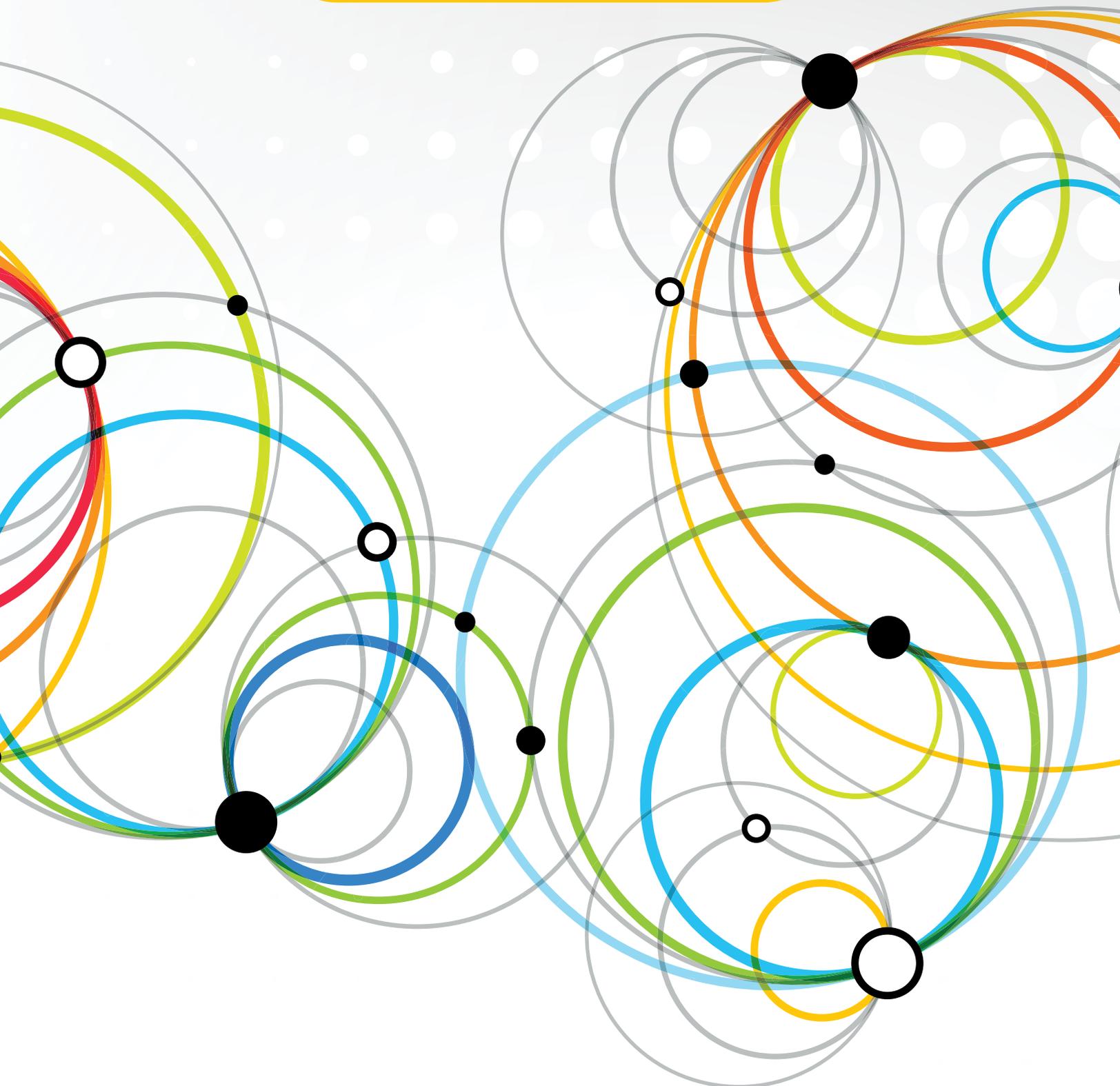


# DESIGN DAY 2016

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## PREFACE

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On behalf of the School of Engineering, welcome to Design Day 2016. This year, you'll see engineering and computer science capstone projects completed in partnership with sponsors including Carlex Glass, Fiserv Solutions, Nashville Metro Arts, Nissan North America, Sterling Ranch Development Company, Quality Manufacturing Solutions, and more.

We thank all of our project sponsors and give special thanks to AT&T for its support of our design program and of the 2016 Innovation Award. This year, Philippe Fauchet, Dean of the School of Engineering, will present the Dean's Awards.

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 and intellectual property. 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 a prototype, process design, or virtual demonstration. Design Day is their showcase.

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



Sincerely,

A handwritten signature in blue ink that reads "Cynthia B. Paschal". The signature is fluid and cursive.

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## 45 DESIGN AND PROJECT FACULTY

Brochure data were collected and managed using REDCap electronic data capture tools hosted at Vanderbilt University<sup>1</sup>. REDCAP (Research Electronic Data Capture) is a secure, Web-based application designed to support data capture for research studies, providing: 1) an intuitive interface for validated data entry; 2) audit trails for tracking data manipulation and export procedures; 3) automated export procedures for seamless data downloads to common statistical packages; and 4) procedures for importing data from external sources. REDCap is supported by a Vanderbilt Institute for Clinical Trials and Translational Research grant (UL1TR000445 from NCATS/NIH).

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

## Stuttering Implicit Association Task

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The Implicit Association Test (IAT) is a popular social psychology tool that assesses how closely people's brains link concepts. A 10-minute measure, the IAT requires test takers to rapidly pair words or pictures from two target conditions (e.g., male and female) with an attribute (e.g., "kind") such that faster responses are interpreted as more strongly associated than slower responses. These unknown cognitive connections may lead to implicit bias, which may influence subtle forms of discrimination. There is a desire to apply the IAT in a research framework to better understand people's implicit biases against those who stutter, yet no currently existing software satisfies this desire. This design uses Java's Swing Graphic User Interface through a JApplet, which allows the Stuttering IAT to be accessed over the Internet and be capable of collecting and storing data. While the primary purpose is the large-scale collection of data for research purposes, the test also provides users with an estimated degree of personal preference/bias (no, slight, moderate, or extreme) for either people who stutter or people who do not stutter.



Implicit biases can be informed by subconscious cognitive associations, such as the connections between stuttering and words of negative connotation. The Stuttering Implicit Association Test seeks to quantify in its users the degree of bias towards people who stutter.

## Fibrotic Liver Ultrasound-based Imaging Diagnostic [FLUID] System

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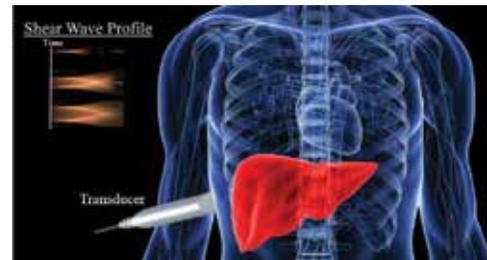
Biomedical Elasticity and Acoustic  
Measurement Laboratory



Liver fibrosis is a condition in which healthy tissue is replaced by scarred tissue after liver damage occurs. As fibrosis progresses, the tissue stiffens, causing impaired liver function. Consequently, severe liver fibrosis, known as cirrhosis, results in over 1 million deaths each year. Many of these deaths occur in low-resource environments due to the high prevalence of Hepatitis B and C, common causes of liver fibrosis in these areas.

A liver biopsy is the current gold standard for assessing liver fibrosis, but this technique is invasive, painful, and expensive. While non-invasive diagnostic methods using advanced imaging modalities exist, these technologies are too complex and costly for use in low-resource environments. Therefore, our team has developed a low-cost, ultrasound-based device to non-invasively assess liver fibrosis.

Our design utilizes a single element transducer and acoustic radiation force imaging (ARFI) elastography to quantitatively measure liver tissue stiffness. By transmitting a long acoustic pulse to generate a shear wave, followed by a series of short pulses, we can displace the tissue and then track the subsequent motion. The motion profile can be correlated with the progression of liver fibrosis.



The transducer emits shear waves to displace liver tissue. This displacement provides a measurement of tissue stiffness, which correlates with the severity of liver fibrosis.

# Clinical Analysis of Speech Rhythms in Language Development Using MATLAB

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**ADVISER:**

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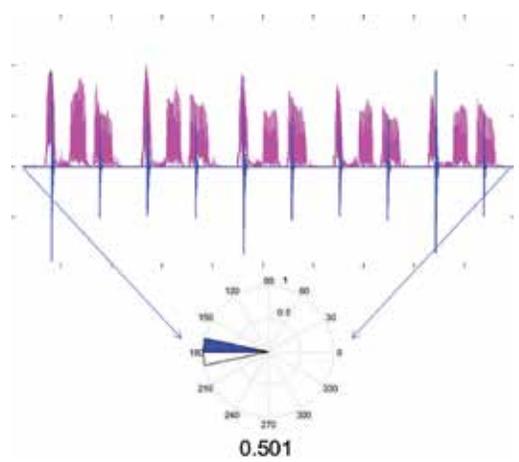
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The ability to identify and produce rhythm has been shown recently to have an effect on language development in children. With new exploration in this interdisciplinary field, the need has increased sharply for a diagnostic tool that benchmarks an individual's language abilities. Currently, no technology exists to measure the rhythmic capabilities of an individual. This design affords researchers and clinicians the opportunity to automatically record, save, and analyze rhythm in speech.

Utilizing MATLAB, speech is analyzed in accordance with a stimulus, the metronome. The metric for determining an individual's speech rhythm abilities is derived from the comparison of the recorded speech and the metronome. The degree to which the rhythm of speech aligns with the metronome is a determinant of synchrony in speech. This tool transcends current research by providing direct value to patients. Preliminary speech patterns serve as a baseline for subsequent tracking of improvement in speech production. This tool will be used in conjunction with music training to aid in determining both the quality of speakers and the impact of music on spoken language.



A circular statistics graph compares the metronome track (presented in blue) to the speech track (in pink).

# Pressurized Prophylactic Treatment Delivery Device for Vascular Bypass Grafts

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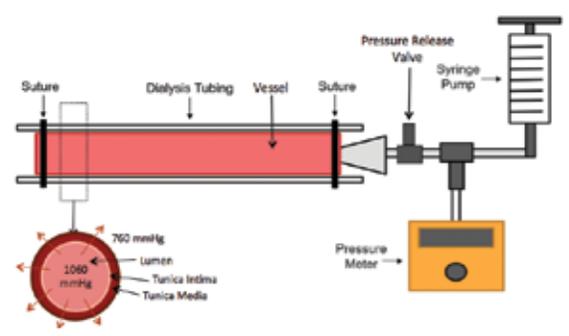
Vanderbilt University Medical Center



Vascular bypass surgeries are a common medical procedure, but graft failure rates can be as high as 43 percent depending on the location of the bypass. Scientists recently have developed a map kinase inhibitor that increases the patency of vascular bypass grafts and decreases their rate of failure. Homogeneous delivery of these therapeutics throughout the target tissue is limited by the inherent diffusional barriers presented by the luminal and adventitial surfaces of the graft vessel.

To address this limitation, this project focuses on developing a pressurization device to improve therapeutic delivery into the vessel wall without causing significant vessel distension and subsequent cellular damage. A pressure gradient will be induced from the lumen to the adventitial surface of the vessel to drive drug permeation into the target tissue of the graft vein while dialysis tubing will be utilized as a protective stent to prevent distension.

This dynamic pressure system will allow for faster, more effective permeation of the target tissue than the current standard of delivery. The device will ultimately reduce the failure rates of vascular bypass grafts, preventing the need for more operations.



Schematic of the prototype of the pressurization device. Included is a diagram showing the convective flow mechanism induced circumferentially by the luminal to adventitial pressure gradient.

# Cardiac ICU Modeling

**TEAM MEMBERS:**

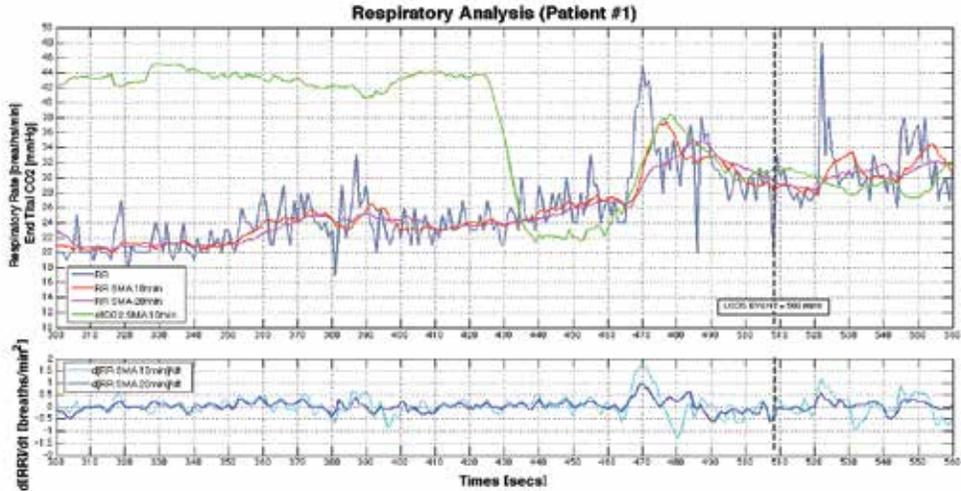
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**Respiratory analysis using simple moving averages for an example patient leading up to a Low Cardiac Output Syndrome (LCOS) event. The variations in these averages as well as deviations from established baselines are used to predict a future drop into low cardiac output.**

Cardiac Output Syndrome (LCOS) is a clinical condition that is caused by a decrease in oxygen perfusion throughout the body. When a patient declines into a state of low cardiac output, a timely response by medical staff is important for decreased long-term effects. In a pediatric cardiac intensive care unit, there is a continuous flow of data points tracking vitals. This includes metrics for heart rate, respiratory rate, blood pressure, venous oxygen saturation, and many more.

The focus of this project is to build a model that integrates patient data in order to alert the physician of an impending cardiac event. This first involves establishing a patient specific baseline for each vital. Then, the patient’s data will be compared to this baseline for variability as well as deviations. Development of an exact algorithm to be used in analysis of each patient’s data is in progress. This algorithm will output a risk score that will be used by medical staff to monitor or take action regarding each patient. There are currently no options for real-time prediction of LCOS.

# Preparing Oral Rehydration Solutions Using Flotation Densimetry

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Monroe Carell Jr. Children’s Hospital  
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Diarrheal disease is a leading cause of childhood mortality, but the condition is easily treated with oral rehydration solution (ORS). While the World Health Organization distributes packets of a salt mixture that can be added to one liter of water to create effective ORS, the care providers mixing the solutions often fail to measure the appropriate volume of water to add to the packets. The goal of this project is to eliminate the need to measure the water by creating a device whose flotation level within the ORS indicates whether the osmolality of the solution falls within the acceptable range.

The device is a small cylinder made of layers of differing densities. The density of the middle layer is equal to that of ideal ORS, with the densities of the rest of the cylinder corresponding to solutions within and outside of the acceptable range. The device is color coded for easy interpretation. Once the water level falls within the green central region, the ORS is ready for consumption. No other device exists to assist with the mixing of ORS. Therefore, this device is anticipated to increase the number of children who receive effective diarrheal disease treatment.



**The device is placed in oral rehydration solution as it is being mixed to indicate when enough salts have been added to the water or vice versa. This ensures that the resulting solution will be effective in treating diarrheal disease.**

## Supplemental Oxygen for Low-Resource Environments

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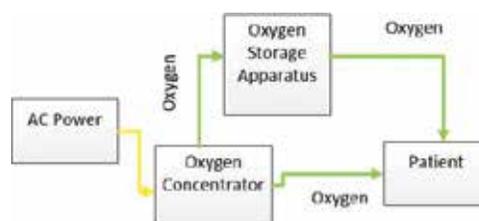
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Vanderbilt University Medical Center, Department of Anesthesiology



Pneumonia is one of the leading killers of children in developing countries despite increased access to antibiotic treatment. Many of these deaths are caused by hypoxemia, which can be treated with oxygen therapy using oxygen tanks or oxygen concentrators. Tanks are too expensive to deliver to remote clinics, and concentrators require a constant power supply, which is often unavailable due to unreliable power grids. The overall goal of this project is to provide an oxygen therapy solution that addresses the needs of low-resource hospitals and clinics. This design uses a combination of oxygen and power storage methods to offer a modular solution that can be adapted to fit the needs of different facilities. Storing uncompressed oxygen reduces the power required to deliver oxygen to patients compared to oxygen tank technology in current use. This project also uses a deep cycle battery to store energy and power the device for times when grid power is unavailable. The modular system offers multiple solutions to address the needs of different facilities, which will increase access to oxygen therapy and, thus, treat more patients.



**Block diagram of the oxygen delivery system. The concentrator is powered by AC power either from the electrical grid or from a battery or solar panel attached to an inverter. From the concentrator, oxygen is pumped to either the patient or the storage apparatus, depending on the need. Once the storage apparatus is filled, oxygen can be pumped from it to the patient.**

## Laparoscopic Gastrointestinal Phantom

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Science and Technology of Robotics and Medicine Lab



Each year, millions of animals and human cadavers are used in medical training and research settings, driving up the cost of medical discovery. Currently, phantoms of the upper gastrointestinal (GI) tract do not exist and colorectal phantoms are not widely available. Therefore, the goal of the project was to create a low-cost, environmentally friendly, and anatomically-correct gastrointestinal phantom to use for repeatable testing of new endoscopy and colonoscopy techniques and devices. The design consists of a model of the upper GI tract, which includes the esophagus, stomach, and upper third of the duodenum, made from a mold of PVC pipe and wet floral foam. The model of the lower GI tract was created using a 3D-printed mold of the colon and rectum derived from a series of CT scans. The entire mold was coated with liquid silicone, which solidified to create a model with exact dimensions and mechanical properties of a human gastrointestinal tract. This resultant model is cost-effective, durable, and eliminates the need for animals and cadavers. Implementation of this model will allow researchers and gastroenterologists to test new medical devices with the fidelity of a human gastrointestinal tract.



**The finalized gastrointestinal phantom will feature anatomically correct dimensions and material properties. The phantom will allow for qualitative testing of new endoscopic devices. The four quadrants of the figure display a) the 3D printed mold of the colon, b) the mold coated in liquid silicone, c) the removal of the cured silicone, d) the silicone phantom.**

## Spatial Hearing Web Application

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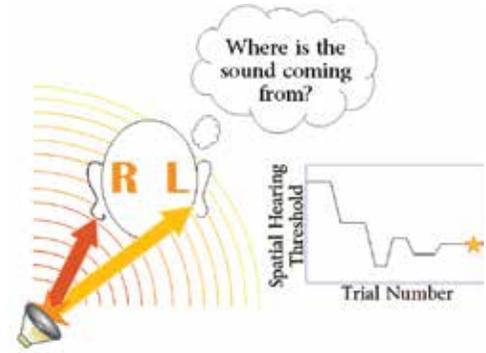
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### SPONSOR:

Vanderbilt University Medical Center, Department of Hearing and Speech Sciences



There are an estimated 285 million people with visual impairments worldwide. These individuals have a difficult time with daily tasks, such as crossing streets. One way to mitigate this problem is to learn more about how people perceive sound. Currently, there is no quick and easy way to test hearing ability, which prompted us to develop a website application for auditory testing. The application is user-friendly for visually-impaired individuals and brings the testing environment to the subject. The tests measure perceived sound level difference and sound time difference between each ear. The level difference test measures a loudness difference between the right ear and left ear. The time difference test measures the time interval between when a sound hits each ear. More data about how people perceive sound will be acquired from our application and will give researchers a better sense of how people of all visual abilities localize sound. This will allow for development of improved technologies and safer interactions for people who are visually impaired.



People use various auditory cues to locate sound sources. Gradually decreasing stimulus differences between the two ears will allow identification of a spatial hearing threshold.

## Dynamic Alarm System for Hospitals (DASH) to Address Alarm Fatigue

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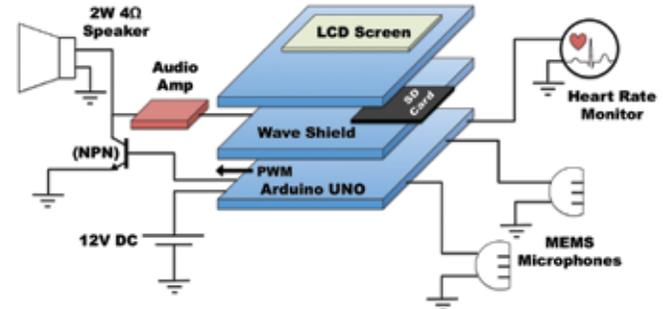
Vanderbilt University Medical Center, Department of Anesthesiology



Alarm fatigue, or failure of staff to promptly respond to valid alarm conditions, has been identified as a top health technology hazard by national regulatory bodies. Current medical alarms elevate ICU noise levels and negatively impact hospital personnel performance, which ultimately leads to alarm fatigue. The project objective is to develop a dynamic alarm system that regulates alarm volume relative to the background noise and, consequently, avoid unnecessarily loud alarms.

The device also addresses other aspects of conventional medical alarms associated with fatigue, such as rhythm and acoustic profile. An advantage of this device compared to conventional medical alarms is the incorporation of novel sounds to reduce the impact of alarm fatigue. An example of novel alarms is a “lub dub” sound to represent the physiological sounds of a heartbeat.

The principal components of the device are an Arduino UNO, a wave shield, an LCD screen, and a pulse sensor. Users can select alarm type (conventional or novel) and relative volume. Compared to a previous design, the current device features increased sensitivity, variable alarm sounds, and physiological monitoring. This device aims to improve psychoacoustic properties of alarm system presentation and hopes to enhance the quality of medical care globally.



This device monitors and displays heart rate and allows the user to control alarm presentation and volume relative to background noise. The sound quality of the alarm is improved by the wave shield and the audio amplifier, while the volume is controlled by input from the microphones.

## FeedRite Feeding Tube Placement System

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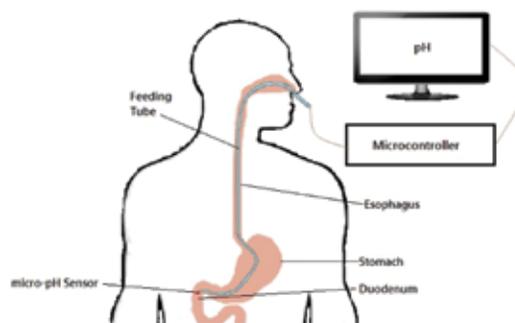
### SPONSOR:

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Gastric bypass is an invasive, risky procedure to promote weight loss and the reversal of obesity-related conditions such as Type II Diabetes. Unfortunately, this procedure is expensive and has restrictions on age, health, and minimum BMI, which results in a narrow patient population. Current analogs include naso-duodenal feeding tubes that rely on repeated fluoroscopic procedures, exposing the patient to unnecessary doses of radiation, or are expensive and unreliable.

The FeedRite feeding tube consists of a removable insert placed inside a standard feeding tube. The insert tip contains microsensors that measure various physiological values. Data are sent to signal calibration units via fiber optic wires, finally interfacing with an Arduino microcontroller to display the physiological parameters detected. The health care provider conducting the placement can then ascertain where the end of the feeding tube is located by comparing the reported values to a list of reference values. The use of radiation-free techniques detecting naturally occurring physiological changes makes the FeedRite feeding tube safer, more affordable, and more reliable than existing analogs to gastric bypass. This design will help patients who cannot afford, or do not qualify for, gastric bypass lose weight until they make lifestyle changes necessary to maintain weight loss.



**The FeedRite Feeding Tube Placement System tracks the physiological environment of the tip of the feeding tube to alert the health care provider to the tube's current position along the gastrointestinal tract as it travels through the nasal cavity, esophagus, stomach, and into the duodenum.**

## Medical Rounds Communication System

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Beside education, a period of time when a physician speaks directly with a patient, is crucial to the patient's understanding of their medical condition. Physicians' rounds are loosely scheduled and patients can become frustrated by waiting or unintentionally miss their physicians, causing ineffective education. Improving education is important for increasing patient compliance and, thus, reducing the number of readmissions to the hospital.

Our system, Dr. Roundabout, seeks to increase communication between physician and patient by allowing the patient to have an estimated arrival time of the physician during rounds. The system uses Bluetooth communication between beacons and the physician's phone in order to determine when the physician is present on a specific floor of the hospital. A smartphone app will allow the doctor to communicate whether or not they are performing rounds. The patients on the floor will then be notified with a time estimate for when the doctor will arrive. No current technology is utilized to enhance this patient-physician connection in hospitals. This technology will optimize bedside education time, improve patient compliance, and increase hospital efficiency.



**Devices utilized in the Dr. Roundabout System – beacon, smartphone with app, and computer**

## Hearing Aid FM Device

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Frequency-modulated (FM) technology for hearing aids has been developed so individuals receive a wireless signal to an ear-level receiver coupled to the hearing aid from a speaker using a microphone. One limitation of this technology is that regardless of where the speaker is within the transmission radius, the speech signal remains at a constant amplitude and is the same for both ears, known as mono. Considering that any acoustic cues indicating distance are lacking, the goal is to recreate multiple cues through software modification of the mono signal so the user has an understanding of speaker distance. This code must be lightweight, as its hardware will eventually be within or a small attachment to a hearing aid, yet must provide cues nearly as strong as cues normal hearing offers.

Although our project calls only for functioning code, we have hardware to display its full functionality. An Arduino gathers an input sound, receives a distance value, applies the filters, and outputs the signal to headphones. As the distance data changes, the listener will be able to detect changes in the output sound. This is a definitive advantage over all current FM hearing aid systems, as they lack any localization cues. This system has the ability to be applied as an added feature to current FM devices.



Headphone used in testing that is similar to hearing aids.

## Anatolution

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### SPONSOR:

Vanderbilt University Department of Psychological Sciences



Current methods employed in stereological research can be extremely tedious and require a high level of expertise. From acquiring images of neural tissues to quantifying the biomarkers within those images, there are several sub-processes that can be streamlined or automated.

Our proposed design solution comes in three parts: automation of image acquisition, creation of a web-hosted database, and post-processing segmentation. Using Micro-Manager, an open source microscopy software, we were able to automate image acquisition across a user-identified region of interest. Instead of manually moving to each probe and focal depth, this program is able to capture hundreds of images automatically. Furthermore, once captured, these images are uploaded to a cloud-based server to allow open access post-processing via our website. However, prior to manual processing, each image is passed through a MATLAB segmentation pipeline that identifies in-focus cells and quantifies cell sizes and counts. Researchers can then use the imaging toolbar to complete quantification of these semi-processed images. Once integrated into the Kaas lab, this system will greatly expedite the imaging process, increase accessibility to these images, and standardize potentially subjective components of imaging research.



Sample tissue from a primate's visual cortex. Note the high cell concentration within the highlighted cuneate nuclei.

## A Slimmer and Improved Hip Protector

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### SPONSOR:

HipCheck



Hip fractures in the elderly due to falls is a serious problem. These hip fractures not only incur billions in health care costs every year, but also severely impair the victims. The mortality rate for the year following a hip fracture is a shocking 33 percent. Current hip protectors show some efficacy but suffer from very poor compliance rates due to their bulkiness.

The HipCheck team is designing and testing a hip protector that is slim (less than 1 inch thick) yet still effective at preventing a hip fracture during a fall. A hip protector protects the user from a fracture by attenuating the force that reaches the upper femur and/or distributing the force away from the upper femur. To achieve proper protection without sacrificing thickness, the team is testing many different foams, gels, and shapes to determine the best combination thereof to be used in a final prototype. A vertical drop tower machine was designed and built by our team to simulate falls for testing the device. Prototypes were shown to nursing home residents to validate that the designs are sufficiently subtle, which has been the major obstacle to hip protector acceptance. This hip protector is expected to achieve compliance rates unparalleled by the competition due to its slimmer and stylish design while still effective at protecting from a fall.



**Hip protector prototype. Despite its slim and stylish design, it still effectively prevents hip fractures in the event of a fall.**

## LUMASIL: A Device for Treating Diabetic Foot Ulcers

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Vanderbilt University Medical Center,  
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Diabetes affects approximately 29.1 million Americans today. Twenty-five percent of diabetic patients develop diabetic foot ulcers (DFUs) over their lifetime. About 80,000 lower-limb amputations occur in the U.S. every year as a result of DFUs. The current standard of care passively treats the DFU with an off-loading total contact cast. Due to this passive healing method, DFUs may not heal completely, which increases the risk of infection and possible amputation. In recent years, studies have shown that low-level light therapy (LLLT) is a viable, active treatment method that accelerates wound healing and decreases the incidence of infection. This team developed a medical device, LumaSil, utilizing LLLT with infrared (IR) and blue light to actively heal DFUs as an addition to the standard of care.

LumaSil is a low-risk, waterproof, shock resistant device that seeks to actively heal DFUs with no additional effort from the patient. This device automatically controls the therapeutic dosage of light using custom circuitry. Incorporated into the cast, the device is simple to apply, durable, and low-profile. Through a feasibility study, the team worked to prove that LumaSil is safe, automated, and will reduce healing time and incidence of infection.



**3D rendering of LumaSil, a low-level light therapy device to aid diabetic foot ulcer healing. Light generated in an external module on the cast is delivered to the wound via fiber optic cables embedded in a silicone halo.**

# SteadyScan: MRI Stabilization Device

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**ADVISER:**

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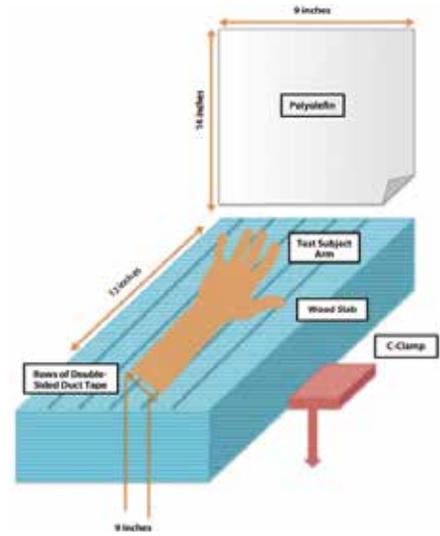
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Of the approximately 30 million MRI scans performed each year in the United States, many must be repeated because a patient involuntarily or unknowingly moves during the scan. These small movements cause image registration issues, which undermine diagnosis. Retaking images wastes both time and money. Our team created an effective, comfortable, low cost, and easy to use solution to this problem. The result is SteadyScan.

SteadyScan consists of a silicone base and a unique polymer plastic that conforms to the patient and adheres to the silicone base. A technician places the silicone base on the surface where the patient rests and exposes the adhesive surface. In our example, a technician places a patient's arm atop the base, then places a plastic sheet atop the patient, molds it to the patient's body, and adheres it to the base. This results in movement confined to less than 1mm without sacrificing comfort, which eliminates significant registration issues, and saves time and money.



SteadyScan diagram



Design Day 2015 in Featheringill Hall.

## Developing Software for Optimal Heat Exchange Networks

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Chemical Engineering  
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Rising energy costs, along with growing demand for environmentally responsible manufacturing, have pressured chemical production plants to reduce environmental impact and energy usage. The use of heat exchange networks (HENs) generally results in 20-30 percent energy savings in heating and cooling utilities, creating the need for a method efficient in designing and optimizing these networks. Our software enables the design of optimal HENs considering various user inputs, design parameters, preliminary cost estimates, and plant constraints. The program will produce various results to aid in designing a HEN, including a graphical representation of the optimally designed HEN, stream data for all material streams involved (at least 50), a preliminary cost analysis of the utilities and capital equipment used, and an intuitive user interface. While there currently are programs that assist designers in producing various aspects of HENs, there is no readily-available and fully comprehensive HEN optimization software. Our program provides such a comprehensive solution. Integration of this program into manufacturing companies will enable engineers to more effectively create optimal HEN designs, and thus, reduce energy usage and utility costs for operations.



**Through an intuitive user interface and graphical solving method, our software allows users to design optimal heat exchange networks, leading to significant energy savings in an industrial setting.**

## Industrial Water Use and Reuse System Design

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Chemical companies spend a substantial amount of money on water usage and wastewater disposal. Often, plants exclusively use fresh water feeds rather than recycle slightly contaminated streams. Production costs can be greatly reduced by integrating these partially impure streams with more robust unit operations.

Software capable of identifying an optimal wastewater recycle system can aid designers in generating a more cost-effective process on either new or renovated plants. Our software will predict an optimal recycle configuration for up to 25 water users and 25 wastewater generators. It will also be equipped with a cost estimator to predict the return on investment for every water integration process that the program designs. This prediction will allow the designer to discern which improvements would be most economical.

An Excel-based program will be used as the user interface. This will allow for widespread implementation and simple customization of our product. In addition to an optimal recycling network, our product will contain features that allow the designer to manually force or forbid certain stream connections, effectively generating more practical, but suboptimal direct recycle systems and water purification methods.



**Our dynamic software aims to reduce the amount of wastewater that is discharged by industrial plants, which allows for greatly reduced utility costs.**

## Selective Catalyst System

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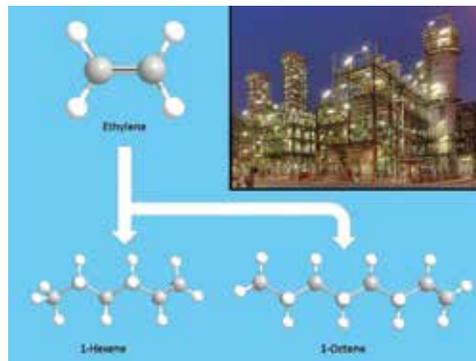
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Linear Alpha Olefins (LAO) are straight chain alkenes with terminal double bonds that are used as co-monomer units in polymer manufacturing. Applications for LAO include polyethylene plastics, lubricant additives, and surfactant intermediates. Traditionally, LAO manufacture produces a wide distribution of monomers. The team sought a process to maximize the yield of 1-hexene and 1-octene, the most commercially viable products. We achieved this by using inexpensive ethylene feedstock reacting with a newly discovered and highly selective catalyst system that only produces the two desirable compounds at adjustable ratios that meet market needs.

We designed an economically feasible plant capable of producing 100 MM lbs/year of LAO. As a function of the catalyst system, the product ratios are adjustable. Additionally, our plant operated within environmental and safety regulations. This design will accrue higher profit margins than other existing competitors because of its ability to reliably generate the lucrative compounds in high yield.



Using a reaction pathway from ethylene to 1-hexene and 1-octene products enabled us to design and cost a linear alpha olefin commercial production facility.

## Designing a Phosgene-Free Process to Produce Polycarbonates

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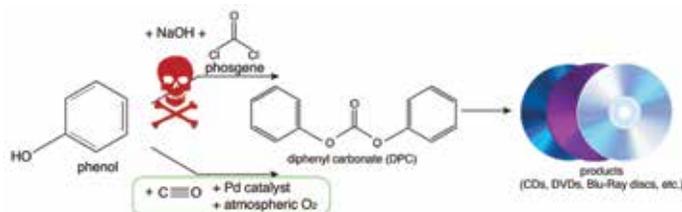
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Polycarbonates are widely used in many applications such as in phones, DVDs, and bullet-resistant windows because of their optical clarity and impact resistance. In the past, polycarbonates have been made with phosgene ( $\text{COCl}_2$ ) as a reactant

to create an intermediate, diphenyl carbonate (DPC). Phosgene is known to be harmful to the atmosphere and highly toxic to humans, causing major injury or even death. In the chemical manufacturing industry, minimizing economic and environmental waste is highly desirable, whether it is through production of highly toxic intermediates in a synthesis plant, disposition of potentially useful chemicals, or pollutant production.

The overall approach is to create a phosgene-free plant design incorporating the direct oxidative carbonylation of phenol to DPC. The process requires a palladium halide catalyst with one of many nitrogen-containing heterocyclic compounds as co-catalysts. An economic analysis is carried out to ensure that the process is economically feasible and profitable. We hope to produce a design that meets the specified production goal of 100 million pounds per year of DPC while also being sustainable and cost-effective.



Phosgene-free diphenyl carbonate production from phenol. DPC is a primary component for polycarbonate, which is used in optical discs due to its high impact strength and optical clarity.

# Designing a Chlor-Alkali Brine Concentration Process to Improve the Recycling of Electrolysis Reagents

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An existing electrolysis process of brine to produce chlorine and caustic soda can be significantly improved by retrofit. The recycle capabilities of such a process can be enhanced, allowing for a more efficient overall process. Our goal was to design and optimize a brine concentration process to recycle sodium chloride from a spent brine stream back to the electrolysis unit. This recycle would reduce the water utility and raw material costs of the existing process. Multiple separation technologies including, but not limited to, crystallization, reverse osmosis, and evaporation will be considered to determine the most cost effective process design. The final design could use a single separation process or a hybrid combination. Our analysis will yield multiple practical design solutions with different separation techniques. These solutions will allow us to identify an optimal process design based on each technology's strengths and weaknesses.



A chlor-alkali electrolysis process we aim to improve by recycling reagents that leave in the waste stream.

# Mobile Wastewater Treatment System for Hydraulic Fracturing Waste

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Hydraulic fracturing (fracking) is an economically viable method of extracting natural gas from shale. The fracking process involves pumping millions of gallons of water into gas wells over a mile beneath the surface, creating fissures in the formations to recover oil and gas. Fracturing fluid consists mostly of water but also contains sand, surfactants, gelling agents, corrosion inhibitors, proprietary chemicals, and other compounds. Approximately 15-80 percent of the injected fluid and naturally occurring chemicals return to the surface as flowback fluid. The fluid can be harmful to the environment, so it is typically stored in surface containment ponds and disposed of in deep-injection wells.



A Dissolved Air Flotation (DAF) tank, shown above, forms the basis of our process to remove chemicals and suspended solids from hydraulic fracturing flowback fluid.

The goal of our project is to design a mobile waste treatment system that treats the waste stream and prepares it for reuse in subsequent fracturing operations. This mobile system will use various chemical processes to remove any constituents hindering the performance of the fracturing fluid. Treated waste streams will be combined with freshwater to produce a fracturing fluid available for reuse. Such a design will help recycle the flowback fluid, reduce water utilities, and minimize the environmental impact the fracking process will cause.

## Production of Chemicals from Ethane Derived from Marcellus Shale

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The project goal is to design a plant that uses ethane to produce 100,000 tonnes of ethylene, 200,000 tonnes of acetic acid and 200,000 tonnes of vinyl acetate monomer (VAM) annually. Ethane can be derived from Marcellus shale which spans across most states in northeastern America, and contains a rich supply of natural gas. Ethane gas is extracted from the shale by drilling and hydraulic fracturing before being supplied to the plant for further processing. Our strategy is to use an integrated ethylene-vinyl acetate monomer process to yield the desired chemicals at the targeted production rate. This process involves the oxidation of ethane to ethylene and acetic acid, and the production of VAM through vapor-phase acetoxylation of ethylene. It is selected based on the information available on the processes, and the ease of simulation. The plant design outperforms existing solutions in energy conservation, product purity, and plant expenditure.



The goal of our design project is to optimize an ethane plant producing ethylene, acetic acid and vinyl acetate monomer.

## Conversion of Natural Gas to Aromatics

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Approximately 14 million tons of benzene, toluene, and xylene (BTX) are produced annually by the United States petrochemical industry. These aromatics are traditionally produced from crude oil by catalytic naphtha reforming or by naphtha steam cracking. With the resurgence of domestic fracking, natural gas can be used as a cheaper feedstock than crude oil to produce BTX with modified zeolite catalysts. Our goal is to design an economical and environmentally friendly process converting natural gas to BTX with a higher fraction of para-xylene than conventionally produced aromatics.



A commodity chemical production facility, as commonly seen in the Port Arthur, Texas area. A facility designed for BTX production contains similar infrastructure as that seen above.

Our design consists of a two-step reaction process. The first step uses a modified zeolite dehydrocyclization catalyst to convert methane in natural gas to benzene. The second step uses another zeolite catalyst to alkylate the benzene to toluene and mixed xylenes with a high selectivity toward para-xylene.

Benzene alkylation requires either methanol or syngas as a reactant. The reactant used in our process is determined by an economic analysis of importing methanol by pipeline versus producing syngas on-site. The rest of our process focuses on isolating valuable para-xylene, which is used in the polyethylene terephthalate (PET) value chain. The remaining BTX is separated into component streams and sold with the pure para-xylene.

## Multi-product Brewing

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Beer brewing is one of the largest industries in the world. Every day, breweries produce more than 100 million barrels a day of beer in various styles and flavors. It is important for beer companies to design their breweries to optimize efficiency and savings while minimizing environmental impact.

Our team designed a large-scale microbrewery capable of 100 million barrels per year. The designed brewery should produce 5 year-round varieties of beer, including IPAs, stouts, pilsners, and lagers, in addition to 4 seasonal and 4 limited edition brews. The design is expected to maximize the recycling of waste products of the process with zero emissions. Our design is more environmentally friendly than the competition. In addition to designing the process, we decided whether to build a new brewery to make all the beers, contract out the production to an existing brewery, or use a combination of the two methods based on economic analysis. We expect our design to be economically optimal while still producing the required volumes of quality beer and meeting the other specified requirements.



An example of typical brewing equipment used by breweries to produce beer.

## Designing a Production Facility for a New Pegylated Fusion Protein to Combat Vision Loss

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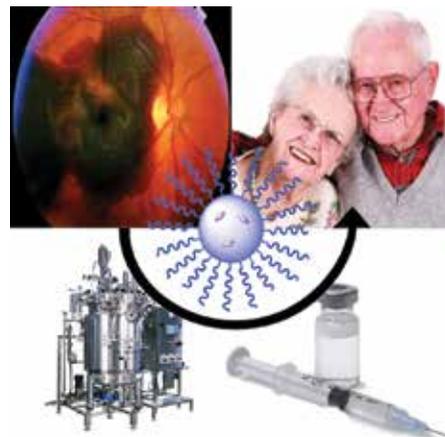
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Currently, more than 2.75 million people are affected by Wet Macular Degeneration (WMD) and Diabetic Macular Edema (DME) across the United States and Europe. These two diseases cause chronic vision loss due to leakage from blood vessels into the eye. The team's goal is to meet the demand of the U.S. and European markets for treatment of these diseases. We accomplished this goal by producing a new pegylated anti-VEGF protein that allows for fewer injection treatments and is longer acting than current products. The team designed the manufacturing process and production facility needed to produce the life-improving protein product on a commercial scale.

For the facility design, a combination of traditional and disposable technologies were used to ease and expedite production. A balance between technologies was determined based upon capital costs, budget, and process efficacy. These technologies were applied across different process stages from vial thaw to purification. The manufacturing facility that was designed allows the company to deliver high quality product to the market and impact the level of care for WMD and DME patients globally.



A manufacturing process for new pegylated monoclonal antibody. This antibody can be used in the treatment of multiple eye diseases.

# Manufacturing of Lysine Ethyl Ester Triisocyanate for Automotive Clear Coats and Biomedical Materials

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Lysine ethyl ester triisocyanate (LTI) has optical properties that can be used in automotive clear coats and resorbable capabilities that can be used in biomaterials. However, the original discontinued production pathway of LTI followed hazardous and expensive processes and materials. A new design offers a more environmentally friendly, cost-effective, and safe method to produce LTI with the decomposition of triphosgene to phosgene and production of lysine ester trihydrochloride salt from lysine hydrochloride and ethanolamine hydrochloride. This design achieves the target production of 1000 kg/year with a \$60/kg LTI production cost, one-fifth the cost of the previous method. The raw materials can be purchased or manufactured on-site, so cost analysis determines which method is the most profitable for each raw material.



This design centers on the manufacturing of LTI through scaling a more cost-effective design. A more effective design will lead to a lower cost production of the chemical needed for bone grafts and automotive clear coats.

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

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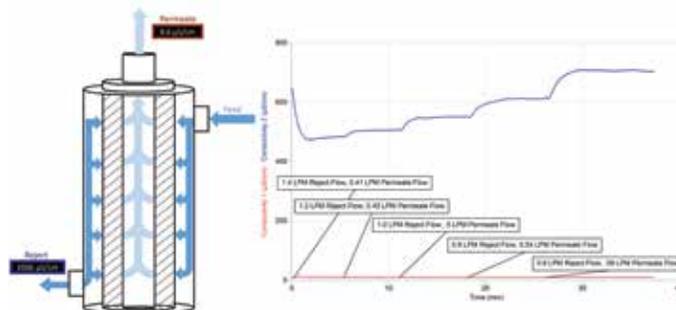
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Vanderbilt's unit operations lab in the Department of Chemical and Biomolecular Engineering allows students to experience the systems that chemical engineers encounter regularly. Each system has a series of probes that must be continually monitored throughout the lab, yet no existing software relates the readings

on these probes to a visual representation. This project connects the measurements from each of the laboratory unit systems to live and unique visual representations. The interface permits greater understanding of the labs while allowing instructors to monitor the progress of the experiments.

A range of connections will link the probes to their station computers. Once connected, LabVIEW programming will process the readings into a user friendly format displaying basic figures and current data on a system-specific diagram. The visual will be wirelessly transferred from the computer to the corresponding external monitor positioned above each station. Previous iterations of the project incorporated basic attempts at interacting LabVIEW with probe readings. Our efforts will complete the connection between these values and the user interface. The interface will provide a clear visual connection between the measurements being made and the system itself. Ideally, the process will be convenient and viable enough to be consistently incorporated in undergraduate labs each semester.



The interface created (example shown above) displays real-time updates of laboratory probe measurements and provides basic graphical interpretations for the users.

# Design and Implementation of a Sensor Inventory System for Chemical Engineering Labs

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In 2013, a measurement lab component was incorporated into chemical engineering undergraduate labs, requiring student groups to design, conduct, and present individual lab experiments. These experiments are to be conducted throughout the course with sensor equipment provided by the School of Engineering's Department of Chemical and Biomolecular Engineering.

More than 100 students use these sensors each semester. However, no computerized inventory system is in place to manage the use of the 50 different sensors and interfaces. To keep track of these expensive pieces of equipment, the team designed a universally accessible, computerized inventory system that not only records the user, date, and location of each of the devices, but also displays the availability of equipment. The inventory system incorporates a series of scanners, the creation of barcodes for each piece of equipment, and the design of Excel software to optimize the sensor check out process. Ideally, the goal is to overlook the implementation of the designed inventory system in all 16 undergraduate lab groups and provide additional mentorship to the groups throughout the course.



**Integration of an automated inventory tracking system for ChBE labs, connecting RFID technology to a spreadsheet, will greatly improve the efficiency and freedom of use of sensors in the lab.**



Design Studio President Dominic Ghilardi (ME'18) readies a 3D printer for a project.

## Steel Team 6: ASCE-AISC Student Steel Bridge Competition

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### SPONSOR:

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Civil Engineers



The objective of the ASCE-AISC Student Steel Bridge Competition is to foster learning and innovation in engineering students by challenging them to apply their skills in a real-world situation. As part of this competition, a team of five civil engineering students designed, fabricated, and constructed a bridge capable of supporting 2,500 pounds. The team identified three priorities to guide design. These priorities—simplicity, efficiency, and aesthetics—led to a bridge design that included a three-dimensional lower truss system and an arched overhead truss. The result was a unique and inspiring bridge design. Through this project, students learned valuable skills such as MIG welding, and gained significant respect for safety, cost, material selection, fabrication, construction, and project management. These considerations can impact design severely but are not always addressed in the classroom. A winning bridge must excel in the areas of lightness, stiffness, deflection, and construction speed.



The 1:10 model bridge weighs 285 pounds, spans 20 feet, and stands 5 feet tall.

## Steel Team 2: BYOB (Build Your Own Bridge)

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Jeremy Tucker  
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The goal was to create a steel bridge in accordance with the American Society of Civil Engineers guidelines with the hopes of competing in the regional competition this year. A major goal was to fabricate a bridge that could hold 2,500 pounds of loading. Given that time and money are concerns in every construction project, the bridge also was designed to be lightweight and easily constructed. The members of this team worked collaboratively to design and fabricate the bridge, utilizing a modular design for the truss sections spanning the bridge. The design is simplistic with the goal of allowing a short construction time and efficient fabrication process. After the first test loading, BYOB decided to modify the bridge and add an under-truss to strengthen the span of the bridge. While BYOB will not be the team representing Vanderbilt at the ASCE regional competition, the project has been worthwhile and has tested all members' project management and civil engineering skills.



BYOB team members construct their bridge at the Vanderbilt mock ASCE Steel Bridge Competition held Feb. 20, 2016.

# Colorado Foothills Zero Energy Home at Sterling Ranch

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National Renewable Energy Lab  
Epic Homes  
Vanderbilt University



STERLING RANCH  
COLORADO



A shortcoming of most home designs today is that they fail to account for their environmental impact and long-term energy costs. Our team is researching methods of producing a cost-effective, zero-energy alternative for the emerging energy-conscious homebuyers of Sterling Ranch, a sustainable development being constructed in Highlands Ranch, Colorado. Using cloud computing to run large-scale simulations in BEopt, an energy and cost optimization program developed by the National Renewable Energy Laboratory, our team analyzed multiple home designs to economically optimize the construction materials and appliances selected.



3D Revit rendering of the Colorado Foothills home design being analyzed for Sterling Ranch

A home obtains zero-energy status when its on-site energy consumption is balanced by an equal or greater amount of on-site renewable energy production. In order to best offset the house's energy demands, photovoltaic cells and other sustainable energy technologies were evaluated in consideration of Sterling Ranch's climate, geography, and available resources. The Colorado Foothills home is one of three floor plan designs being built by the homebuilder Epic Homes in Sterling Ranch's second filing next year. Our team's goal is to provide Epic with a zero energy home design that meets or exceeds the aforementioned criteria in a cost-effective and easily reproducible approach.



Gabbey Tate (left) and Tucker Kirven work in the Vanderbilt Motorsports lab.

# Modern Prairie Zero Energy Home at Sterling Ranch

## TEAM MEMBERS:

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## SPONSORS:

Sterling Ranch  
Vanderbilt University

In the world of design, sustainability is an important factor that is breaching the walls of commercial development and making its way into residential developments, including the Sterling Ranch development. Sterling Ranch is a 12,000-home, 3,400-acre development located southwest of Denver, Colorado, that is emphasizing sustainability for its modern homes. The goal of the project team is to design a Zero Energy Home (ZEH) to be implemented within Sterling Ranch. A ZEH intersects energy efficiency and renewable energy generation in order to produce as much—or more—on-site energy as energy that is consumed by the home. Throughout the project, the team worked closely with Sterling Ranch, the National Renewable Energy Laboratory, and local engineering design firm Smith Seckman Reid, Inc. Initially, the team completed a preliminary energy analysis on the given home to understand the baseline energy usage and identify areas for improvement. During the rest of the year, the team set out to achieve both greater energy efficiency and energy generation through research and selection of optimal building materials, appliances, and solar panels to complete the Zero Energy Home Design.



Revit rendering of Modern Prairie on site at Sterling Ranch



Civil engineering majors Maia Alexander, Austin Channel and Kofi Christie (L-R) lab test wind shears and wind speeds from the blades.



STERLING RANCH  
COLORADO

VANDERBILT UNIVERSITY

# Sterling Ranch Community Water Monitoring System

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## SPONSORS:

Sterling Ranch  
Vanderbilt University

Due to water scarcity in Colorado, Sterling Ranch places high emphasis on sustainable water management practices to ensure that residents have long-term access to safe and affordable water resources while minimizing impacts to the environment. To assist Sterling Ranch in its efforts, the team's goal is to develop a water quality monitoring system and sampling and analysis plan to gather information throughout the site in order to support decisions regarding collection, storage, and reuse of harvested rainwater. Based on Sterling Ranch objectives, hydrologic analyses, and site plans, the team developed recommendations for key water quality monitoring points, monitoring equipment, a monitoring strategy, and corresponding cost estimates. These items were included in a proposal package for Sterling Ranch. The team's recommendations were presented and a decision will be made regarding implementation of the team's work. The deliverables represent a cost-effective system developed through an iterative design and feedback process that provides data to support the sustainable efforts of the community through continued system modification. This system embodies the ideal of sustainability by meeting both the present and future needs of Sterling Ranch.



This shows the proposed water monitoring sampling locations and their relationship to the Sterling Ranch development and the Chatfield Watershed.



# Solar Powered Desalination with Capacitive Deionization (CDI)

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## SPONSORS:

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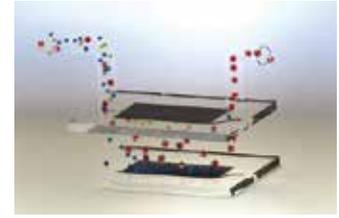


STERLING RANCH  
COLORADO

VANDERBILT UNIVERSITY

Access to safe drinking water remains a significant challenge to many communities, especially those with limited access to large-scale infrastructure of power and water supply. Furthermore, in some of these areas, the only possible water source left is brackish groundwater, which contains variably less saline than seawater. Existing water treatment technologies all have significant limitations when applied in small-scale and off-grid brackish groundwater desalination. For instance, reverse osmosis is more suitable for continuous operation, which poses a challenge using the intermittent solar energy, whereas distillation processes are inherently energy inefficient.

The solution to this issue is the emerging desalination process known as Capacitive Deionization (CDI), which deionizes water by applying an electrical potential difference over a pair of porous carbon electrodes. During the process, anions (negatively charged ions) are removed from the water and stored in the positively polarized electrode; likewise, cations (positively charged ions) are stored in the negatively polarized electrode. Consequently, this has motivated our goal for the project which is to design and build a scalable, integrated solar-powered water desalination system using CDI as the core technology. Ultimately, the team would like to implement a pilot system in a relevant community in the U.S. or abroad for field testing.



The device will desalinate a salt solution by attracting the ions in the water to oppositely charged electrodes.



# Sterling Ranch Community Energy

## TEAM MEMBERS:

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Virinchi Juttukonda  
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## SPONSORS:

Sterling Ranch  
Development Company  
Xcel Energy  
Vanderbilt University



Sterling Ranch is a sustainable community currently under construction a few miles south of Denver. The community energy team is working to determine the amount of energy that can be generated at the Sterling Ranch development site by photovoltaic (PV) solar panels. The community energy team is utilizing a tool developed by the National Renewable Energy Laboratory named BEopt to generate models of the homes in the development. These models can be used to estimate the amount of energy the PV panels will generate as well as the amount of energy consumed by the home. This data will be used to determine time-of-day PV generation and analyzed to determine what house designs and orientations generate the most energy for the community. Additionally, consideration of a 2 megawatt solar farm will be included in analysis. The team will present a final recommendation to the Sterling Ranch Development Company to help them optimize the layout and development of future housing projects.



STERLING RANCH  
COLORADO

# Photovoltaic (PV) Water Heating System

## TEAM MEMBERS:

Nurnabilah Abu Hassan Sha'ari  
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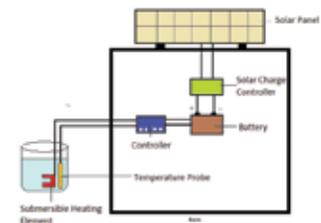
Ralph Bruce, Professor of Practice of Electrical Engineering

## SPONSOR:

Amaroo Hills Emu Farm

**AMAROO HILLS  
EMU FARM**

Water freezes in sub-zero temperatures, thus threatening the water supply for the emu birds at Amaroo Hills Emu Farm. The current method used to counter this problem involves manually replacing the frozen water from the container with fresh water. The present method is less efficient and time-consuming. Therefore, our main purpose of this project is to design a system which utilizes solar energy to provide drinkable water for the birds. This system negates the manual labor required to replace the frozen water. By using renewable energy, we are able to create a system which is environmentally friendly and sustainable. The sunlight collected during the day will be stored in the battery, which will then provide power to the heating element at specific conditions. The system will be activated when the temperature falls below -2 degrees Celsius. Overall, the system provides an easy solution for farm owners to ensure a sufficient amount of drinkable water during extreme cold weather.



The overall system design for the PV-based heating

## Autonomous Utility Robot

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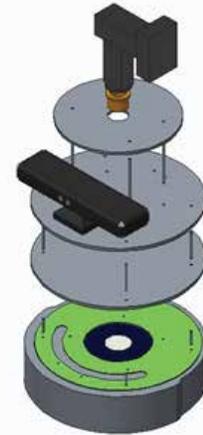
### SPONSOR:

Metova



Traditional asset tracking systems require objects to be scanned manually or necessitate that specific infrastructure be in place before an asset's location can be ascertained. The Autonomous Utility Robot aims to solve this problem by automating the asset location process. To do this, the team developed a robot capable of driving around mapped surroundings and completing this tracking process without a need for human intervention. Operating in a well-defined space, the robot continuously navigates its environment, searching for assets. Once located in space, the robot updates the asset's location relative to its position on an internal world map. The end result is a user-faced map of the entire environment containing the location of every asset detected throughout the process.

Navigation is achieved using a combination of internal odometry and simultaneous localization and mapping (SLAM). Once an initial map of the environment is generated, the asset location process begins. Tracking is achieved using a combination of radio-frequency identification (RFID) tags and an ultra-high frequency (UHF) receiver. All local processes are completed through Robot Operating System (ROS) on the onboard system on a chip (SoC) computer before being shared with the end-user through a web-based platform.



Model of a constructed Autonomous Utility Robot

## Android Application Security Analyzer

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### SPONSOR:

Metova



Metova, the project sponsor, is a professional services company that develops mobile applications. Recently, Metova expanded into the government sector and thus needs to ensure security in the mobile applications it develops. Metova currently has an internal application that depicts the status of its various mobile applications. However, only two security tests exist in this internal application.

The project is to build a web application that analyzes the security of mobile applications. Authorized users will be able to add Android applications for automated testing. The web application will provide robust reporting tools which will help engineers quickly identify the origin of security issues in the application. The team has been leveraging free, open-source software to implement portions of the project. Metova plans on integrating what the team develops with their own mobile application dashboard. This will provide a valuable service to Metova, since it will allow them to have a better way to test their mobile applications and only allow safe applications to get to the market.



An illustration of the analyzer

## Walk-all-Ova: Indoor Positioning System

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### SPONSOR:

Metova



We are Walk-all-Ova, the Metova Indoor Positioning System (IPS) team. The Metova IPS project serves to solve the complications that arise from being in an office: "Where is John Doe employee?" "How long has John Doe been gone today?" or even "I forgot to turn off notifications for my meeting." These problems are disparate, but they have a common solution. Tracking smartphones over time throughout the day will allow a company to know where their employees have been, for how long, and other exciting possibilities. The goal of this project is to track Bluetooth-capable phones through an office.

By placing Bluetooth-emitting beacons around the office, an individual's phone can tell a web-based application which beacons it is close to. This data is cross-referenced with a list of what beacons are where. The results are a searchable database of smartphone locations around the office. This is better than a word-of-mouth system, or any other employee-based system, because it is passive; there need not be any input from other employees.



IPS workflow

## ISDE Satellite Tracking and Communication

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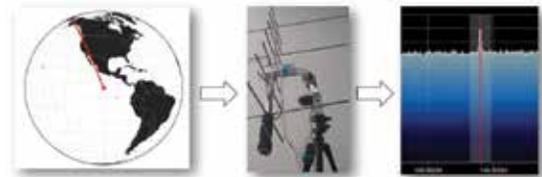
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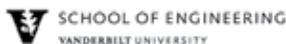
Institute for Space and Defense  
Electronics

Just last fall, the Institute for Space and Defense Electronics (ISDE), in partnership with the Amateur Radio Satellite Corporation (AMSAT), launched a small satellite called a CubeSat containing experiments regarding radiation effects on electronics in space. ISDE has several other CubeSats scheduled for launch in the near future but currently has no ground station of their own for communicating or gathering data from their satellites in orbit. For now, the satellite data can be accessed through AMSAT's extensive network of amateur radio operators worldwide. Our project's objective is to design and build ISDE a low-cost, complete satellite tracking and communication system of their own, making use of a software defined radio (SDR) to handle the central signal processing.

To accomplish this, the team developed an application that tracks satellites in real time. These data are then fed to a mechanical rotation system, which points an antenna directly at the satellite as it passes across the horizon. Signals received from the antenna are processed and decoded using the SDR, and from there the results are sent to the web for further research and analysis. Ultimately, this system will be handed off to ISDE and will be instrumental in facilitating their growing CubeSat program and future research efforts.



An overview of project sub-systems



## Acoustic Pill Mass Sensor

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### SPONSOR:

Quality Manufacturing  
Systems Inc.



Automated mail-order pharmacies fill thousands of prescriptions every day, and it is crucial that they dispense the right pills in the right quantity for every patient they serve. Pharmacies have safeguards to ensure the correct medication is loaded into each dispenser, but contaminants or broken pills cannot be detected once the machines are filled. Our team is building a sensor to enable a new generation of pill-dispensing machines that will not only count at high speeds but also check that every pill is intact.

Our design bounces each pill on a glass plate, and it measures the energy as the plate vibrates using a piezoelectric microphone. Besides accurately counting pills, the sensor will alert the facility's operators if an object that is too heavy or too light passes through. This analysis runs in real-time on a low-power microcontroller, enabling dispensing rates exceeding three pills per second.



An early prototype of our sensor analyzes the sound that pills make as they drop onto a glass plate.

## Vandy Van Bus Shelters

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### SPONSOR:

Vanderbilt University  
Police Department



Vanderbilt provides a valuable service to its students in the form of the Vandy Van system, but it lacks shelters to protect its patrons in inclement weather. The Vandy Van Bus Shelter design is a protective, useful, and aesthetically appealing shelter that will enhance user experience by providing riders with services they did not previously have available to them. This design incorporates safety, utility, and seating through elements that are both sustainable and ergonomic in order to satisfy the needs of students. The proposed solution is based on Vanderbilt architecture and includes electronics and security features, such as live route information and an emergency phone, that are absent in most standard urban designs. The brick and limestone model provides a more substantial construction that will seamlessly blend with campus architecture and add another visually pleasing structure to the university. It is the hope that, upon installation, students will come to value this resource as essential, driving the construction of shelters campus-wide.



Digital rendering of the proposed bus shelter at the Branscomb stop location

# OCRicket: Optical Character Recognition Service and Web Application

## TEAM MEMBER

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School of Engineering



```
{"response":{"language":"en","textAngle":0,"orientation":"Up","regions":[{"boundingBox":"9,95,255,72","lines":[{"boundingBox":"9,95,255,72","words":[{"boundingBox":"9,95,255,72","text":"OCRicket"}]}]}]}
```

Results of the OCRicket system parsing an image of the handwritten word "OCRicket"

So often, end users of software are required to enter information themselves that is easily accessible from another source. Unfortunately, the data contained in these sources (images, sounds, videos) are incredibly difficult to parse, clean, and store as machine-readable information. The best optical character recognition (OCR) engines are normally reserved for scientific research and are not available to the masses. OCRicket aims to fix this issue and help even the amateur developer build smarter apps through OCR. OCRicket is a service that allows users to submit images (via a url), which it analyzes, pulls out text in the image, and returns a data structure containing that text. OCRicket is a multi-layer web application exposing a RESTful API with publicly accessible routes allowing a user to "textify" their preferred images. To power the image-to-text conversion capability of the API, OCRicket utilizes Microsoft's Beta version Project Oxford, providing Artificial Intelligences as a service. Recent tests of OCRicket have revealed proper operation of the API and impressive parsing results from Microsoft's OCR service. Future implementations of this software could include features such as tiered-usage plans, personalized OCRicket profiles, and social sharing options.

## Locale

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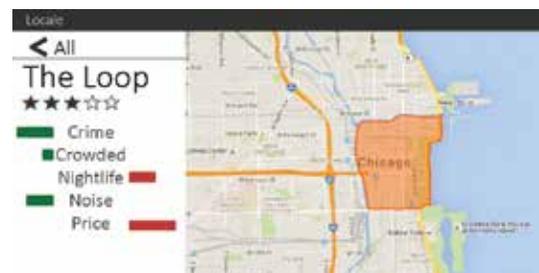
## SPONSOR:

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When moving to a large city, it is often difficult to find a community that matches your personality and budget. Locale aggregates data collected by municipalities, allowing users to easily compare communities. First, users answer simple questions to gauge their tolerance for crime, noise, nightlife, and several other metrics. Locale then uses these preferences to rank communities relative to the city average and displays the results on an interactive map.

Publicly available data is retrieved from city databases, Google Places, and Trulia. This data is then normalized and stored for quick lookup. No existing solution combines data from multiple sources or allows users to easily compare multiple communities. Once completed, users will be able to quickly find a compatible community, which will dramatically narrow their housing search.



This is a proposal for the final user interface. Here, the user has selected a community that matches three out of five criteria. The colored bars indicate which criteria match and how much each differs from the city average.

# SurveyGen: A Versatile, Intuitive and Secure Survey Application for Research Scientists

## TEAM MEMBERS:

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## ADVISER

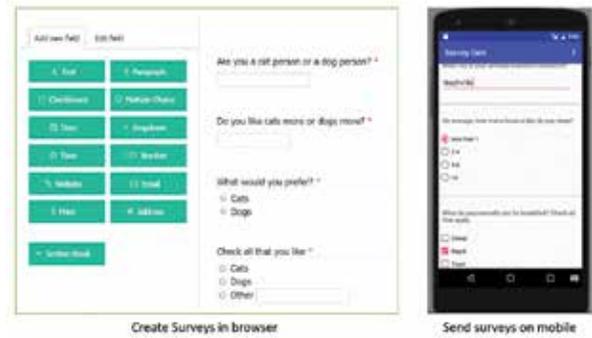
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## SPONSOR:

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Surveys are critical data collection tools for sociologists, psychologists, and biologists. They allow research scientists to gather self-reported and automatically reported data from large samples of targeted individuals over an extended period. SurveyGen provides scientists with a streamlined but still privacy-conscious means of creating and disseminating intuitive surveys for mobile devices.



Screen shots of surveys

Most currently available survey generators do not support collection of nonstandard data types. They also do not offer easy-to-use interfaces for survey managers and survey participants. The few survey generators that do advertise these features fail to provide intuitive, dynamic mobile interfaces. SurveyGen avoids these pitfalls by supporting the collection of geolocation data and periodic data, offering convenient user interfaces for both managers and participants, and by using stringent security protocols that meet the standards of research scientists. These improvements increase the incisiveness of surveys and lower the barrier to survey creation and participation, all while maintaining compliance with academic standards.

# Clique: A Democratic Approach to Creating Playlists

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At house parties across college campuses, the choice of music is usually decided by the party host. This system will almost certainly fail to satisfy the people going to the party. The phone application Clique will try to solve this problem by making the playlist-building process dynamic and democratic.



A screen shot of Clique

When using this application, one user will have "master" status to the playlist. The master user will set a password for the playlist. Anyone wishing to connect to the playlist must know this password to participate. Once someone has input the password to the playlist, they will be able to vote for any song that is local on the phone. All participants will be available to vote for which song should be played next. If the song is not a local file, participants can also suggest a song from YouTube. The app will use a node.js express backend using mongoDB as a database and will be implemented on Android and iOS. Other applications usually use platforms such as Spotify to create playlists like this. Not everyone has these platforms. Our application is more accessible and flexible through the use of YouTube.

## Pixel Perfect Recreation of Maze War

### TEAM MEMBERS:

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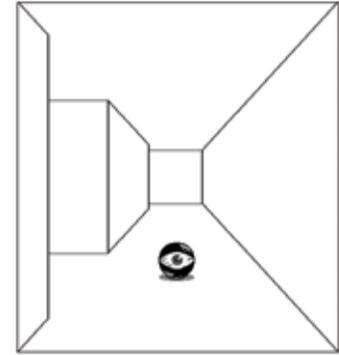
### SPONSOR:

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Maze War was the first First Person Shooter (FPS) game ever created and a fundamental piece of software that paved the way for many of today's modern games. The goal for this project was to recreate the 1977 version of Maze War for the Xerox Alto with pixel-perfect accuracy so that current and future generations can experience this key part of software and videogame history.

This project integrated outdated visual technologies such as one-point-perspective 3D rendering with current artificial intelligence, rendering, and network systems. Most of the work to recreate this game was dedicated to finding and implementing reference materials. Fonts, user interface layouts, and perspective points had to be carefully measured and recreated to achieve a pixel-perfect replica. Additionally, care was taken to ensure that any additional features added did not affect the visual aesthetic or game-play of the original. The final product's source code is openly available on GitHub and can be run natively on Windows and OSX, or through a web browser using WebGL.



Final gameplay UI for Maze War

## Hanseatic: A Model-Integrated Gaming Framework

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### ADVISER

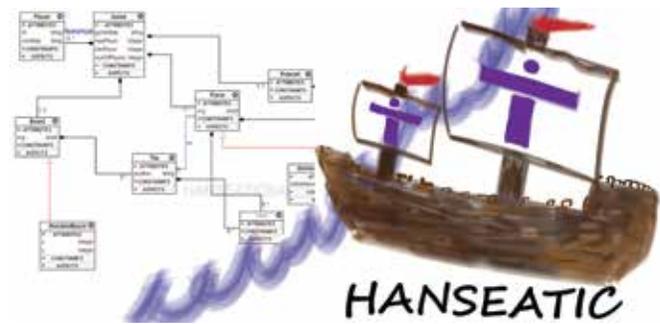
Jules White, Assistant Professor of Computer Science and Computer Engineering

### SPONSOR:

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Tabletop games contain a limitless variety of functional elements. Players of these types of games interact with dice, cards, pieces, rules, and win conditions in both cooperative and competitive contexts. By applying the principles of Model-Integrated Computing, a high-level programming paradigm



Hanseatic League, the future of game design

that provides a simple framework for the auto-generation of code from generic models, our team has created a framework called Hanseatic for modeling tabletop games. The end goal of our project is to create a flexible web platform whereby players can both play classic tabletop games as well as innovatively create, share, and test new games within an online community.

Hanseatic is completely model-driven. The WebGME engine that backs the project captures individual game elements and their associated functionality as a state machine. Hanseatic unites back-end scripts written in JavaScript with a graphical user interface generated using the react.js framework. By applying a model-based approach to tabletop game design, Hanseatic allows players to combine elements of familiar games without confronting the entry barriers typically associated with online game development. We believe that this tool will revolutionize the way that new games are created.

## Arena-Sports Pick'em App

### TEAM MEMBER

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### SPONSOR:

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School of Engineering



Screenshots from the Arena app from left to right: Splash screen, Game Feed, The Arena, Player Profile, and Leaderboard

There are currently no pick'em leagues that offer all sports in one interface with the option of challenging individual friends. Current pick'em leagues have limited functionalities and are not optimized for mobile. Arena provides a simple, clean, and quick way to predict winners of sports games. Arena also allows users to see how they stack up against themselves, their friends, and users worldwide. The app is split into four main sections: the Gamefeed, the Arena, the Leaderboard, and the Player Profile. These four sections are dedicated to game selection, league creation, ranking, and displaying user performance. Users can either challenge their friends in a League or a Callout. A League is a private group of users that are assigned selected games to pick. The user who selected the most number of games correct is deemed the winner. A Callout is the same as a league except it is a one-on-one matchup. The goal of this project is to gain experience doing the front- and back-end development of an app and to release a polished app to the App Store.

## Android Automation

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Vanderbilt University  
School of Engineering



Many college students always have their eyes glued to their phones. This can cause a plethora of issues, whether it be with safety, loss of human interaction, or even loneliness. Why do we spend so much time on our phones? Because there are some things that we can only do on our phones, such as texting, alarms, etc. To combat these issues, this application provides an innovative and more efficient way to interact with your Android phone. Need to send a text, but you are on your computer and your phone is in the other room? How about setting an alarm on your phone from your computer? This application is designed to extend the usage of your Android phone onto your computer. Users are able to schedule texts, alarms, events, and perform other tasks, all from a web-based interface on a computer. This simple concept profoundly extends your control of your Android device and its capabilities without the need for "root" or a special home screen. By providing this web-based scheduling interface, users are able to increase efficiency, interact with their phones from their computers, and have some time away from their phones.



The Android icon

## Social Application-esc

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Vanderbilt University  
School of Engineering



This design project focuses on building a social application for the iPhone to connect students during their free time. It lets other users know whenever there is a break in a friend's schedule for a quick meet up, to grab a bite to eat, or connects with other students in your classes to form a study group. There will be three categories users can express availability in: eat, study, and chill. The application will also be able to specify the duration of their availability, as well as the option to set the user's profile so that availability will be sent only to those they follow and have been added to their friends list. If the location service is turned on, the app can automatically let friends know where the user currently is, otherwise the app will require users to specify their location so others can locate them easily. If the private feature has been turned off, the user can connect with strangers who have also signed up for the app. Users will be limited to the college campus community to encourage safe meet ups.



The picture represents the three choices that the user can make: eat, study, or chill. Once the user presses one of the buttons, the duration and location of availability will need to be specified.

## Experimental Scheme-Based Programming Language

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Vanderbilt University  
School of Engineering



This variant of the scheme programming language is intended to address the tradeoff between ease of development and semantic verification as well as the difficulty in facilitating code reuse. This programming language is an attempt to unify the strengths of languages that check the semantics of a program before execution with the strengths of languages that check semantic validity of an operation as it is performed. This compromise is achieved by allowing, but not requiring, semantic meaning to be checked before a program is executed. This approach allows the programmer to quickly create a prototype and then lock down meaning once the benefits of having strongly-enforced interfaces outweigh the benefits of being able to very rapidly write code.



Proposed logo

To aid in allowing code to be reused, this language is designed such that programmers are encouraged to decompose algorithms into small functions that may then be used generically without tying an algorithm directly to the representation of the aggregate data on which it operates.

# Predicting the Price of Magic: The Gathering Cards Using Machine Learning

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A subset of predicted prices vs. actual prices is the result we hope to achieve.

As Magic: The Gathering becomes more and more popular, many players have been spending a large amount of money on buying the cards. Some even buy cards and re-sell them as a way to profit. Despite the growing market, no one has yet published anything about price prediction of the cards. In addition, the traditional method on predicting stock prices or other prices of products may not be applicable here. Thus we plan to use various tools of machine learning techniques such as neural network, SVR, and decision tree to predict prices based on the various features of cards like power, magic cost, etc. We are going to collect our price data from eBay, as well as websites like mtgprice.com. We hope to get our predicted prices to be within a 20 percent error range of the actual prices after trying different algorithms.

## Predicting eBay Auction Prices

## TEAM MEMBERS:

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eBay auctions allow one or many parties to place bids on items being sold by a single user. An intrinsic question of this model is whether or not the final prices accurately reflect the items' retail value and what factors might contribute to the inflation or deflation of the final auction price. The auction environment provides a unique set of potential learning features, as it is conjectured that final selling price will be a function of both the item's intrinsic value as well as the variable attributes of the auction itself. Using the predictive information, both buyer and seller strategies can be improved. The prospective ending price for an auction can inform the bidding behavior of interested parties, especially in cases where the item is predicted to sell at a price that is higher than its intrinsic value. Similarly, if an item is projected to sell at a loss, or to not gather any bids, the seller can restructure auction attributes or gravitate toward auctioning more popular items. Finally, the group bidding behavior that results in an item being sold with higher profit margins can further explain what attributes of an object may increase its perceived value, such as uniqueness or collective interest.

## Learning Mutation From Nanopore Currents

### TEAM MEMBERS:

Anna Hwang  
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### ADVISER

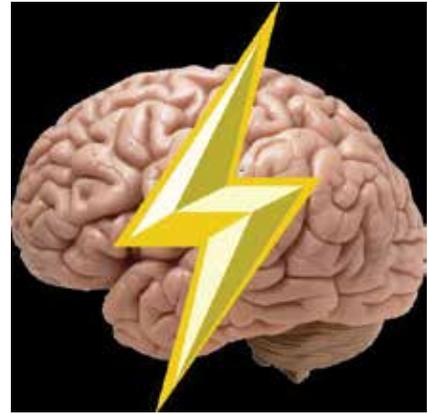
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DNA can be damaged in a variety of ways, including methylation and UV dimerization. Quickly and reliably quantifying the amount and type of DNA damage in a sequence opens the door for greater insights into causes of DNA damage and their relative effects. Currently, recognition of DNA damage with nanopores has been limited to a simple approach of applying a chemical tag and detecting whether the nanopore current breaches a given threshold value. Our lab is investigating whether a more complex machine learning approach using a Hidden Markov Model or other related construct would allow for reliably detecting multiple types of damage without extensive preprocessing. Nanopore devices read DNA sequences five bases at a time and produce a recognizable current spike on each type of 5-mer. We would attempt to classify whether the current spike deviates significantly from a recognizable spike for all known types of 5-mers.



**We are seeking to reliably detect multiple types of DNA damage without extensive preprocessing.**

## Sentence-Level Sentiment Analysis of Reviews Using Topic Modeling for Clustering

### TEAM MEMBERS:

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Our project is the binary sentiment classification of sentences, where a classifier determines whether a sentence has positive or negative sentiment. There are numerous reasons someone might want to analyze sentiment. For example, sentiment analysis can be very useful in understanding reviews on sites like IMDB, Amazon, and Yelp. By understanding the overarching sentiment in reviews, these sites can provide an aggregate of people's feelings toward a particular movie, product, or business. Sentiment analysis is a much-studied problem with many proposed techniques. In this work, we test a variety of methods for sampling from training data to build a general classifier that performs well when the original sentence source (i.e. IMDB, Amazon, or Yelp) is unknown. The data consist of a total of 3,000 sentences, each labeled 1 (positive) or 0 (negative) originating from IMDB, Amazon, and Yelp reviews.



**Sentiment analysis allows us to quickly extract the feelings people express in text without needing to read everything they have written.**

# Project Premonition Unmanned Aerial Vehicle

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National Science Foundation



**A quad-rotor unmanned aerial vehicle**

This project is modifying an existing quad-rotor unmanned aerial vehicle (UAV) to address the challenge of distributing and collecting a specially designed mosquito trap as part of Microsoft's Project Premonition to detect infectious diseases and a National Science Foundation Cyber-Physical Systems research grant. Four sub-teams are focused on sensing the trap's location in the environment, picking up and putting down the trap at specified locations, autonomous flying, and simulating various missions, including deploying multiple UAVs and traps simultaneously. This interdisciplinary class requires hands-on effort towards successfully competing in a competition based on Project Premonition. The ability to fly with, pick up and put down the trap requires knowing the UAV's approximate location based upon an a priori map and on-board sensing. The UAV must sense the trap's position in order for the UAV to position itself properly to manipulate the trap, which can be impacted by wind, sensor errors, miscalculations, and hardware failures. Team members designed a mechanism to manipulate the trap and worked with other sub-teams to ensure that the mechanism will not impede sensing the environment and trap or the UAV's ability to fly.



## Redesign of Carlex Blade Dispensing System

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### SPONSOR:

Carlex Glass Company



This project seeks to redesign a blade dispensing system in a large manufacturing environment in order to decrease system errors and wasted materials. Windshields are created by heat-treating two pieces of glass with a layer of vinyl between them. At Carlex Glass Company, the resultant vinyl edge is trimmed using razor blade-wielding robotic arms. The mechanism by which blades are delivered to the arms has caused ongoing and costly failures resulting from three factors: positional inaccuracy of the dispensed blade, dispensation of multiple blades at once, and magnetism or residue applied to the blade.

Our design addresses these issues while also allowing blades to be loaded into the dispenser without pausing the production line. This design employs rotating arms and an actuator to carry cartridges of blades into position within the production cage. A solenoid ensures positional accuracy by locking the arm in place as it moves into the path of dispensation. The plunging solenoid then pushes a blade through an aperture toleranced to the width of a single blade. An array of sensors, integrated with the mechanical control of the dispensing system, signals the solenoid to dispense another blade or move the next cartridge into position when necessary.



Redesigned blade dispenser and blade cartridge

## CubeSat Solar Panel Deployment System

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Vanderbilt University  
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CubeSats are miniaturized satellites typically designed for use in experimental research. Because of their relatively low cost and complexity, CubeSats offer a popular alternative to conventional satellites for extraterrestrial research. Recently, increasingly ambitious research goals have raised the demands placed on CubeSat's onboard power systems. For instance, the CubeSat which served as the inspiration for this project, NASA's NEA Scout, has especially high power requirements so that it can perform reconnaissance on a near-Earth asteroid.

To generate power, CubeSats rely on high efficiency solar panels. Since power generation is directly proportional to the total solar panel working area, increasing power requirements have led to ever-increasing area requirements.

The objective of this project is to develop the first off-the-shelf solution for a large-area, remotely deployable CubeSat solar array. The design can be divided into two main subsystems: the securement system and deployment system. The securement system consists of a synthetic tie-down cable which is released with a nickel-chromium thermal knife, while the deployment system uses two servo-motors which engage a nested cylindrical driving mechanism to fan out six solar panels - one set of three from each of two corners. The advantages of such a system over existing deployment mechanisms include: high area-to-volume ratio, no reliance on bulky hinges, compatibility with off-the-shelf electronics, and modularity.



Depiction of CubeSat system with solar panels fully deployed

## Exhaust Gas Recovery Device

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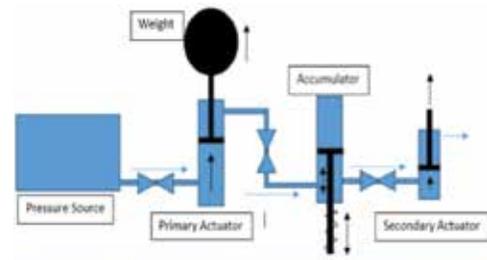
### SPONSOR:

DENSO Manufacturing  
Tennessee Inc.

**DENSO**

DENSO uses compressed air to power pneumatic cylinders that are fired back and forth to cut, bend, and move automotive parts. Each time compressed air fires the cylinder in one direction, the leftover compressed air from the previous firing in the other direction is exhausted into the plant. When this compressed air, which still has the capability to do work, is exhausted, money is lost. DENSO's goal for us is to create an economically viable way to reuse the energy in that air, and propose practical scenarios for implementation.

In order to accomplish this objective, we implemented a "Strain Energy Accumulator," which stores the exhausted air in a spring/pneumatic cylinder device. This device holds the energy until it can be used to fire another cylinder. The accumulator is electronically programmed to release its accumulated energy in between the timed cycles of the DENSO machines to prevent delays. This system could result in significant cost savings for DENSO if calibrated appropriately to the cylinder it collects exhaust from and the cylinder it fires.



Schematic diagram (top) and system setup (bottom) of Strain Energy Accumulator

## Optical Inspection System for Magnetic Float

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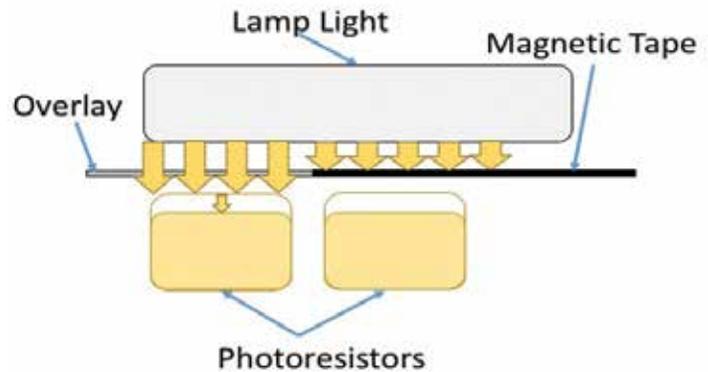
### SPONSOR:

Fiserv

**fiserv.**

Fiserv is a global financial services technology company that manufactures credit, debit, and other types of cards in Nashville. Magnetic float, the misalignment of magnetic stripes, is a common and costly manufacturing process error when making these cards. The goal of the project is to create a system to determine if the

magnetic float occurs during a specific step of the manufacturing process. Our team's solution uses a system of light and photoresistors to ensure that the magnetic stripes are in the correct place. If magnetic float is present, the system alerts operators that magnetic float is occurring so the manufacturing process can be stopped. Previously, Fiserv did not have a solution to inspect this part of the manufacturing process. Our team anticipates that the solution will identify where magnetic float occurs during the manufacturing process and aid Fiserv in reducing instances of magnetic float.



An aligned magnetic stripe and a single set of light and photoresistors

## Automated Fender Manipulation

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### SPONSOR:

H.E. Parmer Company



H.E. Parmer is a metal fabrication company that has been operating in Nashville since 1889. The company manufactures high quality metal parts, as well as custom metal parts. Currently, steel sheet metal used for several different trailer fenders is cut by a die machine, creating a burr on the top-side. The metal blank must then be manually flipped so that the burr is on the bottom of the blank for safety reasons. Our design team was tasked with automating the flipping process. The team engineered a solution that uses an adjustable angled conveyor and a flipping bar. The metal blank travels over the angled conveyor and rolls out onto the flipping bar. The blank begins to flip and falls onto the second conveyor, which completes the flip. The conveyor is adjustable so that it can flip multiple sized blanks. This solution frees an employee to work on more productive tasks and increases the speed of the assembly line. The team utilized a spare conveyor at H.E. Parmer, and with their help converted it into an adjustable angled conveyor. After additional evaluation at Vanderbilt to ensure the safety and precision of the conveyor, it will be installed on site.



Fender flipper prototype

## Mobile C-Arm Robotic Platform

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### SPONSOR:

Vanderbilt Institute in Surgery  
and Engineering



C-arms are medical devices used for intra-operative imaging. Currently, two types of C-arms are employed: stationary C-arms and mobile C-arms. Stationary C-arms require a dedicated operating room, but allow for direct position control by the surgeon. Mobile C-arms can be easily moved throughout the hospital, but they are passive and require a technician for intra-operative positioning. The goal of this project is to provide a robotic platform that can support the weight of a C-arm and give direct position control of the C-arm to the surgeon.



C-Arm on an automated platform

The core element of the robotic platform is a mecanum drive, consisting of four independently driven mecanum wheels. A mecanum wheel is a type of wheel with passive, angled rollers attached along its circumference. By using four of these wheels with independent speed and direction controls, the platform can be driven in any direction without turning. The robotic platform also features positional memory, which is useful in surgeries that require frequent motion between specific positions. Ultimately, this system improves the surgeon's control of a mobile C-arm and could reduce or eliminate the need for a technician.

## MRI Tactile Stimulation Device

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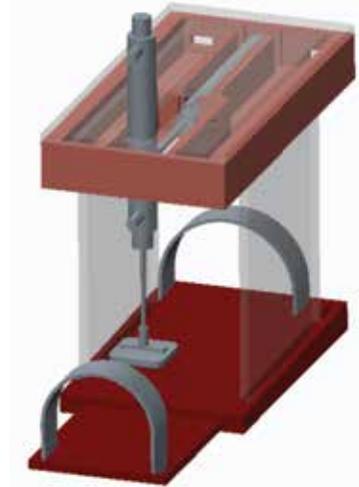
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### SPONSOR:

Vanderbilt Kennedy Center

The team was tasked with creating an MRI-compatible device that applies tactile stimulation to a section of a subject's arm. The purpose is to provide the Vanderbilt Kennedy Center with the ability to analyze neural response to the stimulus in order to reliably identify the earliest risk markers in Autism Spectrum Disorder (ASD). ASD is not yet able to be reliably diagnosed in time for preventative treatment. Recent research has shown that the tactile response of infants can provide important information regarding sensory trajectories that can be extremely useful in identifying ASD. This design solution uses pneumatic cylinders powered by a compressed air system to stroke the subject's arm linearly in one direction in order to safely mimic affective touch. Currently, this is done manually with little precision and an inability to accurately monitor brain activity. It is anticipated that this device will aid in the progression of ASD research.



3-D model of Tactile Stimulation Device



## NASA Additive Manufacturing Project

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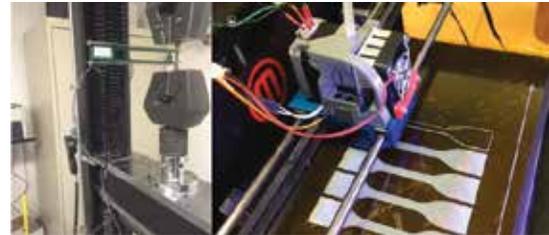
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NASA Marshall Space  
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A 3-D printer was installed in the International Space Station in late 2014, creating a cost-effective and versatile method of solving problems for the astronauts. Using additive manufacturing, a variety of tools can be produced. However, before solid tools can be utilized in space, proper material testing of the 3-D printed ABS plastic must be conducted. Materials testing as well as the design of 3-D printed tools are 3DOG's (3-Dimension in Zero Gravity) project goals. We are performing load frame and instrumentation tests to accurately characterize the material printed with various 3-D printer settings. These settings include infill percentage, infill shape, layer height, and angle offset. Using the experimental data, analysis can be performed on Stress-Strain curves to calculate necessary properties. The team has created a database of these material properties that can be referred to for more precise design for in-space printing solutions. Using the experimental material properties, 3DOG is able to perform finite element analysis on the designed CAD tools. FEA allows for the optimization of the designs by minimizing material, and improving strength and reliability through stress and strain analysis.



The printing process and test procedure.



## Nashville Citizen

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### SPONSOR:

Public Art Program, Nashville  
Metro Arts



*Citizen* is an art installation of two statues in downtown Nashville. The statues are intended to be dynamic, interactive pieces. A large wheel at the base allows passersby to rotate the pointing figure at the top. However, the mechanical system that allows these statues to rotate is non-functioning, in addition to requiring excessive maintenance. The statue is suffering from issues of overloading stemming from weak components, public misuse, and a higher frictional load than the components can handle. Any proposed solution must maintain the artistic integrity of the pieces while addressing both financial and feasibility concerns.

For a prototype, the team has constructed an approximately one-third scale model of the statue with similar mechanical components in order to replicate both the physical constraints that a real-world solution will need to overcome as well as test for the impact of adding components. The final solution to Metro Arts is a tiered repair plan, consisting of recommendations ranging from “quick fixes” (torque limiter, smaller wheel) to a complete repair of the internal mechanism (replacing bearings, shaft, sprockets, and chain).



The male Nashville *Citizen*

## Nissan Karakuri Engine Kit Cart

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### SPONSOR:

Nissan North America



The Nissan Karakuri Team is working with engineers from Nissan’s Smyrna, Tenn., manufacturing plant to redesign an engine kit cart. Currently, engine components sit on a 30-inch high cart with an engine suspended above the cart. To improve the assembly process from an ergonomic standpoint, the parts will be raised 6 inches. Because the cart is on an assembly line, the solution must require very little maintenance and not interfere with existing assembly methods. In addition, the cart must be designed with Karakuri principles, meaning that it must be a zero-impact solution. The cart cannot use any of the plant’s electricity, compressed air or hydraulics.

Our solution is to generate air pressure using the motion of the cart throughout the factory. Using a drive wheel, chain and sprocket, rotating arms and air pumps, the cart generates compressed air from motion. When parts are needed by a technician, a switch is flipped and pneumatic cylinders on the cart actuate using the stored air and move the trays of parts 12 inches horizontally, to avoid the engine, and 6 inches vertically, to make them more accessible. Once the assembly process is complete, the technicians toggle the switch to return the platforms.



Engine kit cart illustration

## SAE Baja Off-Road Vehicle

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### SPONSOR:

Vanderbilt University



The Society of Automotive Engineers hosts a yearly competition challenging collegiate teams to design and fabricate a vehicle capable of traversing rugged terrain. The Vanderbilt Motorsports team has designed, fabricated, and tested a vehicle to compete in the SAE Baja design series.

The team designed the vehicle to be low cost, lightweight, safe, durable, easily serviceable, and ergonomically accommodating to drivers of various size. Innovative solutions and high manufacturing standards optimized vehicle dynamics while remaining compliant with the extensive competition rule guide. These solutions began with a TIG welded 4130 Chromoly steel chassis and a lightweight fiberglass/carbon fiber composite seat. The drivetrain utilized a CVT to ensure maximum performance from the required Briggs & Stratton engine. The braking system was constructed with dual vertically-mounted master cylinders, a single inboard rear brake, as well as custom wave rotors. The suspension employs progressive air shocks, independent double A-arms, and rack and pinion steering in order to allow 10 inches of vertical travel, minimal bump steer, and a 7-foot turning radius. Optimized vehicle dynamics combined with driver experience and training increase of points awarded through a series of both static as well as dynamic events at competition.



2016 VU Motorsports Baja SAE off-road vehicle

## Electromechanical Paper Ejection Mechanism

### TEAM MEMBERS:

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Lie Tang, Ph.D, Control Specialist

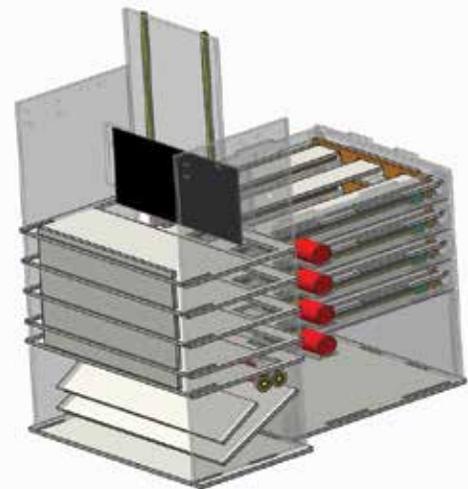
### SPONSOR:

Quality Manufacturing  
Systems, Inc.



QMSI designs automated pharmacies whose main purpose is to process labels and package pill bottles with prescription information to send to customers. Currently, the medical paper packets are ejected from a collator and manually folded and placed into a package with a patient's prescription. In order to avoid misplacement of medical information documents that violate a patient's privacy rights, the process of ejecting and folding these documents must be automated.

In this solution, an operator presses a button that triggers the ejection of a specific tray. A horizontal rack and pinion setup will slide paper from the called collator tray onto the folding platform. A dull metal blade attached to a vertical rack and pinion pushes the paper at its midline through a set of spinning rollers below the folding platform. The rollers crease the paper and eject it through a chute to be packaged. By harnessing an automated mechanism, the possibility of an operator wrongfully placing one's medical information into another patient's packaging is minimized.



Automated ejection and folding mechanism

# Suborbital Rocket with Monopropellant Hydrogen Peroxide Thruster

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NASA Marshall Space  
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Full-scale rocket with open payload window before launch

Rockets designed for spaceflight require thrusting capabilities for attitude control, liquid fuel management under varying g conditions, and structural analysis for insuring structural integrity and minimizing weight where available. This year's Student Launch team takes on all of these challenges by designing, building, testing, and launching a fully reusable rocket to a mile above ground. The rocket payloads include a "green" monopropellant hydrogen peroxide thruster, a slosh abatement system that provides a continuous source of fuel to the thruster, and a suite of accelerometers to provide vibrational data for structural analysis. In addition, the rocket sees up to 12gs of acceleration, necessitating a carbon fiber body.

Extensive results from testing the rocket and its payloads verified the design functionality for each of the aforementioned payloads. The  $H_2O_2$  thruster was verified as an excellent "green" alternative to standard attitude control methods with up to 10N of thrust after a minimal 190ms startup time. The slosh abatement system extracted 75% of the fuel in a worst-case -1g condition. The structural analysis payload used ground based tap tests and in-flight data to correlate a finite element model within a 4% error for the first and second bending modes, demonstrating the high fidelity of the model and ensuring a satisfactory factor of safety. The work done for this year's rocket has required tremendous team cohesiveness and attention to detail to ensure mission success.

# Improvements on a Paper Product Packaging Process

## TEAM MEMBERS:

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## SPONSOR:

WestRock



The finishing department of WestRock in Lebanon, Tenn., produces paper-board six-fold food trays for a variety of companies such as Church's Chicken and Dunkin' Donuts.

Currently, WestRock uses Jagenberg packing machines to collect finished paper goods from the gluer machine and package them into cases. However, the Jagenberg packer cannot be used to package six-fold trays because the thickness of the trays causes them to collide when fed sequentially into the case. Instead, an operator manually collects the trays from the production line and packs them into the cases.

Our team has designed a solution that allows six-fold trays to be packed into boxes in a semi-automatic fashion, dropping all of the trays into a case at the same time instead of packing them sequentially. The design solution is expected to work for a variety of tray sizes. WestRock will be able to pack at the same speed with half as many operators, and our solution improves ergonomics for an operator, which can reduce the risk of back injury.



The team tests a prototype at the WestRock facility.



L-R, Dr. Gerasimos Bastas, Dustin Fleeman and Andrew Ekelem make their way down the hall. The FDA has approved the Vanderbilt-designed Indego exoskeleton for clinical and personal use.

## 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 2016 and have transformed our Class of 2016 into young professionals.



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