term(s) from a provided input, while preserving the total execution time profile. The algorithm first detects what language or languages are being used, reducing the collection of words to check to only the specified language. The team has developed a prototype model employing this strategy and continues to experiment with other methods. The team expects to eventually surpass the speed of the company's current algorithm.



Web application showcasing output of improved trademark algorithm

TM TKO

TEAM
Zakariyya Al-Quran, CompE
Adam Benevento, CompE
Patrick Darmawi-Iskandar, ECE

ADVISERS
Alex Durgin, TM TKO
Matt Schneller, TM TKO

SPONSOR
TM TKO

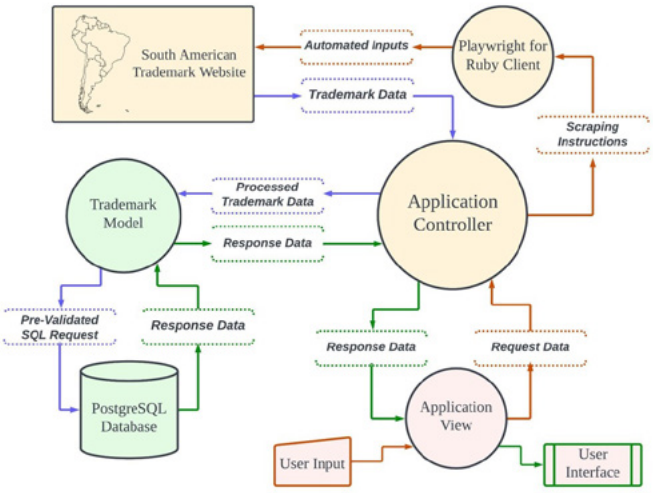
ELECTRICAL AND COMPUTER ENGINEERING

ECE-6

Automating international trademark data acquisition

TM TKO provides legal services for organizations holding or seeking trademarks, including tracking and analyzing foreign trademark registrations. Intellectual property offices from each country typically publish trademark data in the form of a searchable web database or scheduled PDF document releases. The structure of these databases can vary and cannot easily be queried together. The goal is to build a Ruby on Rails application that collects, organizes, and stores trademark data from several South American countries. The application uses Playwright for Ruby to interact with the websites and collect the information from JSON messages, HTML, and PDF documents. Due to the varied nature of the websites, a unique Playwright script is used to collect the data from each country. Raw data is processed and cleaned, then stored in a single PostgreSQL relational database. Ultimately, the program will be integrated with existing TM TKO software for collecting trademark data from other countries.

TM TKO



This diagram shows the flow of data through the application when a user requests the collection of new data. The Application View controls the user interface, accepting the user input and displaying results. The Application Controller controls interaction with each other component and processes the raw data. The Trademark Model handles all interaction with the database, allowing for database changes to be made without updates to the Application Controller or View.

ENGINEERING SCIENCE
ES-1

TEAM
Alexandra Kusio, ES
Avery Smith, ES
Andrew Utesch, ES
Leqi Yin, ES

ADVISER
Professor Courtney Johnson, GE

SPONSOR
Airport Cooperative Research Program (ACRP)

Airport management design competition

The Airport Cooperative Research Program (ACRP) hosts an annual research and design competition challenging teams of university students to explore and offer a solution to a problem threatening the world's airports. One such problem is inefficient fuel consumption by airlines as an airplane taxies from its designated gate to its designated runway, or from its runway to its gate. For example, a 15-minute taxi in a Boeing 747 burns around one ton of fuel, which equates to roughly $800 at current aviation fuel prices. Therefore, decreasing inefficient fuel consumption during taxies can save airlines millions of dollars annually, help airports shorten their taxi times and improve their overall customer experience. The team's research and solution will offer a unique proposal as well as a cost-benefit analysis and suggested implementation plan to gradually decrease inefficient fuel consumption on a large scale.

Restructuring gate assignment based on a gate's proximity to an airplane's runway shows a promising ability to decrease airplane taxi times and, coincidentally, airplane fuel consumption.

ACRP AIRPORT COOPERATIVE RESEARCH PROGRAM

ENGINEERING SCIENCE
ES-2

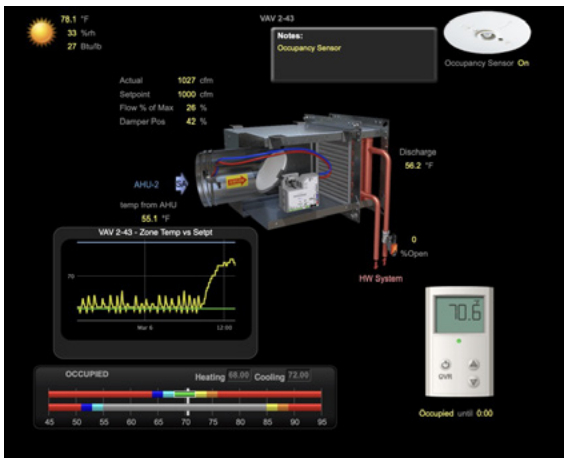
TEAM
Owen Boersma, ES/Econ
Xeria Keys, ES
Alek Sherstyuk, ES/Math

ADVISERS
Mark Harrington, Facilities Department
Jonathan Edwards, Facilities Department
Damon Varble, Facilities Department
Bret Campbell, Facilities Department

SPONSOR
Vanderbilt University Facilities Department

Campus HVAC control strategy

Vanderbilt University is committed to grow energy efficiency savings. The goal of this project is to determine the most efficient control strategies for heating, ventilation, and air conditioning (HVAC) in various campus settings using current automated systems. Given the historic architecture present on campus, many buildings have varying levels of automation infrastructure, much of which has not been optimized. Thus, there are opportunities to boost energy efficiency by implementing new HVAC controls. By experimenting with new parameters, current infrastructure, and various manual imitations of non-implemented infrastructure, the team looks to make recommendations for optimized logic controls and potential hardware investments. Through a partnership with the Vanderbilt University Facilities Department, this project will bring Vanderbilt closer to achieving its FutureVU sustainability goals and reduce energy expenditure costs, while maintaining environmental comfortability on campus.



Metasys Automated Control software interface is used to interact with, monitor, and control environmental conditions on campus through existing HVAC infrastructure.

VANDERBILT UNIVERSITY

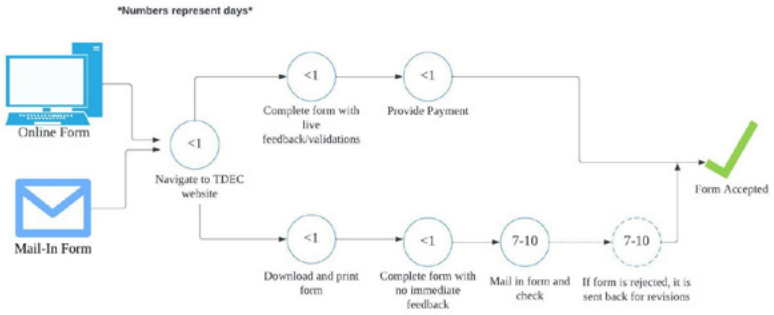
TEAM
Conrad Hansen-Quartey, ES
Simon Michael, ES
Philip Alexander Mills, ES/ENGL

ADVISERS
Vojin Janjić, Tennessee Department of Environment and Conservation
Bryan Pope, Tennessee Department of Environment and Conservation

SPONSOR
Tennessee Department of Environment and Conservation, Division of Water Resources (TDEC-DWR)

ENGINEERING SCIENCE
ES-3

Conversion of water quality state operating permit paper application to an electronic system



TDEC-DWR is digitizing its CN-1251 state operating permit application form so applicants may submit the form online.

Currently, the TDEC-DWR receives 150 CN-1251 permit applications each year. This form must be obtained by anyone in the state of Tennessee (individual, property owner, corporation, etc.) who operates a sewage treatment system that does not have a direct discharge to any surface or subsurface waters. The goal of this project is to digitize the CN-1251 form using TDEC's existing online portal so customers may submit their applications online instead of by mail. Digitizing the CN-1251 form will modernize the submission process, make it more time-efficient, and provide the customer with live feedback and integrated guidance to ensure that the form is completed correctly. Over the course of this project, our team intends to do in-depth research on web form design, as well as conduct an analysis of past CN-1251 permit applicants in order to gain a richer understanding of TDEC's clientele.

TN Department of Environment & Conservation

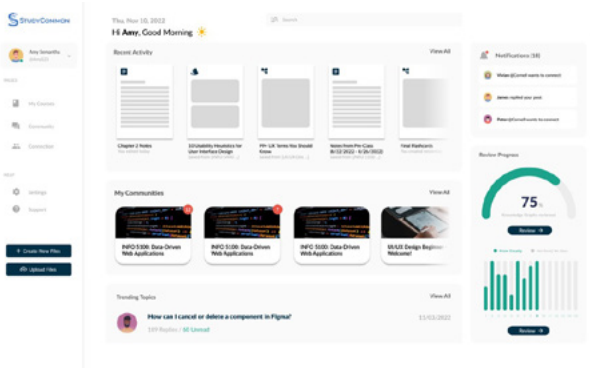
TEAM
Tariq Bolden, ES
Lorena Cruz, ES/CD
Imad Faqih, ES
Joe Hommrich, ES

ADVISERS
Casey Ward, StudyCommon
Andrew Ward, StudyCommon

SPONSOR
StudyCommon

ENGINEERING SCIENCE
ES-4

Focus groups and expansion of the StudyCommon EdTech application



The dashboard design includes proposed changes based on feedback from users.

StudyCommon is a startup working on redesigning the beta version of their study app. StudyCommon is designed to revolutionize the way students study with customized learning tools and interactive neuroscience-backed study techniques while building communities of learning. The app incorporates machine learning and AI to process course materials and create custom self-testing sessions leading to better knowledge retention and improved outcomes. The company's goal is to conduct focus groups and interviews with university undergraduates and professors to gather feedback on the redesign that will drive the implementation of new features of the app and improve user experience, as well as strategizing entry methods to other markets using a business-to-business model. Recent feedback has helped identify hesitancies with using the app as well as new ideas for continuous improvement.

StudyCommon

ENGINEERING SCIENCE
ES-5

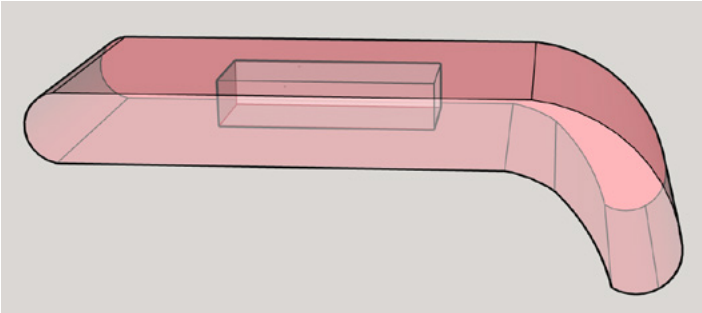
TEAM
Jonah Haffner, ES
Xavier Kahn, ES
Max Kirimi, ES
Andy Mathis, ES

ADVISER
Professor Courtney Johnson, GE

SPONSOR
The Product Development and Management Association (PDMA)

Global Student Innovation Challenge powered by PDMA

The goal of the Global Student Innovation Challenge, powered by the Product Development and Management Association (PDMA), is unique in that it encourages and supports students developing novel, real-world offerings that include products, software, or services. The team is working to optimize the magnetic clip design that has been the incumbent solution for holding a wet paintbrush to a paint can when a painter is taking a break. The main elements of the design include a double-sided magnet to connect to the paintbrush and can, a curved end to angle the paintbrush downwards into the can, and a paint can opener. In addition to creating a product prototype, the team is looking to decrease the solution cost to be competitive in the market.



The product will facilitate holding a paintbrush onto a paint can without a clipping mechanism. The final design will include a way to open a paint can as well as connect itself magnetically to the steel wrap of a paintbrush and the rim of a paint can.

ENGINEERING SCIENCE
ES-6

TEAM
Lannawill Caruth, ES
Sophia Fein, ES/Econ
Jiachen(Annika) Xu, ES/Soc
JunYi(Evelyn) Zhu, ES/Econ

ADVISERS
Eric Bartlett, Booz Allen Hamilton
Bryana Wilson, Booz Allen Hamilton
Rojae Johnson, Booz Allen Hamilton

SPONSOR
Booz Allen Hamilton

Semi-autonomous distributed mesh framework for versatile drone usage

Drones, or unmanned aerial vehicles (UAVs), offer versatile and affordable solutions across various fields. Despite the versatility of a drone, one major drawback is the lack of one framework that serves the needs of multiple industries. We aim is to provide a modular solution that can leverage advanced technologies to fill multiple purposes without significant rework on the user's part. The challenge is to provide a viable cost-benefit and feasibility analysis for developing a multiuse, semi-autonomous distributed mesh framework. The framework components include the drone (aerial, sensor-mounted, ground, or sea), the ground station, a mesh/swarm network, AI, and potential cyber influences. This project encompasses the analysis, research, and design of potential business cases, architectural/technical requirements, and cost analysis for developing a semi-autonomous distributed mesh framework.

The four business cases being investigated for the semi-autonomous distributed mesh framework include infrastructure inspection, agriculture mapping and wildlife monitoring, public safety, and supply chain management.

TEAM
Sophia Clark, ES
Nathan Mjema, ES
Harrison Rogers, ES
Marina Shi, ES

ADVISER
Christopher Abiodun, TrakRx LLC.

SPONSOR
TrakRx

ENGINEERING SCIENCE
ES-7

Smart pill bottle cap for tracking medication adherence

Patient adherence with their medication is a major problem in the health care system. This lack of adherence is costing many people their good health and the health care system billions of dollars. Our project goal is to enhance the current design of TrakRx's smart pill bottle cap to create a marketable model that detects, measures, and counts medication. The design includes a content counter to track of the number of pills administered and remaining, and a biometric locking mechanism that controls a patient's access to their medication. Additionally, the cap is designed to sync to a mobile application so patients can receive reminders to take their medication, view dose history, remaining pills, and locate their pill bottle if they misplace it. Overall, this project aims to combat some of the common causes of medication non-adherence, in addition to prioritizing a data-driven health care model.

The novel pill bottle cap adapts to all pill bottle sizes and monitors pill count for patient adherence through revolutionary wired technology.

TrakRx

MECHANICAL ENGINEERING
ME-1

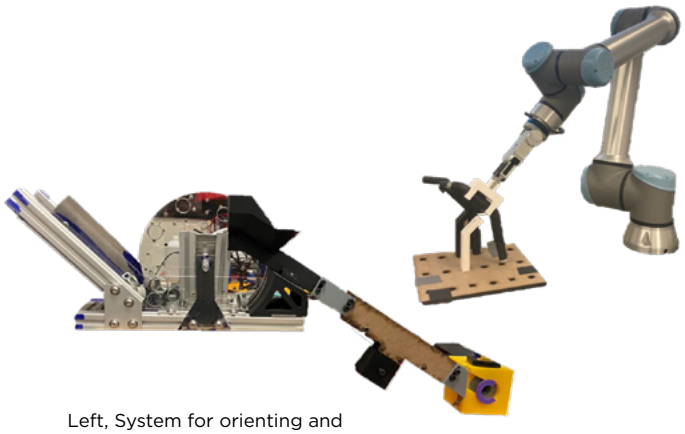
TEAM
Khattab Ahmed, ME
Josh Assef, ME
Alice Byrnes, ME/Math
Chey Sirota, ME
Eric Zhang, ME

ADVISERS
David Blaylock, Nissan North America
Bryan Meadows, Nissan North America
Derrick Young, Nissan North America

SPONSOR
Nissan North America

Nissan hose clamp automation project

The goal of this project is to automate the process of presetting hose clamps onto hoses to streamline engine installation at the Nissan Smyrna assembly plant. This process is currently done by a single person performing a repetitive process with aging machinery. The new process will run automatically by orienting clamps in two stages. First, a vertical magnetic hopper dispenses clamps into a chute, and a dispenser helps rotate and insert clamps into the opening mechanism at a controlled rate. The mechanism is then powered by a stepper motor that pushes the prongs of the clamp together, opening it wide enough to have a hose inserted. While this process is happening, a collaborative robot is picking up a new hose from a pallet. The pallet constrains the hoses in a defined position to remove variability from the system. The robot then inserts a hose from the pallet into the mechanism, which releases the clamp onto the end of the hose. The robot rotates the hose and repeats the process on the other end, and the product is complete.



Left, System for orienting and dispensing hose clamps and (right) UR10e robotic arm and mechanism putting the hose clamps onto the hoses.

MECHANICAL ENGINEERING
ME-2

TEAM
Gehrig Abbattista, ME
Paul Abdelmessih, ME
Andy Haworth, ME
Randy Kim, ME
Tre' Sands, ME

ADVISER
Dr. Christy Halbert, Boxing Resource Center

SPONSOR
Boxing Resource Center

Light-based target training tool

A key component to the sport of boxing is reaction time, properly reading and responding to the actions of the opponent. Typically, these critical skills can be practiced with a coach or against a sparring partner. However, during times when the gym is crowded or when training at home, this becomes difficult. The team is developing a modified reflex bag to address this problem. Our new device has LEDs embedded beneath the surface that will flash random colors at random intervals. Each color corresponds to a different move which the boxer should respond to. The unpredictability of the flashes enables the boxer to practice reacting to an opponent rather than deciding on the move themselves. Additionally, an accelerometer inserted inside the bag adds punch detection capabilities, providing instant feedback on the boxer's timing and speed. The device is durable, proved by strength testing all materials and protecting the electronics. It is also intuitive to use, featuring an easy-to-use control box that can be operated while the boxer has gloves on.

The new reflex bag contains embedded LEDs protected by light diffuser channels and surrounded by protective padding with system microcontroller to allow for customized user settings. Inside the reflex bag is a 3D-printed core with housing for an accelerometer to allow for custom user feedback.

TEAM
Muhammad Elezabi, ME
Keegan Fong, ME
Aleksander Lucy, ME
Isabel Peppard, ME
Praful Sigdel, ME

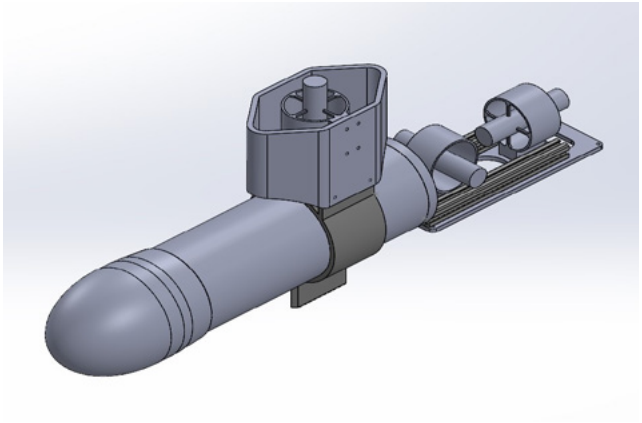
ADVISERS
Adrian Perez, Booz Allen Hamilton
Rojae Johnson, Booz Allen Hamilton
Eric Bartlett, Booz Allen Hamilton

SPONSOR
Booz Allen

MECHANICAL ENGINEERING
ME-3

Low-cost autonomous modular submersible

Autonomous underwater vehicles provide unique benefits compared to traditional manned vessels as they are used in numerous commercial, industrial, and research applications. However, current barriers of cost and complexity prevent these vehicles from being used by the average consumer. This project aims to resolve these issues by creating a cost effective and easily assembled submersible. We concentrated on the hull, the propulsion systems, and the internal electronics. With user customizability and modularity in mind, the hull is composed of easily accessible components such as PVC, as well as utilizing cost-effective 3D printing to manufacture parts. Implementation of a high-powered, multi-axis propulsion system provides high maneuverability and fine vehicle control, while application of a popular, commercially available controls system allows for user customization and the ability to easily integrate external sensors to the vehicle. With high functionality and a total cost of around $500, our final product provides an innovative addition to the growing field of autonomous underwater vehicles.



The streamlined hull design consists of a cylindrical base with a custom developed nose cone. Rear thrusters mounted to a plate provide a full plane of control, while a mounted dorsal thruster connected to the hull by a 3D printed collar provides the vehicle's depth control.

Booz Allen

TEAM
Matthew Grunzweig, ME
Kaelon McNeece, ME
Rilwan Shittu, ME
Gavin Yun, ME

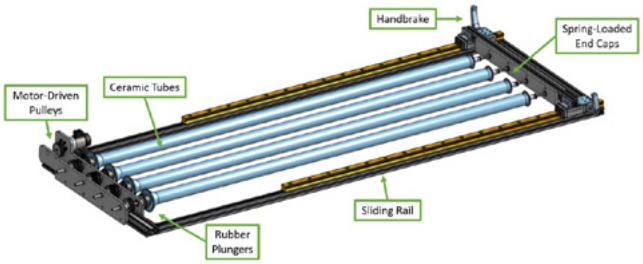
ADVISER
Jesse Li, Utility Global

SPONSOR
Utility Global

MECHANICAL ENGINEERING
ME-4

Mechatronic design/build of a hydrogen generation spray machine

Utility Global recently has developed a novel process to mass produce clean hydrogen. The current process involves coating ceramic tubes with a proprietary ink that facilitates the production of hydrogen. This process is time consuming and labor intensive, which will only further compound as the company scales production. The team's goal is to automate the tube spraying process to increase production feasibility. The team built a large chassis containing an ink spray nozzle called the UltraSpray in which a tube rack can pass through and be sprayed within a closed environment. The primary design objective was to build a tube rack to concurrently rotate four ceramic tubes that would safely pass through the UltraSpray. Additional design features include accommodations for variation in tube length and diameter, easily adjustable rotation speed control, and support for at least three continuous hours of operation. The system is a reusable support structure that yields even ink coatings along the surface of any ceramic tube mounted within it to help expedite the production of this sustainable energy source.



The tube rack is the central focus of the project. Tubes rotate as a separate spray nozzle coats them with a proprietary ink to facilitate the mass production of clean hydrogen.

UTILITY

MECHANICAL ENGINEERING
ME-5

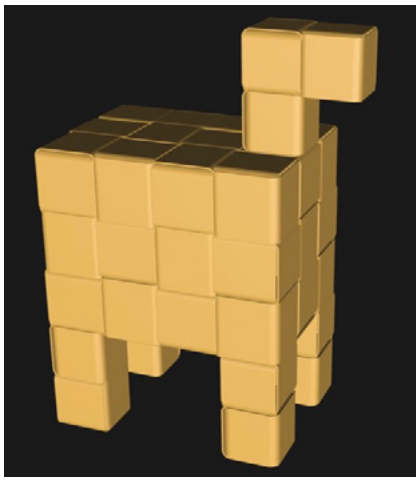
TEAM
Nora Ait Boucherbil, ME
Adam Fortner, ME
Gabrielle Small, ME
Sam Torres, ME

ADVISERS
Deanna Romanello, Nashville Zoo
Sarah Kriebel, Nashville Zoo

SPONSOR
Nashville Zoo at Grassmere

Firehose ungulate enrichment device for the Nashville Zoo

The Nashville Zoo tasked the team with creating an enrichment device of firehose to help better stimulate natural behaviors of its Sumatran tigers and Andean bears. Animals in human care receive enrichment to encourage natural behaviors. Zoos provide enrichment devices such as toys, scents, and novel stimuli to help engage animals mentally and physically. For tigers and bears, these behaviors include attacking, pouncing, biting, and dragging prey. The solution was to construct a device by weaving firehose into a model resembling a natural ungulate to appear like their prey while also remaining safe for the carnivores and zookeepers. Some safety considerations include: no exposed bolts, no holes in the firehose weave, no hanging strips that limbs can be snagged on, and a weight limit of 200 lbs. The design weighs 140 lbs. and is roughly four feet tall and five feet long. The team also will provide a step-by-step instruction manual on how to replicate a firehose ungulate. The ultimate goal is for the device to last multiple years and help the animals better connect with their innate instincts and behaviors.



Model of the ungulate, woven out of durable firehose with a schedule 80 PVC frame and no gaps or exposed bolts to provide enrichment and safety for the Sumatran tigers and Andean bears at the Nashville Zoo.

MECHANICAL ENGINEERING
ME-6

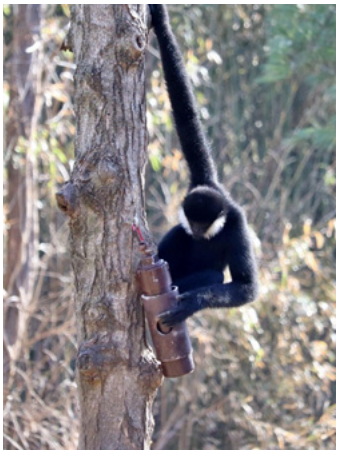
TEAM
Lauren Chang, ME
Andy Du, ME
Erin Frankland, ME
Lauren Grohowski, ME/CSET
Mason Schmidt, ME

ADVISERS
Brittany Canfield, Primate Supervisor, Nashville Zoo
Whitney Roman, Primary Keeper for Gibbons, Nashville Zoo

SPONSOR
Nashville Zoo at Grassmere

Primate food delivery and enrichment device for the Nashville Zoo

The Nashville Zoo is home to two species of endangered primates: white-cheeked gibbons and siamangs. In the wild, these animals are primarily motivated by food, and forage extensively for leaves and fruits. In a zoo environment, they are fed by a series of easily manipulated devices left on their island exhibit. This results in overeating and eating too quickly, leaving the primates to develop unnatural habits since they do not forage for food. To promote natural behavior, we developed four enrichment devices to occupy the primates throughout the day. Two of these devices are puzzle-based feeders to challenge the primates intellectually by requiring multiple schemas of manipulation, forcing greater engagement between the primate and the device to reach the food. Another feeder uses ice as a timing mechanism to delay food release throughout the day. The final device is a slow-release feeder that forces the primates to engage with a lever, scattering the food to promote foraging. Each of these devices aims to provide the primates with novel forms of enrichment.



White-cheeked gibbons at the Nashville Zoo were given the opportunity to interact with our collar puzzle feeder, one of our four enrichment devices. This PVC feeder successfully created fruitful and prolonged interaction with the primates. (Photo: Taran Magee)

TEAM
Steven Cermeno, ME
Riley Deutsch, ME
Sebastian Harkness, ME/Math
Niav Layton, ME
Mariana Smith, ME

ADVISER
Chris Hornsby, Cumberland River Compact

SPONSOR
Cumberland River Compact

MECHANICAL ENGINEERING
ME-7

Tree conveyor system to deliver 500,000 trees

Cumberland River Compact has launched a Root Nashville campaign to deliver 500,000 trees by 2050 to the city of Nashville. Root Nashville has found it difficult to maintain an even load distribution on their trailer as they distribute trees. Unbalanced trailer loading results in increased wear on the rear tires as well as safety issues due to vehicle dynamics. Our tree conveyor system allows Root Nashville to redistribute the trailer weight in a safe, efficient and easy manner. The core design elements include custom platforms to hold trees with HDPE glides to reduce friction, a rail system that acts as the conveyer, and magnetic pin locking mechanisms on each platform. Our solution reduces the force required to move the trees, allows for movement of multiple trees at once, and creates a more organized loading and unloading process. We anticipate our rail system will require less volunteer labor for Root Nashville, increase rear tire lifespan, and lead to safer weight redistribution on the trailer.

Each platform is intended to hold 11 trees positioned in the custom designed slats with glides to lower the force for moving platforms and a locking system to hold the platforms securely to the trailer. This system aims to help increase the safety and lower the cost to deliver 500,000 trees.

TEAM
Thomas Dintino, ME
Ava Minarovic, ME
Michael Sardella, ME/Econ
Sophia Viner, ME

ADVISERS
Matthew Bays, Ph.D., Naval Surface Warfare Center
Professor Jason Mitchell, ME

SPONSOR
Naval Surface Warfare Center - Panama City Division

MECHANICAL ENGINEERING
ME-8

Vanderbilt modular and portable underwater vehicle for NAVSEA

Vanderbilt Underwater Vehicles (VUV) is working with the Naval Surface Warfare Center (NSWC) Panama Division to develop modular, and easily transportable unmanned underwater vehicles (UUVs). These UUVs have high-risk roles in Naval operations including mapping underwater terrain, and seeking and destroying underwater mines. Currently, the UUVs that carry out these missions are up to 8 ft long with weights around 150 lb. Navy UUVs have undisclosed prices, but commercial ones have price tags starting around $4,000. Due to the high-risk nature and increasing demand for underwater missions, it is beneficial for UUVs to be rapidly deployable and easily replaceable. VUV focused on developing low-cost, easily transportable, and easily manufactured UUVs by leveraging rapid prototyping technology, testing inexpensive means of waterproofing, and designing unique magnetic couplings. With these techniques, VUV aims to create a completely controllable and waterproof UUV with detachable fins and nose cone for modular capabilities.

An assembly drawing of the Vanderbilt unmanned underwater vehicle system, including the key features of detachable fins, a PVC body, and a modular nose cone.

MECHANICAL ENGINEERING
ME-9

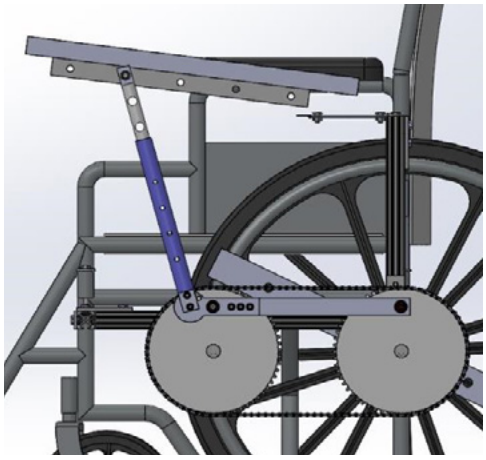
TEAM
Derek Mulholland, ME
Myles Nowak, ME
Cameron Thomas, ME
Lia Vargas, ME

ADVISERS
Justin Stehr, OTR/L, CHT, WCC, CEAS, CPAM, Department of Plastic Surgery, VUMC
Manny Fitzgerald, Mechanical Engineer

SPONSOR
Vanderbilt University Medical Center

Stroke rehabilitation device for upper extremity patients

Every year in the U.S., 800,000 people suffer strokes and 80% of them lose arm mobility. Therapy sessions are often not enough for a stroke patient to quickly regain neuromuscular functionality and joint mobility. The goal of this project is to redesign an adjustable attachment for mainstream wheelchairs that allows for functional, repetitive motion of the upper extremity. The prototype uses a standard wheel chair with a custom chain and sprocket transmission to transfer wheel motion to an arm rest via a a six-bar linkage system. The system mimics reaching forward and stimulates the movement of the shoulder and elbow joints, allowing the arm to experience 5 inches of lateral movement and 20 degrees total motion above and below the horizontal. The mechanism is sleek enough to allow the wheelchair to move through standard doorways and includes a padded and strapped armrest with enclosed moving mechanisms for user comfort and safety. The solution allows for horizontal and vertical movement of the arm and a reduction in friction with the chain and sprocket transmission.



A stroke rehabilitation system attached to a standard wheelchair driven by a chain and sprocket transmission. This system allows arm movement to promote healing, joint functionality and mobility.

VANDERBILT UNIVERSITY MEDICAL CENTER

MECHANICAL ENGINEERING
ME-10

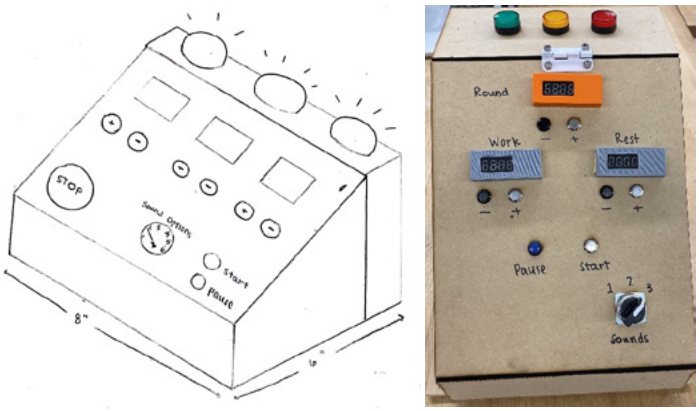
TEAM
Christopher Jang, ME/CS
Brendan Kornatz, ME
Sydney Marohn-Johnson, ME
Reed Stasko, ME

ADVISER
Dr. Christy Halbert, Boxing Resource Center

SPONSOR
Boxing Resource Center

Timing system for Boxing Resource Center

The timing system at the Boxing Resource Center needed a complete update. It used a manually controlled stopwatch, bell and hammer system to alert the boxers to the time remaining remaining. When multiple matches are going on, the sound of the bell led to confusion among the boxers, referees and spectators. Our sponsor wanted a system that would display the timing for the round, total round numbers, and resting time and that would automatically deliver all the necessary information through displays, LED lights and sounds. Our solution is a simple micro controller based design with all screens and functions easily laid out for the user to time the boxing match or training session accurately and efficiently. The new system allows for less confusion between the boxers and has greater functionality so the system can be used in multiple settings within the gym allowing for a more versatile timing system for all.



Left, concept drawing. Right, working prototype. The custom timing system includes a Raspberry Pi microcontroller, LCD display screens for the round display, work and rest periods, incrementing and decrementing timing controls for each display, LED status lights for quick activity indicators, a sound system, an emergency pause/stop button and an audio output sound selection control.

BOXING RESOURCE CENTER

TEAM
Garrett DiRienz, ME
William Drake, ME
Andrew Fish, ME
Adam Levin, ME

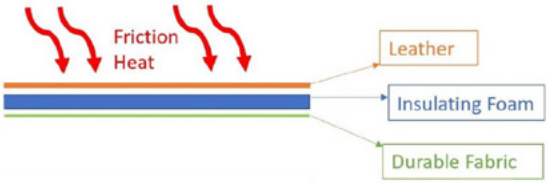
ADVISER
Craig Kuphall, Civil-Military Innovation Institute Inc.
Scott Homer, Civil-Military Innovation Institute Inc.

SPONSOR
Civil-Military Innovation Institute Inc.

MECHANICAL ENGINEERING
ME-11

United States Army fast rope insertion gloves

1



2

(1) A completed fast roping glove and (2) the exploded view of material layers and direction of friction heat that will travel into the glove.

The United States Army fast rope insertion teams conduct missions where soldiers rappel out of helicopters into combat zones. The standard issue gloves are ineffective at mitigating the heat caused by the frictional contact with the rope and they are too bulky to perform combat maneuvers like safely operating a rifle. To perform key dexterous tasks in the field, soldiers must swap fast roping gloves with combat gloves. Additionally, the alternative fast roping gloves that some soldiers choose to purchase can cost more than $100. Our goal is to produce a low-cost pair of gloves with better thermal insulation that can still maintain high dexterity for combat situations. Our glove construction method quilts heat-resistant foams between the exterior leather and interior fabric of the glove. This practice improves traditional all leather gloves providing more heat protection. In the future, the materials and construction method will be presented to the Army to provide a safer fast roping glove option that can be affordably mass-produced.

CIVIL~MILITARY INNOVATION INSTITUTE

TEAM
Eric Holst, ME
Matthew McGown, ME
Andrew Noonan, ME
Edward Wedgbury, ME

ADVISER
Professor Amrutur Anilkumar, ME

SPONSOR
Vanderbilt Aerospace Design Laboratory
NASA

MECHANICAL ENGINEERING
ME-12

Rocket with autonomous camera payload for RF command imaging

The tail section design is imposed next to the landed configuration after a full-scale launch. The tail is supported above the ground after landing. The camera bay rotates to extend the key camera and antenna upwards. After extension, the camera receives commands and swivels to image its surroundings.

The Vanderbilt Aerospace Design Laboratory has designed and built a reusable rocket that carries a payload to compete in the 2023 NASA University Student Launch Initiative. The rocket flies 4,500 feet before descending under drogue and main parachutes. The payload is a robust system that, upon landing, receives radio frequency (RF) commands to autonomously control three cameras. Several subsystems support this mission. Upon landing, the parachute is detached to prevent the payload from being dragged by the wind. A passive leg deployment system raises the payload section above the ground. This allows for the camera bay to rotate such that the key camera can lift upward. After receiving RF commands with two antennas, the camera raises itself out of the vehicle with a five-stage pulley system to clear ground obstacles. The camera levels itself to the ground and then performs the received mission. Possible commands include taking photos, rotating the camera, and applying image filters. A secondary payload uses four actuated wings to alter vehicle aerodynamics, enabling greater control over trajectory and altitude targeting.

Design and project faculty

**Biomedical Engineering,
Chemical Engineering,
Civil and Environmental Engineering,
Electrical and Computer Engineering,
Engineering Science, and
Mechanical Engineering**

We take great pride in recognizing these faculty members who are the core of our design program in their respective departments. Their outstanding contributions and excellence as instructors, advisers and mentors have led to the work demonstrated on Design Day, April 24, 2023.

JASON MITCHELL
Assistant Professor
of the Practice of
Mechanical Engineering

WALTER COLLETT
Professor of the
Practice of Electrical
and Computer
Engineering

MARC MOORE
Associate Professor of the
Practice of Biomedical
Engineering

RUSSELL DUNN
Professor of the
Practice of Chemical
and Biomolecular
Engineering

RANJANA SAHAI
Assistant Professor
of the Practice of
Mechanical Engineering

SCOTT GUELCHER
Professor of Chemical
and Biomolecular
Engineering

LORI TROXEL
Professor of the
Practice of Civil
and Environmental
Engineering

COURTNEY JOHNSON
Assistant Professor of
the Practice of Technical
Communications

THOMAS WITHROW
Assistant Dean for Design
Associate Professor of the
Practice of Mechanical
Engineering

Administration

Dean
Philippe Fauchet,
Bruce and Bridgitt Evans Dean
philippe.fauchet@vanderbilt.edu
(615) 322-0720

Senior Associate Dean for Graduate Education and Faculty Affairs
E. Duco Jansen
duco.jansen@vanderbilt.edu
(615) 343-3773

Senior Associate Dean for Undergraduate Education
Cynthia Paschal
cynthia.paschal@vanderbilt.edu
(615) 343-3773

Vice Dean of Engineering
Douglas Adams
douglas.adams@vanderbilt.edu
(615) 322-2697

Associate Dean for Research
Cynthia Reinhart-King, John R. Hall
cynthia.reinhart-king@vanderbilt.edu
(615) 875-8309

Associate Dean for Development and Alumni Relations
Teresa Rogers
teresa.rogers@vanderbilt.edu
(615) 322-4934

Associate Dean for Academic Success
Julie Vernon
julie.vernon@vanderbilt.edu
(615) 322-2441

Associate Dean for Strategic Learning Program
Jules White
jules.white@vanderbilt.edu
(615) 343-7472

Assistant Dean for Academic Services
Adam McKeever-Burgett
adam.w.mckeever-burgett@vanderbilt.edu
(615) 343-8061

Assistant Dean for Graduate Education
Gabriel Luis
gabriel.w.luis@vanderbilt.edu
(615) 343-3128

Assistant Dean for Professional and External Education Programs
Joanne Wang
joanne.wang@vanderbilt.edu
(615) 875-8386

Assistant Dean for Design
Thomas J. Withrow
thomas.j.withrow@vanderbilt.edu
(615) 322-3594

Departments

Department of Biomedical Engineering
Michael King, Chair, J. Lawrence Wilson Professor of Engineering
mike.king@vanderbilt.edu
(615) 322-3521

Department of Chemical and Biomolecular Engineering
Paul Laibinis, Chair
paul.e.laibinis@vanderbilt.edu
(615) 936-8431

Department of Civil and Environmental Engineering
Caglar Oskay, Chair,
caglar.oskay@vanderbilt.edu
(615) 322-2697

Department of Computer Science
Xenofon Koutsoukos, Chair
xenofon.koutsoukos@vanderbilt.edu
(615) 322-8283

Department of Electrical and Computer Engineering
Bennett Landman, Chair
bennett.landman@vanderbilt.edu
(615) 322-2771

Department of Mechanical Engineering
Nilanjan Sarkar, Chair,
David K. Wilson Professor of Engineering
nilanjan.sarkar@vanderbilt.edu
(615) 322-2413

Division of General Engineering
Yiorgos Kostoulas, Director
yiorgos.kostoulas@vanderbilt.edu
(615) 343-4965

School of Engineering

PMB 351592
2301 Vanderbilt Place
Nashville, TN 37235-1592

Connect with us:

vanderbiltengineering

@VUEngineering

@VanderbiltEngineering

youtube.com/vanderbilt

Web: engineering.vanderbilt.edu

School of Engineering

INSIGHT • INNOVATION • IMPACT