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School of Engineering
April 22, 2019
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Preface

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

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

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

Sincerely,

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43 DESIGN AND PROJECT FACULTY

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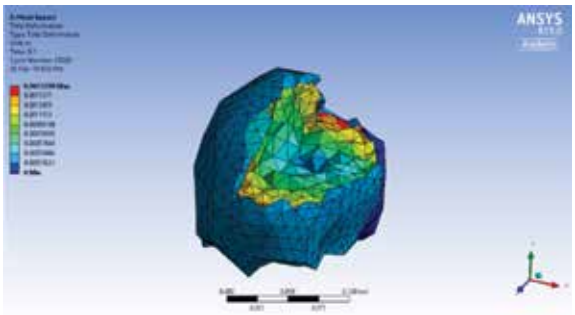
Finite Element Model of the Human Brain

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



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

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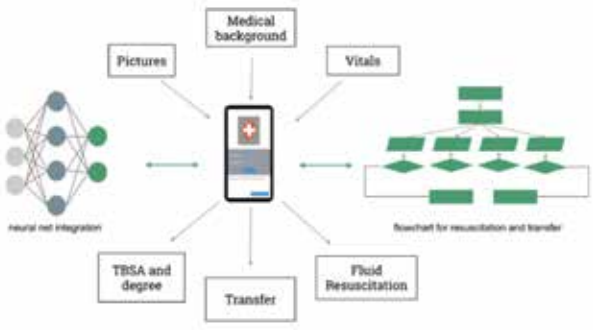
Burn Resuscitation and Management for Early Responders

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

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



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

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Multisensory Pre-alarm Device for Physicians

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

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

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

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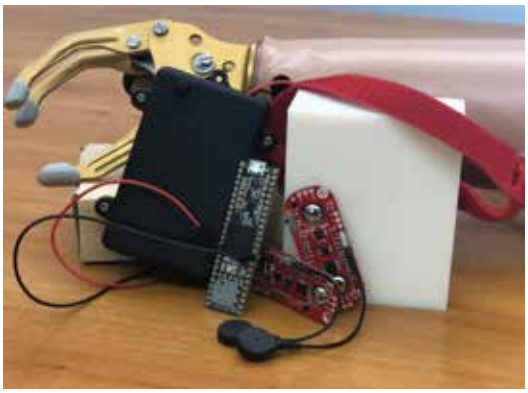
BIOMEDICAL ENGINEERING

Continuous Force-based Control System for a Myoelectric Hand Prosthesis



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

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

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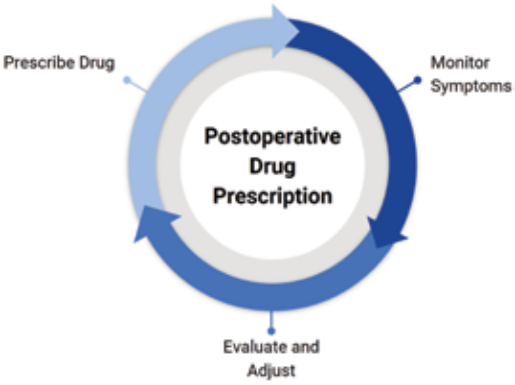
Pharmacogenetic Trial for the Prevention of Postoperative Effects of Cardiac Surgery

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

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



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

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

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

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

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

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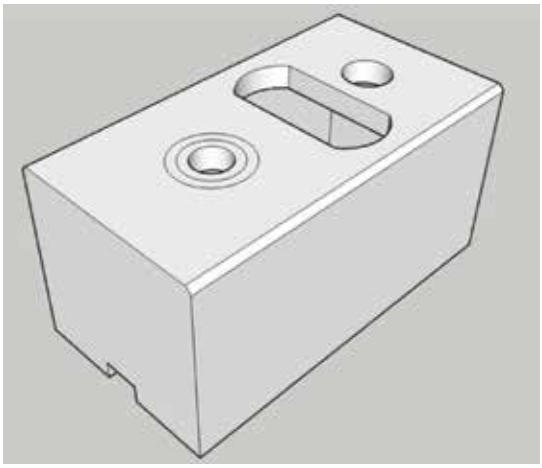
BIOMEDICAL ENGINEERING

X-ray Localization Device for Radiation Oncology Mouse Studies

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

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

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



X-ray shielding device prototype.

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BIOMEDICAL ENGINEERING

Co-culture Device to Study Minimal Microbiomes

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

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

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

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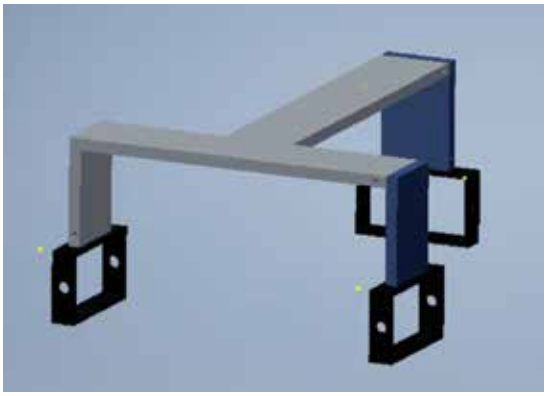
Ultrasound Brain Helmet

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

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



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

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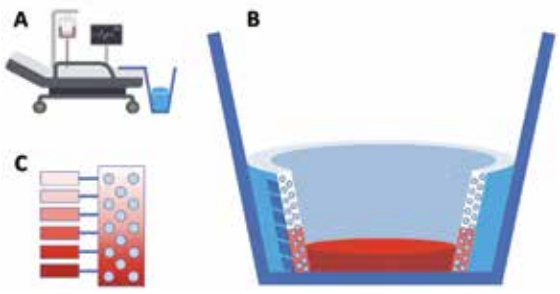
Quantifying Blood Loss in Vaginal Births to Reduce Maternal Morbidity and Mortality

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



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

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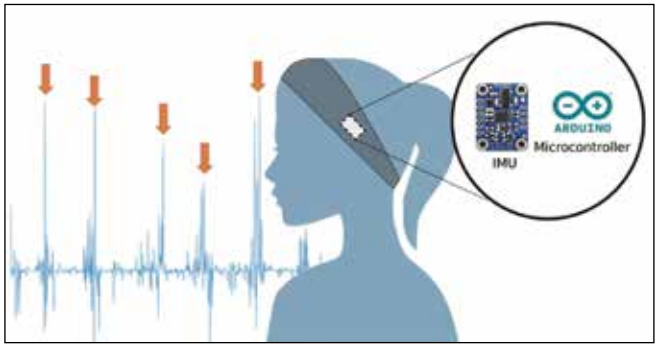
BIOMEDICAL ENGINEERING

Head Rotational Tremor Alert Device

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

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



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

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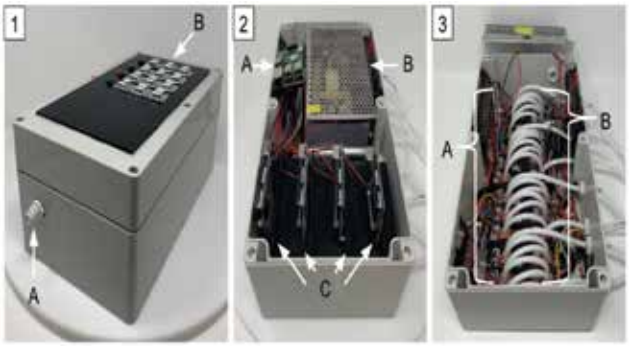
BIOMEDICAL ENGINEERING

Multichannel Peristaltic Pump System with Non-contact Inline Flow Sensors

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

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

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



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

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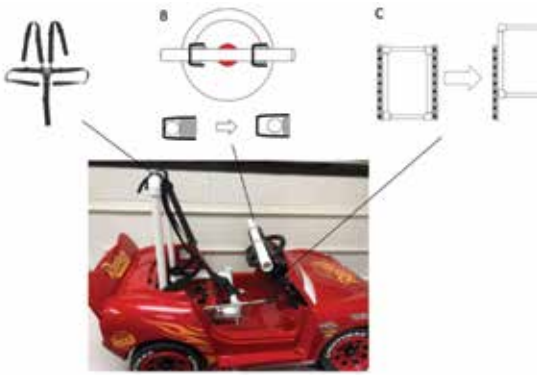
Optimization of Devices to Aid in Cognitive and Physical Development in Children with Mobility Restrictions

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

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



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

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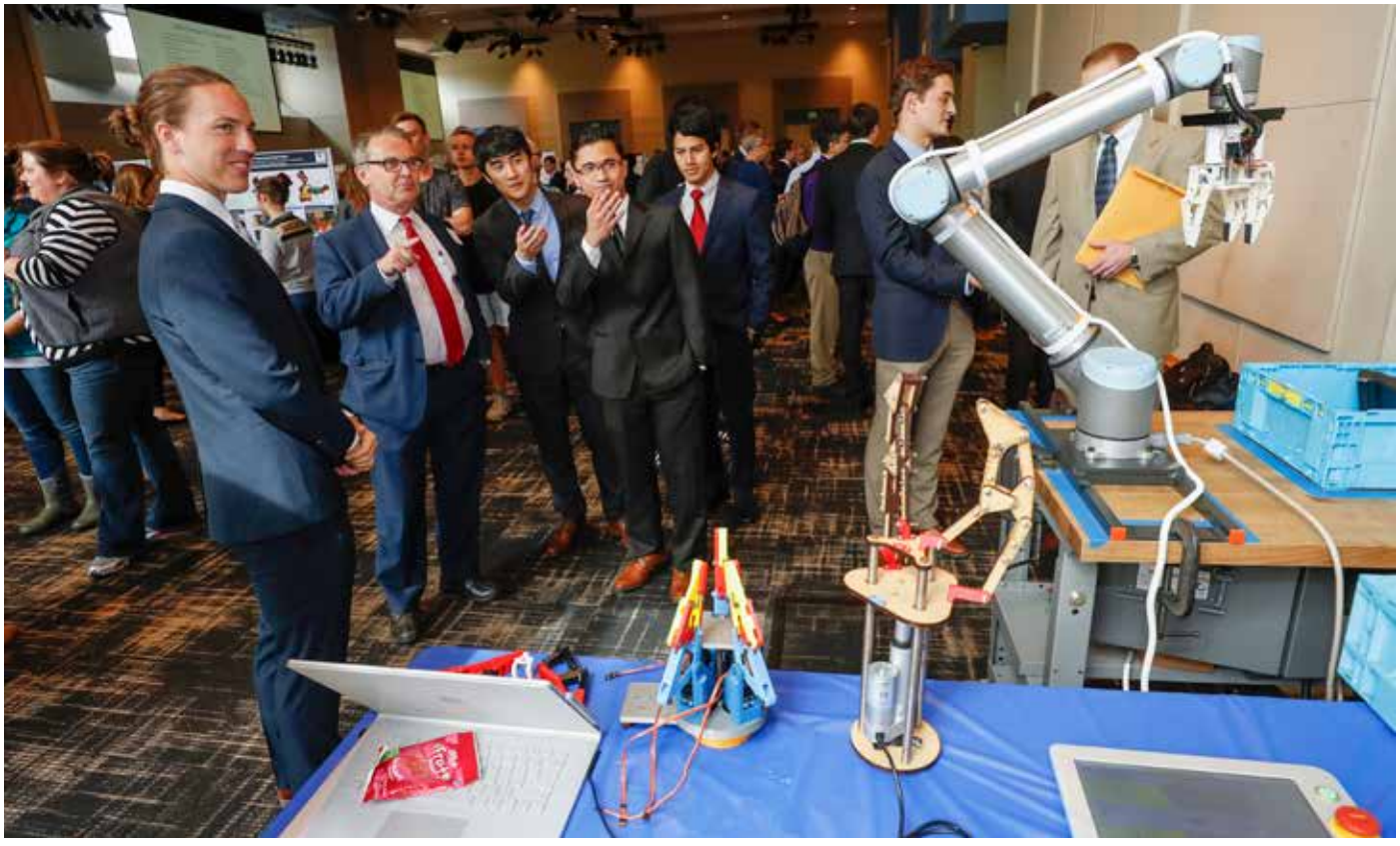

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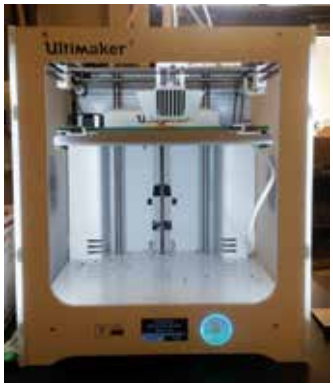
CHEMICAL AND BIOMOLECULAR ENGINEERING

3D Printing of Lab Scale Chemical Reactors and Peristaltic Pumps

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

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



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

Polymer & Chemical Technologies, LLC

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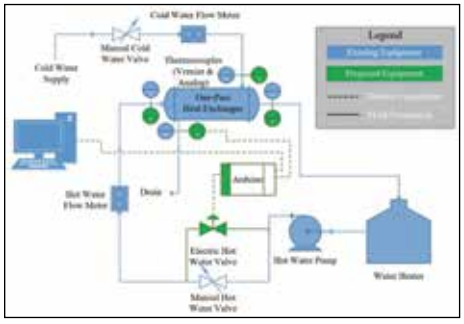
CHEMICAL AND BIOMOLECULAR ENGINEERING

Design and Analysis of a Process Control Laboratory Module

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

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



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

Chemical Engineering Design Advisory Board

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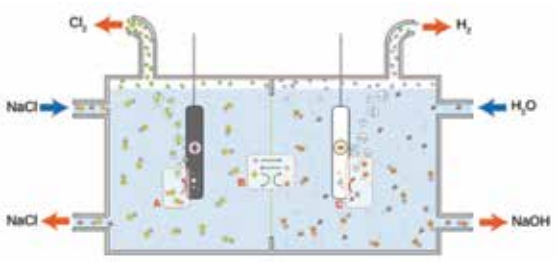
Design of a Continuous Chlor-alkali Electrolysis Process and Lab Module



Model of a continuous Chlor-Alkali generator.

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

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

CHEMICAL AND BIOMOLECULAR ENGINEERING

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3D-Printed Prosthetics for Canine with Below Knee Amputation

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

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

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

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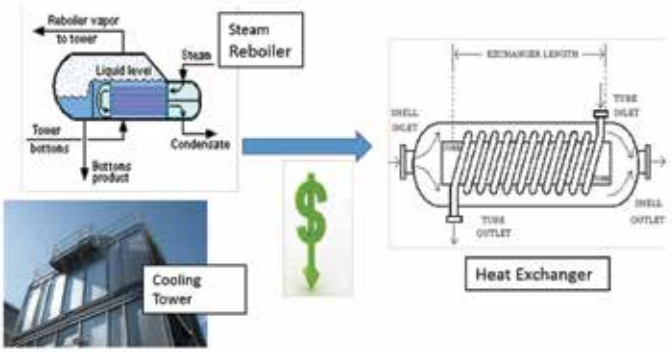
CHEMICAL AND BIOMOLECULAR ENGINEERING

Utility Optimization in a PVC Plant Through Heat Integration Design



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

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

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

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CHEMICAL AND BIOMOLECULAR ENGINEERING

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

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

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

CHEMICAL AND BIOMOLECULAR ENGINEERING

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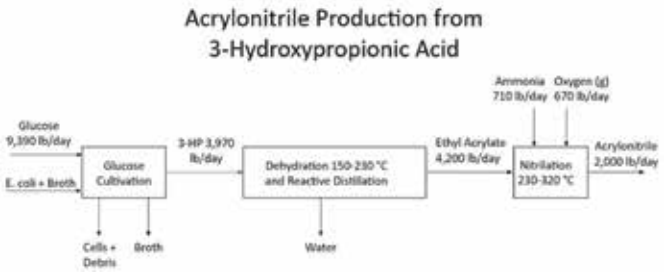
Design of an Environmentally Friendly Acrylonitrile Production Facility



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

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

Polymer & Chemical Technologies, LLC

Chemical Engineering Design Advisory Board

CHEMICAL AND BIOMOLECULAR ENGINEERING

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

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

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

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

Chemical Engineering Design Advisory Board

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CHEMICAL AND BIOMOLECULAR ENGINEERING

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

A rendition of a typical sulfuric acid plant.

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

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

CIVIL AND ENVIRONMENTAL ENGINEERING

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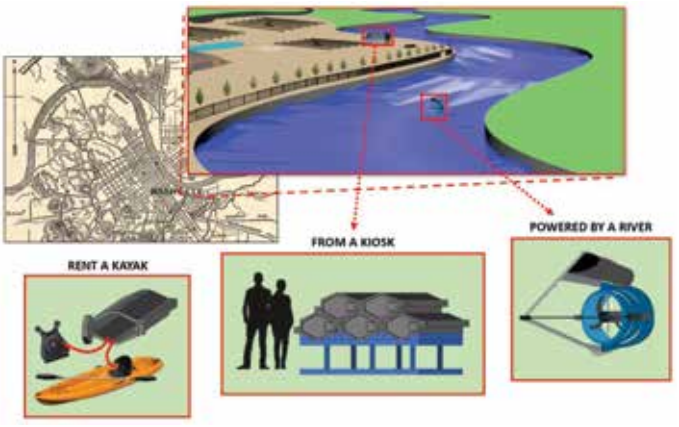
Cumberland River Compact

Boat Kiosks with Power Generation

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

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



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

CIVIL AND ENVIRONMENTAL ENGINEERING

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Capping the Interstate

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

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

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

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CIVIL AND ENVIRONMENTAL ENGINEERING

Infill Housing Above the WeGo Central Station

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

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

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

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CIVIL AND ENVIRONMENTAL ENGINEERING

Living Building and Transportation Hub

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

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

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

CIVIL AND ENVIRONMENTAL ENGINEERING

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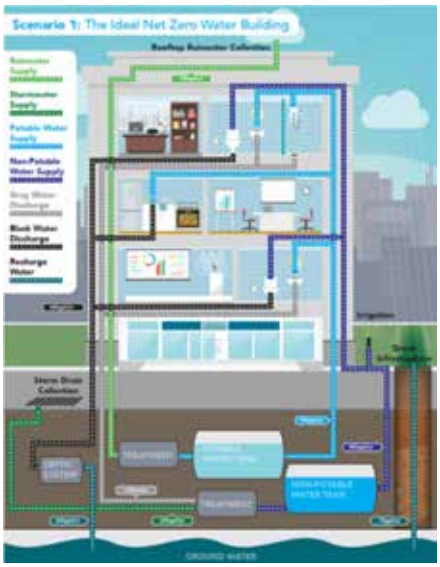
Future VU, Vanderbilt University
Nashville Metro Water Services

Living Building Modular Water System

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



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

CIVIL AND ENVIRONMENTAL ENGINEERING

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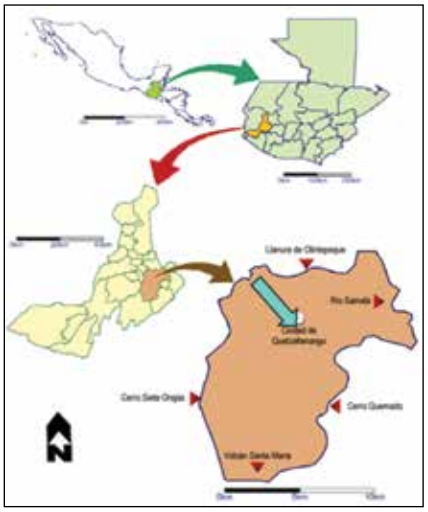
Guatemala Water Treatment

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

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



Location of the water treatment system in Guatemala.

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CIVIL AND ENVIRONMENTAL ENGINEERING

Steel Bridge Competition

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

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

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

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CIVIL AND ENVIRONMENTAL ENGINEERING

Adaptation of the Built Environment to Emerging Shared Mobility Systems

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

Bird scooters ready for pickup after a morning of charging.

ELECTRICAL ENGINEERING AND COMPUTER SCIENCE

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East Tennessee Technology Park History Center Electric Vehicle Charging Station

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

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

UCOR

VANDERBILT
School of Engineering

ELECTRICAL ENGINEERING AND COMPUTER SCIENCE

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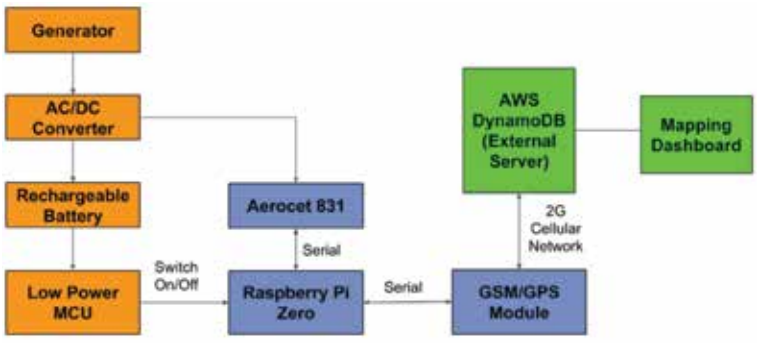
Air Quality Evaluation and Data Collection with Nashville's B-Cycles

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



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

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Vanderbilt Motorsports

ELECTRICAL ENGINEERING AND COMPUTER SCIENCE

Electrical System Design for Formula SAE Electric Vehicle

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

Formula electric vehicle with battery boxes in side pods.

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Cooper Garrison, CompE

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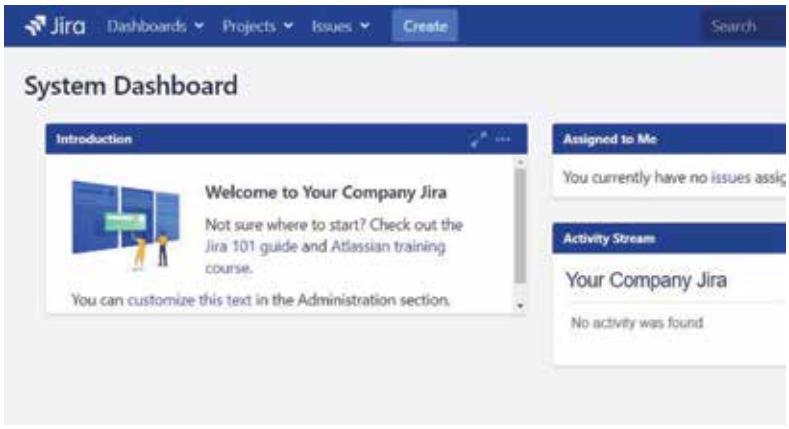
Inventiv Tools

ELECTRICAL ENGINEERING AND COMPUTER SCIENCE

Critic Plugin for JIRA

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



Atlassian JIRA interface.

ELECTRICAL ENGINEERING AND COMPUTER SCIENCE

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Metova

LoRa Locate

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

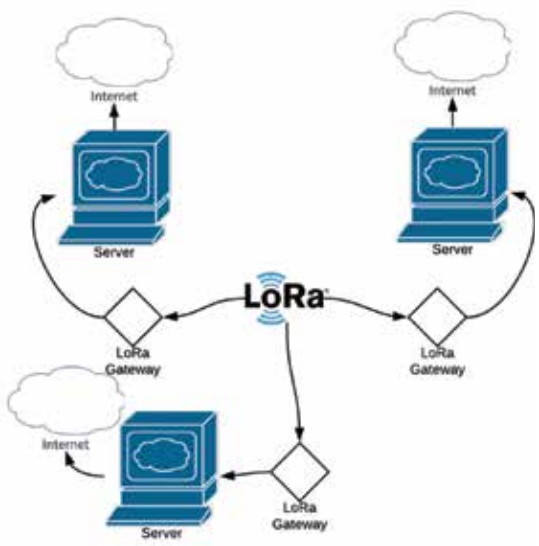

Illustration of how LoRa transceivers will communicate with LoRa gateways to determine location.

ELECTRICAL ENGINEERING AND COMPUTER SCIENCE

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SPONSOR
SFEG

IoT Integration for Excel Dryer

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

SFEG's Excel Dryer-Xlerator.

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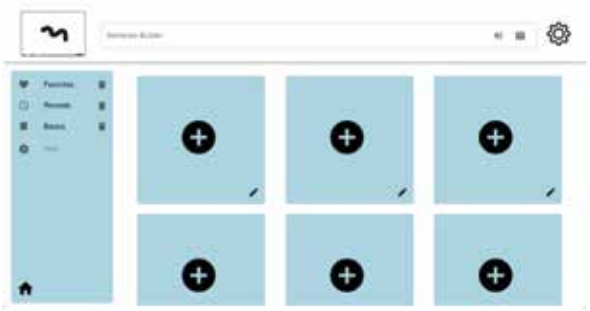
ELECTRICAL ENGINEERING AND COMPUTER SCIENCE

Assistive Technology App for Aphasia Remediation

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



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

VANDERBILT UNIVERSITY MEDICAL CENTER

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Pi Beta Phi Rehabilitation Institute, Vanderbilt University Medical Center

ELECTRICAL ENGINEERING AND COMPUTER SCIENCE

Aphasia Remediation App

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

Word and concept categories with visual navigation.

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Peabody College, Vanderbilt University

Ultra Low-cost Eye Tracking System for Educational Research

Eye-tracking prototype.

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

VANDERBILT. Peabody College

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Vanderbilt Aerospace Design Laboratory

NASA Marshall Space Flight Center

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

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

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

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

NASA

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Change++

ELECTRICAL ENGINEERING AND COMPUTER SCIENCE

Nashville Affordable Living Application

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

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

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ELECTRICAL ENGINEERING AND COMPUTER SCIENCE

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

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

Research study preview screen.

ELECTRICAL ENGINEERING AND COMPUTER SCIENCE

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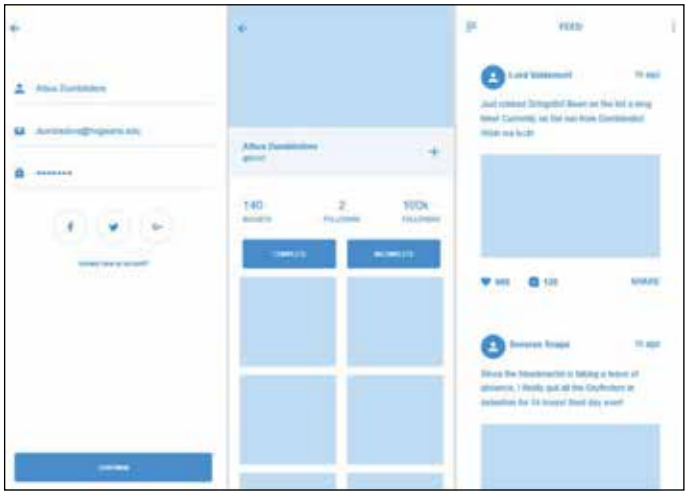
BucketList

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



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

VANDERBILT
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ELECTRICAL ENGINEERING AND COMPUTER SCIENCE

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Vanderbilt Wond'ry, Innovation Garage

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

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

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

theWONDRY

VANDERBILT.
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ELECTRICAL ENGINEERING AND COMPUTER SCIENCE

SideScroller

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

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

VANDERBILT
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Vanderbilt-Ingram Cancer Center

ELECTRICAL ENGINEERING AND COMPUTER SCIENCE

Cancer Genetic Counseling

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

Opening page of web application.

VANDERBILT-INGRAM CANCER CENTER

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International Bridges to Justice
Change++

Change++: Connecting Lawyers and Clients in Syria

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

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

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

ELECTRICAL ENGINEERING AND COMPUTER SCIENCE

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Stevenson Tour Guide

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

The splash screen for the Stevenson Center Tour Guide app.

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ELECTRICAL ENGINEERING AND COMPUTER SCIENCE

JACKAL: College Rental Marketplace

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

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

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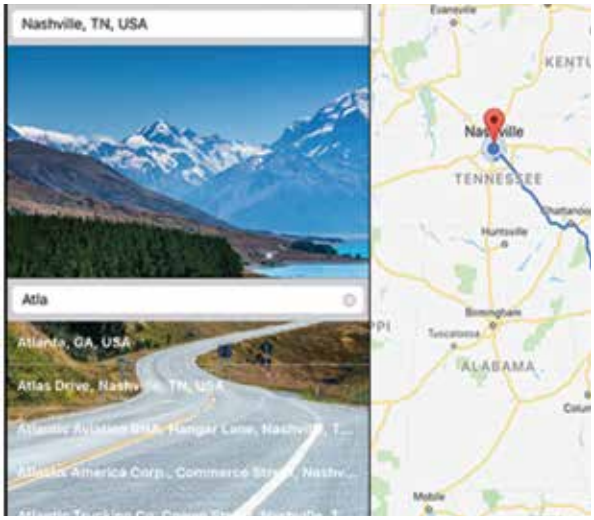
ELECTRICAL ENGINEERING AND COMPUTER SCIENCE

Trippy: The Comprehensive Road Trip Planner

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



Creating a road trip route from Nashville to Atlanta.

VANDERBILT
School of Engineering

ELECTRICAL ENGINEERING AND COMPUTER SCIENCE

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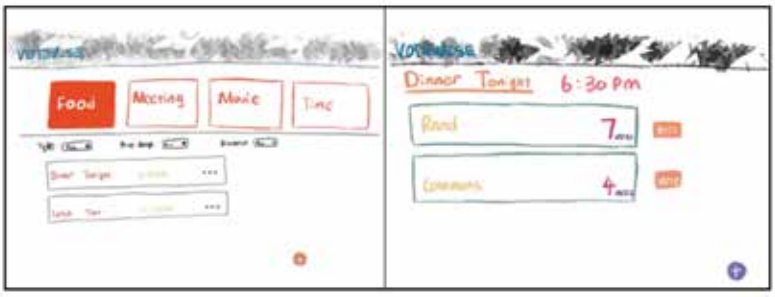
VoteWise

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

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



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

VANDERBILT
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ELECTRICAL ENGINEERING AND COMPUTER SCIENCE

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Using Machine Learning Models to Study Financial Market Movement

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

A glimpse into the financial market.

VANDERBILT
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Vanderbilt University Medical Center, Department of Biomedical Informatics

ELECTRICAL ENGINEERING AND COMPUTER SCIENCE

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

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

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

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

VANDERBILT UNIVERSITY MEDICAL CENTER

VANDERBILT School of Engineering

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Vanderbilt University, School of Engineering, Department of Computer Science

Vanderbilt University, Blair School of Music

ELECTRICAL ENGINEERING AND COMPUTER SCIENCE

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

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

Boy bands, past and present.

VANDERBILT Blair School of Music

VANDERBILT School of Engineering

ELECTRICAL ENGINEERING AND COMPUTER SCIENCE

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Flight Delay Predictor

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

The struggle with flight delays is real.

VANDERBILT
School of Engineering

ELECTRICAL ENGINEERING AND COMPUTER SCIENCE

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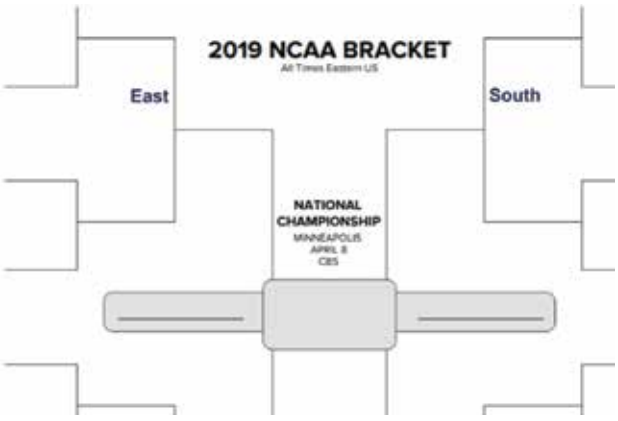
Predicting March Madness Using Machine Learning

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



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

VANDERBILT
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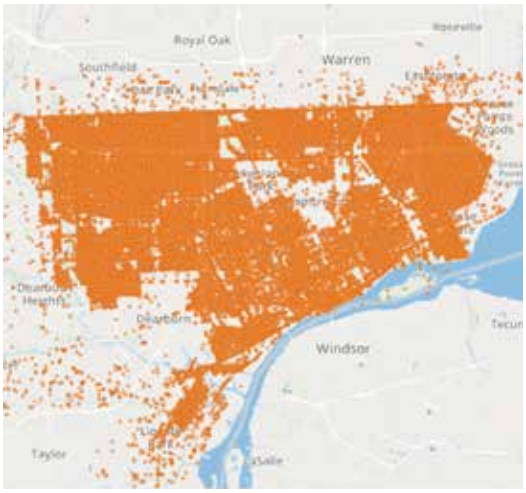
ELECTRICAL ENGINEERING AND COMPUTER SCIENCE

Exploring Police Response Times in Big Cities through Machine Learning

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



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

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ELECTRICAL ENGINEERING AND COMPUTER SCIENCE

Supervised Learning Algorithms for March Madness Bracket Predictions

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

NCAA MARCH MADNESS

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

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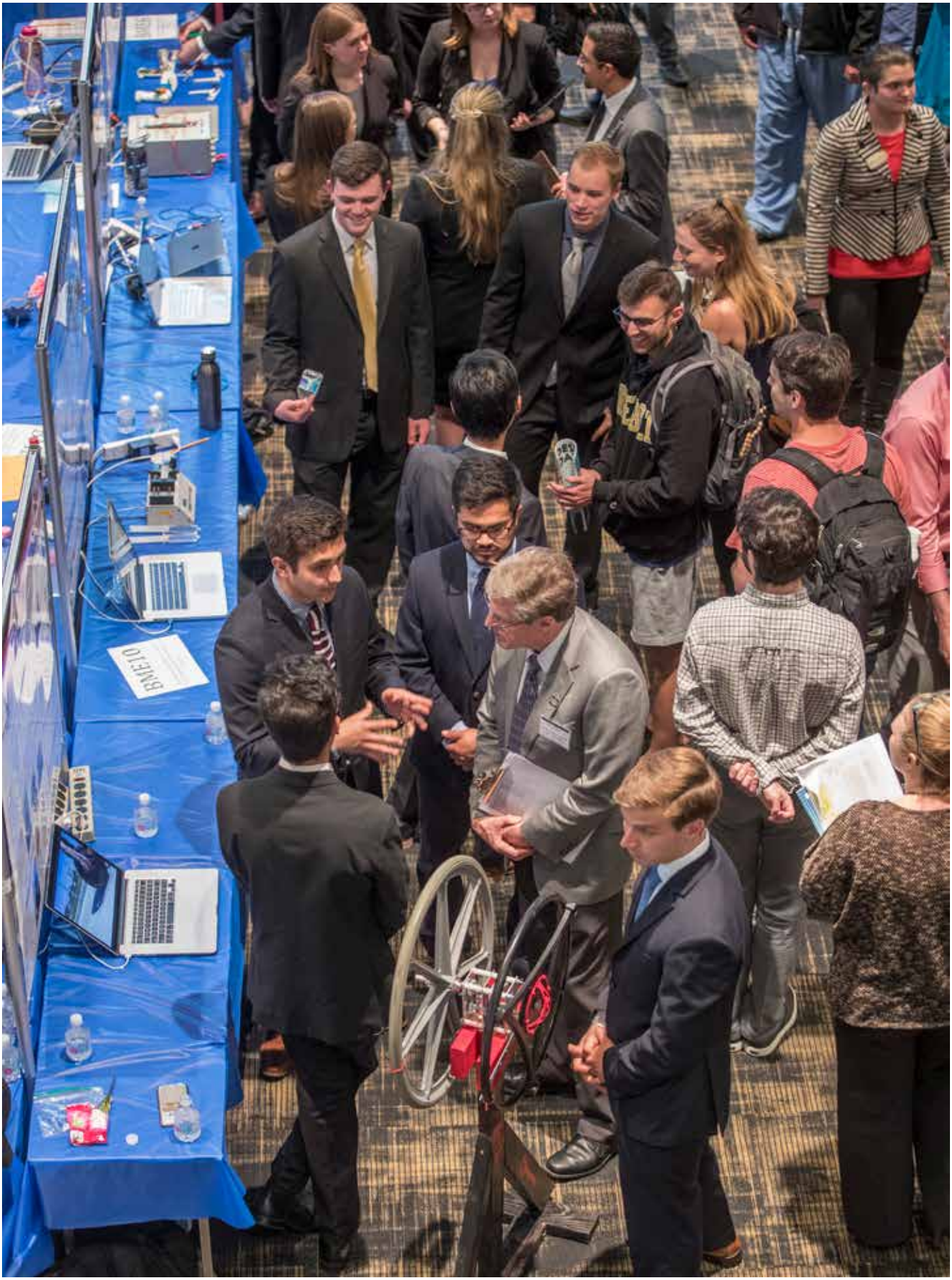
School of Engineering


BME10

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MECHANICAL ENGINEERING

Prevention of Building-Related Bird Strikes

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

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

VANDERBILT
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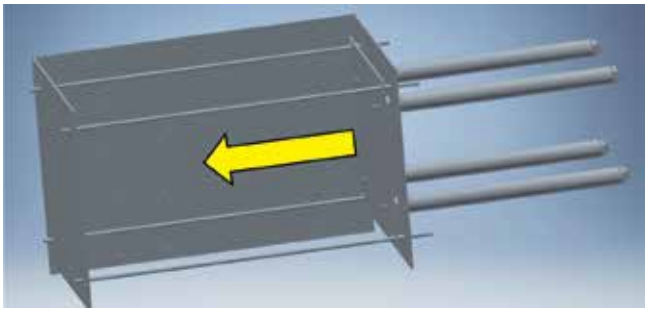
Nissan North America

MECHANICAL ENGINEERING

Cardboard Conveyance Project by Nissan North America

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

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



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

NISSAN

MECHANICAL ENGINEERING

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Surgical Analytics Lab
Vanderbilt Institute for Surgery and Engineering

Surgical Video System Design Project

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

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

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

MECHANICAL ENGINEERING

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NASA

Design and Construction of a Martian Habitat

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

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

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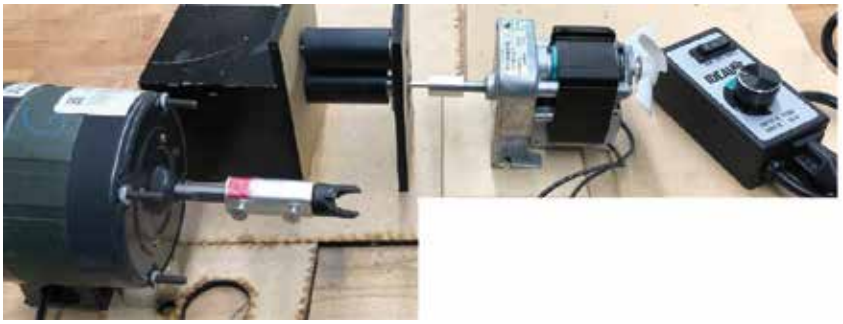
MECHANICAL ENGINEERING

Polymer Pelletizing Project

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



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

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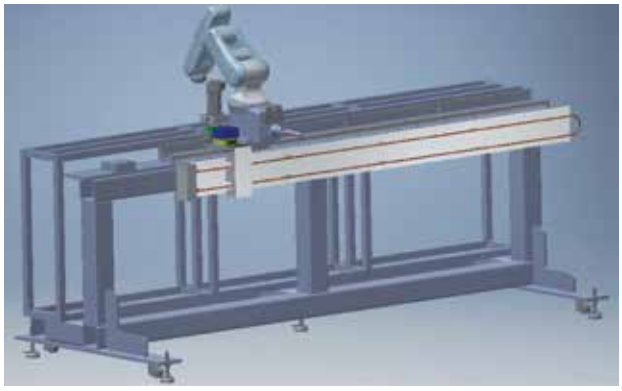
MECHANICAL ENGINEERING

DENSO 400W Wireless Power Transfer System Development

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



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

MECHANICAL ENGINEERING

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FedEx Express

Development of the Next-generation Courier Station

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

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

MECHANICAL ENGINEERING

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Nissan North America

Nissan Information Display Project

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

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

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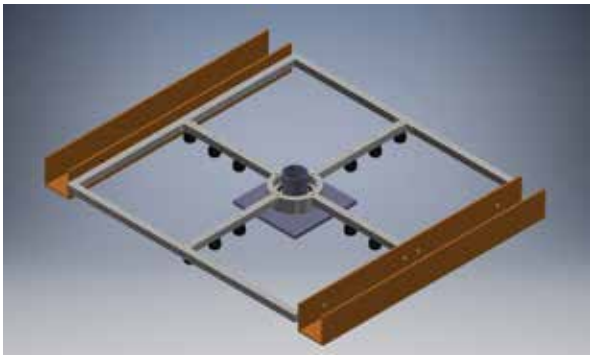
Nissan North America.

MECHANICAL ENGINEERING

Manufacturing Kit Cart Project

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

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



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

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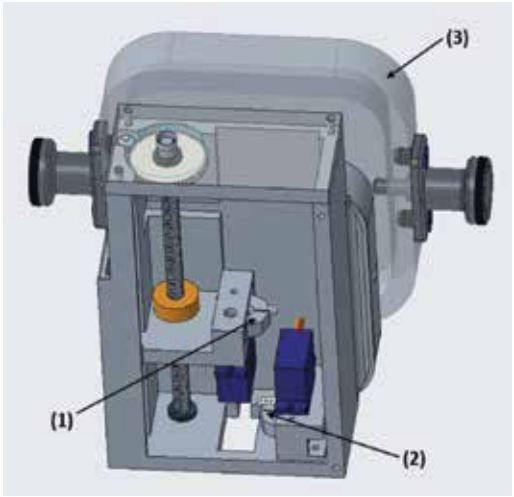
MEDLab, Department of Mechanical Engineering

MECHANICAL ENGINEERING

Mechatronic Design of a Surgical Robot

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



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

MECHANICAL ENGINEERING

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Permobil

Permobil: Accessibility Robotic Arm

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

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

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Seth Thomas, Technical Advisor
Beau Johnson, Technical Advisor

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

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

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

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Naval Surface Warfare Center, Panama City Division

MECHANICAL ENGINEERING

Physiological Monitoring Sensor Suite for Divers

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

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

NAVSEA WARFARE CENTERS PANAMA CITY

VANDERBILT School of Engineering

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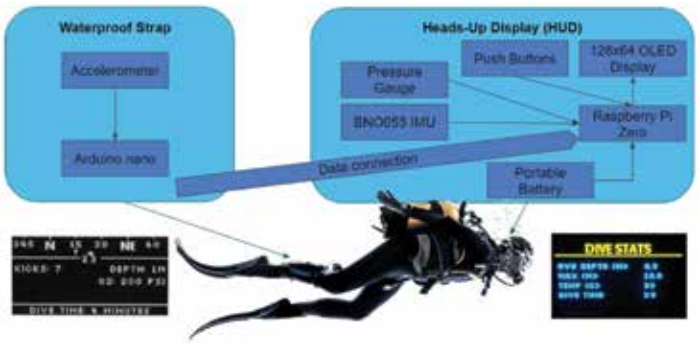
Department of Mechanical Engineering

MECHANICAL ENGINEERING

Special Forces Diver Information Display

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



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

VANDERBILT School of Engineering

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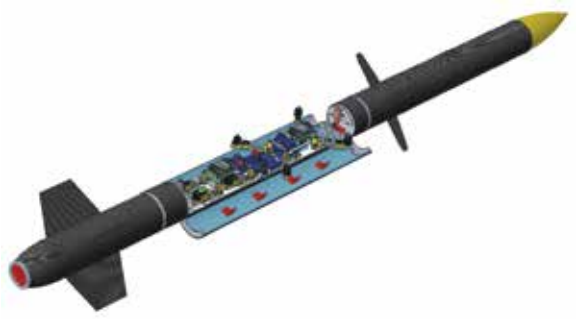
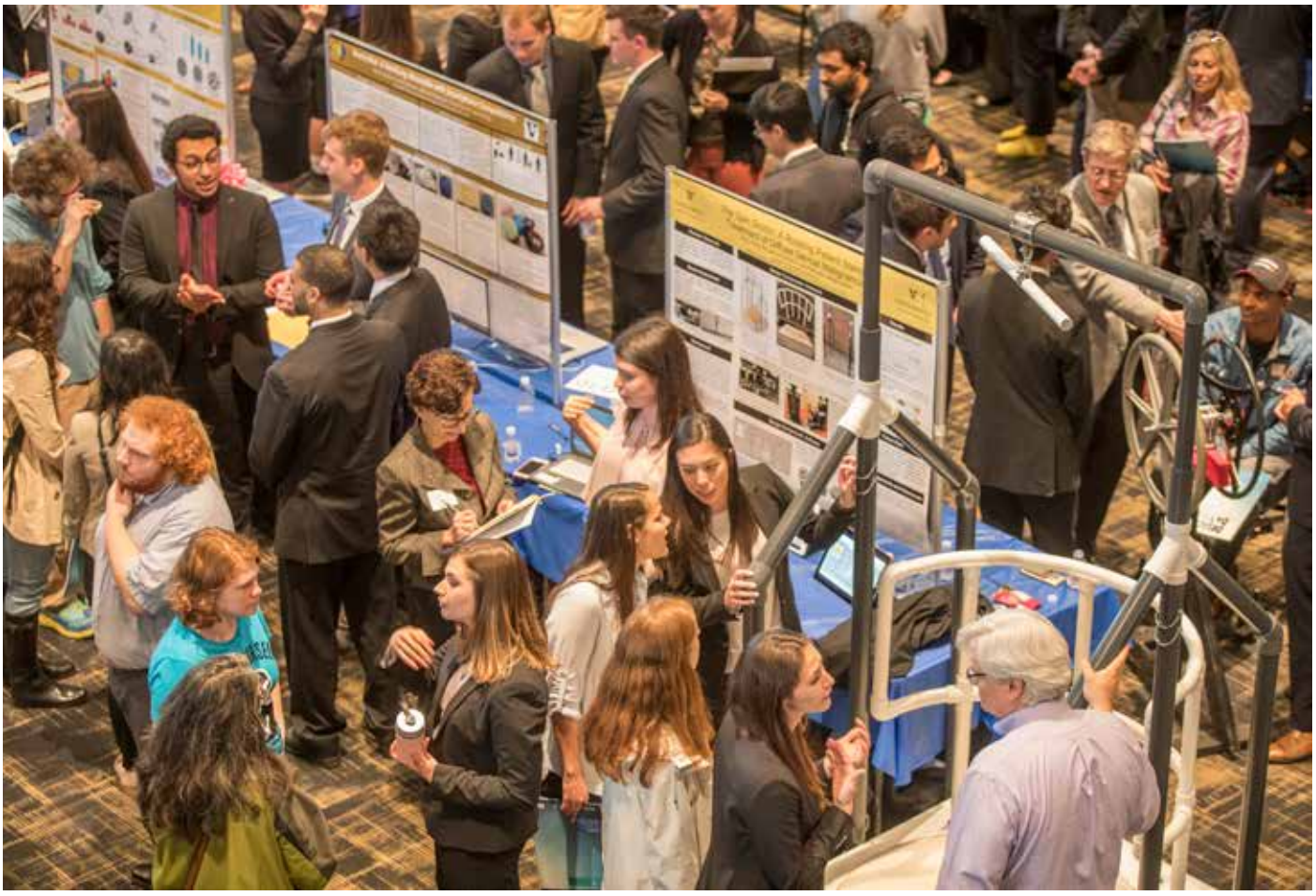
NASA Marshall Space Flight Center

Spacecraft for Delivering Deployable UAV Payload

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



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



Design and project faculty

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

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