DESIGN DAY 2018

april 23, 2018 • student life center

3:00–6:00 p.m. • vu.edu/design-day

VANDERBILT UNIVERSITY SCHOOL OF ENGINEERING

INSIGHT • INNOVATION • IMPACT®

THANK YOU TO OUR SPONSORS

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

- American Society of Civil Engineers
- Chemical Engineering Design Advisory Board
- Christ's Gift Academy
- DENSO Manufacturing Tennessee, Inc.
- Geeks and Nerds
- Halma Holdings Inc.
- MAX Mobility, LLC
- Metova Inc.
- NASA Marshall Space Center
- Natural Computing
- NAVSEA Warfare Centers—Panama City Division
- Nissan North America
- Polymer and Chemical Technologies, LLC
- Quality Manufacturing Systems, Inc.
- RoWheels Incorporated
- SFEG
- Siemens
- Sterling Ranch
- Tesla
- Urban Housing Solutions
- U.S. Navy Supervisor of Salvage
- Vanderbilt Aerospace Design Laboratory
- Vanderbilt School of Engineering
- Vanderbilt Eye Institute
- Vanderbilt Green Fund
- Vanderbilt Campus Planning
- Vanderbilt University Medical Center
  - Department of Anesthesiology
  - Department of Critical Care Medicine
  - Department of Medicine, Division of Dermatology
  - Department of Neurology
  - Department of Orthopaedics
  - Department of Pharmacology
  - Department of Radiation Oncology
  - Patient Care Informatics
- Volumetrix
- Xcel Energy

PREFACE

On behalf of the School of Engineering, welcome to Design Day 2018. This year you'll see more than 60 engineering and computer science capstone projects completed in partnership with sponsors including Nissan North America, Siemens, Metova, Xcel Energy, NAVSEA, Sterling Ranch Development Company, DENSO, NASA Marshall Space Flight Center, and more.

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

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

Sincerely,

Thomas Withrow
Assistant Dean for Design
Associate Professor of the Practice of Mechanical Engineering
514 Olin Hall
615-322-3594
thomas.j.withrow@vanderbilt.edu

Mailing address:
PMB 351592
2301 Vanderbilt Place
Nashville, TN 37235-1592

CONTENTS

23 DEPARTMENT OF ELECTRICAL ENGINEERING AND COMPUTER SCIENCE

FACULTY ADVISERS

Ralph Bruce, Professor of the Practice of Electrical Engineering
Jules White, Assistant Professor of Computer Science and Computer Engineering

27 DEPARTMENT OF MECHANICAL ENGINEERING

FACULTY ADVISERS

Thomas Withrow, Assistant Dean of Design and Associate Professor of the Practice of Mechanical Engineering
Jason Mitchell, Research Assistant Professor of Mechanical Engineering

34 DESIGN AND PROJECT FACULTY

BIOMEDICAL ENGINEERING

TEAM
Foard Naumann, BME/EE
Jad El Harake, BME
Jason Wang, BME
Michael Ripperger, BME
Trevor Simon, BME

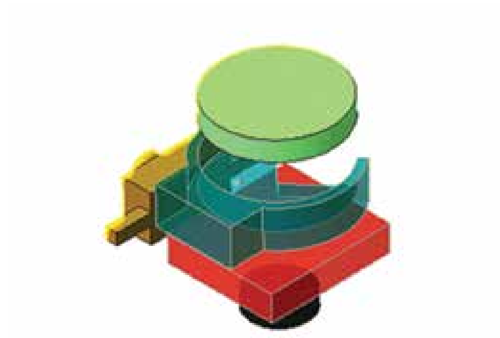
ADVISER
Lucas Schoch, Project Supervisor

SPONSOR
Natural Computing

A Notifying Wearable with Smartphone Compatibility

Western medicine has traditionally diagnosed and treated health issues only after they arise in harmful ways. While this approach is necessary to combat acute trauma, preventative measures can address other health complications. Chronic stress is one such public health issue that has not yet been thoroughly confronted with preventative care.

To decrease chronic stress with mindfulness-based breathing practices, the team designed and developed a biomedical, two-part wearable that can monitor and remind users to control their breathing. The device consists of two modules. An embedded accelerometer monitors respiration rate from placement around the neck, using chest movements. The core, disc-shaped module vibrates periodically to remind users to become aware of their breathing. Mindfulness-based breathing practices have been shown to reduce chronic stress, and performing the short breathing instructions, prescribed on the second module, can help users decrease and better manage stress. Over time, and with smartphone configuration, this practice supports development of the habit of mindfulness – and reduces user likelihood for developing negative health outcomes related to stress.



An internal schematic of the core notification module

BIOMEDICAL ENGINEERING

TEAM
Niki Budgell, BME
Erin Euliano, BME
Leah Fassinger, BME/Russian
Natalie Hawken, BME

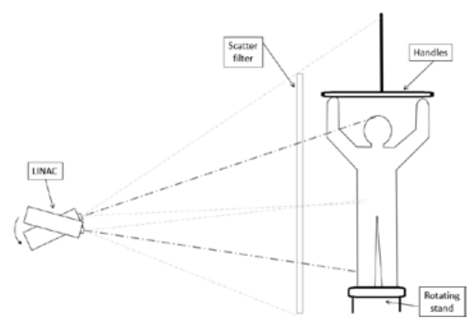
ADVISERS
Eric Shinohara, M.D., Associate Professor and Vice Chair, Department of Radiation Oncology
Michael Price, Associate Professor of Radiation Oncology

SPONSOR
Department of Radiation Oncology, Vanderbilt University Medical Center

Rotating Patient Stand for Total Skin Electron Therapy

Diffuse dermal malignancies encompass skin patches, plaques, and tumors that can occur on the entire body surface area. They must be treated with total skin electron (TSE) irradiation. A rotating stand that accommodates patients for this treatment at the Vanderbilt University Medical Center Department of Radiation Oncology has reached the end of its useful life and the project sponsor wants an upgraded device with newer technology.

The new design increases the range of handlebar adjustability, makes the platform easier to sterilize, creates a more aesthetically pleasing device, and incorporates fall prevention measures. The project also included creating a user interface through LabVIEW to control the platform and the radiation treatment and to track patient information. The new design will help increase patients' level of comfort as well as increase the ease of use by providers.



The redesign of a patient stand from the 1980s increases patient comfort and operator ease of use for TSE therapy.

VANDERBILT UNIVERSITY
MEDICAL CENTER

TEAM
Sneha Chhachhi, BME
Elizabeth Curvino, BME
Sarah Elliott, BME
Madeline Ragland, BME
Emily Schafer, BME/Neuroscience

ADVISER
Michael Froehler, M.D., Ph.D., Assistant Professor Neurology and Neurosurgery

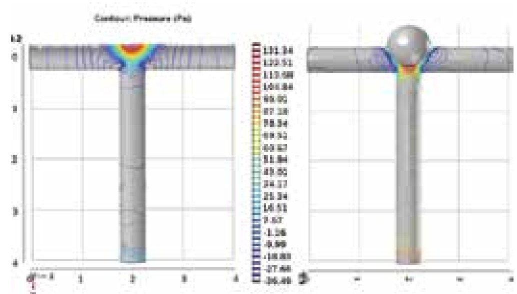
SPONSOR
Vanderbilt University Medical Center

BIOMEDICAL ENGINEERING

Cerebral Aneurysm Vascular Stent Prototype

Brain aneurysms occur in instances of high blood pressure and when cerebral vessel walls become weak and balloon outward. Between 1½ and 5 percent of all American adults develop brain aneurysms during their lifetime. Existing treatment options for aneurysms, including clipping the aneurysm or inserting micro-coils into the aneurysm body, are relatively ineffective for wide-necked aneurysms at bifurcation points.

This project aims to treat cerebrovascular aneurysms at a bifurcation point using a flow-diverting stent. The stent will be able to divert blood flow to both vessels at the bifurcation point, and the device will be functional in wide-necked aneurysms without the use of micro-coils. The stent design contains two specific parts: the trunk and the canopy. The trunk is deployed into the parent vessel and provides the base and subsequent support for the canopy. The canopy spans the neck of the aneurysm and diverts blood flow away from the aneurysm. The potential efficacy of the stent is analyzed using the following parameters: maximal coverage at the neck of the aneurysm, pressure differences between the aneurysm and the vessel, and velocity flow in and around the aneurysm.



Areas of high pressure lead to the ballooning out of weak vessel walls at a bifurcation point in the brain. A computational flow dynamic model demonstrates before and after representations of how the pressure build-up leads to the formation of a cerebrovascular aneurysm.

VANDERBILT UNIVERSITY MEDICAL CENTER

TEAM
Josh Bender, BME
Sparsh Gupta, BME
Clint Holt, BME/ChemE
Adithya Sivakumar, BME

ADVISERS
Michael Froehler, M.D., Ph.D., Assistant Professor of Neurology and Neurosurgery
Matthew Walker, Associate Professor of the Practice of Biomedical Engineering

SPONSOR
Vanderbilt University Medical Center Department of Neurology

BIOMEDICAL ENGINEERING

Optimization of Direct Aspiration Thrombectomy Technique for Clot Removal

Direct aspiration thrombectomy is a recently developed endovascular treatment for ischemic stroke. If optimized, the new procedure has great potential to minimize the loss of neurological tissue. The team designed a dynamic flow model so that physicians can mimic vacuum thrombectomies in a simulated environment to optimize the thrombectomy procedure, improve quality of care and surgery success. Direct aspiration thrombectomy efficacy could be improved by temporarily increasing intracranial pressure, which will allow for an increased suction force at the tip of the aspiration catheter as well as a decreased pressure gradient across the clot.

The team tested the idea by increasing the pressure in its model while precisely measuring the vacuum force achieved when performing an aspiration thrombectomy on a simulated thrombus lodged in the model center. This increase in intracranial pressure could be translated to an *in vivo* technique through the temporary constriction of jugular blood flow leaving the brain. Ultimately, the model could improve thrombectomy procedures by introducing a non-invasive procedure of vessel constriction.

VANDERBILT UNIVERSITY MEDICAL CENTER

A flow model of the cranial cavity using a pump and thin-walled tubing accurately mimics blood flow through the cerebral arteries while monitoring pressure at multiple locations.

BIOMEDICAL ENGINEERING

TEAM
Jesse Onyango, BME
Mark George, BME
Chiedza Chauruka, BME
Austin Hardcastle, BME

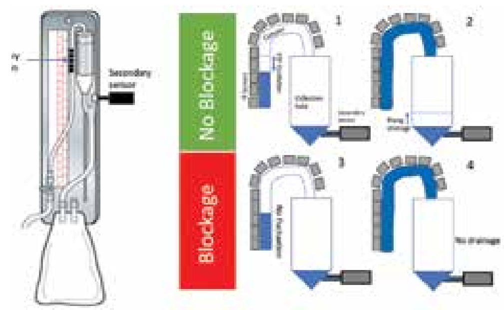
ADVISERS
Truc Le, M.D., Assistant Professor of Pediatrics and Neurosurgery
William Gabella, Research Assistant Professor, Department of Physics and Astronomy
Matthew Walker III, Associate Professor of the Practice of Biomedical Engineering

SPONSOR
Vanderbilt University School of Medicine

SensiFlow: A Smart Blockage Detection Device for Extraventricular Drains

Extraventricular drains (EVDs) are crucial pieces of equipment in any neurological intensive care unit. These life-saving devices drain cerebrospinal fluid (CSF) from patients' heads when they cannot do so on their own due to injury or surgery. Despite high success rates and widespread adoption, EVDs can be harmful to patients if they become clogged by debris in the fluid or inadvertently clamped by a healthcare provider. SensiFlow is a product designed to detect these dangerous blockages and notify appropriate personnel to prevent long-term brain damage.

SensiFlow does not impede providers' normal routine because it attaches with ease externally, which maintains sterility and allows for full visibility of the drain. Traditionally, nurses check EVD function hourly but if a blockage occurs between checks, the patient can be injured. SensiFlow provides real-time safety monitoring when doctors and nurses cannot monitor CSF drainage directly.



A new blockage detection device is superimposed onto the extraventricular drain. Four operational scenarios are displayed.

SCHOOL OF MEDICINE
VANDERBILT UNIVERSITY

BIOMEDICAL ENGINEERING

TEAM
Kevin Fialkowski, BME
Chad Keller, BME
Christopher Khan, BME
Kelly McGee, BME

ADVISERS
Eric Tkaczyk, M.D., Ph.D., Assistant Professor of Dermatology and Biomedical Engineering
Arved Vain, Ph.D., Visiting Associate Professor of Medicine, Division of Dermatology

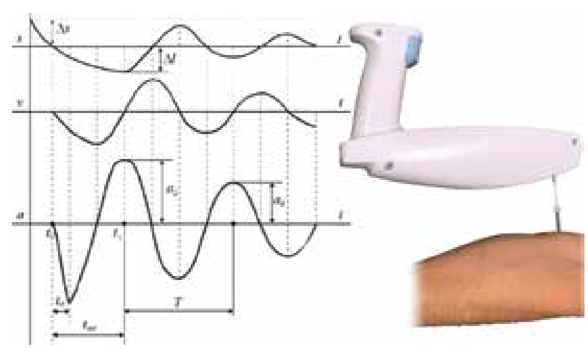
SPONSOR
Vanderbilt University Medical Center Department of Medicine, Division of Dermatology

Omniton: Device to Quantify Changes in Muscle and Skin Biomechanical Properties

Many debilitating dermatologic conditions, such as sclerotic graft-versus-host-disease (cGVHD) and burn wounds, result in changes to the biomechanical properties of skin. Sclerotic cGVHD, for example, is the leading cause of long-term mortality and morbidity in leukemia survivors. The only cure is a bone marrow transplant.

The way to assess progression of these conditions is a subjective grading scale that lacks a quantitative component and produces a high variance among medical practitioners. A device to quantitatively measure skin properties such as stiffness and elasticity would decrease this variance and record more precise measurements. The team modified a Myoton, a handheld myometer now on the market, to measure skin and muscle mechanical properties.

The new design replaced a handmade solenoid actuator with a tunable micromotor. The micromotor moves a lever arm that contacts the skin and delivers a mechanical impulse. The impulse induces naturally damped oscillations in biological tissues that can be measured with an accelerometer, allowing calculations of the tissues' biomechanical properties.



After delivering a mechanical impulse, the device records the acceleration of induced soft tissue oscillations, from which biomechanical properties such as stiffness and elasticity can be calculated.

VANDERBILT UNIVERSITY
MEDICAL CENTER

TEAM
Xiaoyue Judy Li, BME
Nur Khairah Bahirah Safian, BME
Anna Word, BME
Sophie Xie, BME

ADVISER
Morgan Amsler, Director of Innovation, Visual Diagnostics

SPONSOR
Halma Holdings Inc.

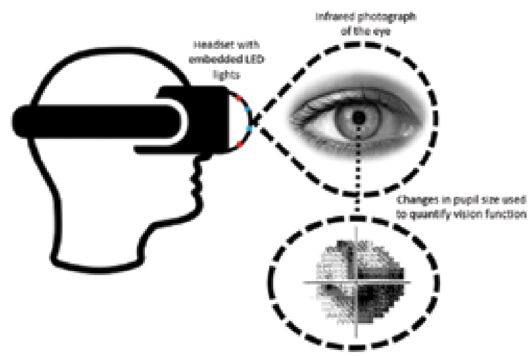
BIOMEDICAL ENGINEERING

A Portable Device for Objective Visual Field Measurement

Glaucoma is characterized by a loss of peripheral vision and by 2020 an expected 78 million people will be affected. However, half of those with glaucoma are unaware they have the disease. The existing diagnostic standard is a subjective visual field test that relies on patient response to flashing lights. These devices are uncomfortable, inaccurate, and complicated for both patient and physician.

Halma has constructed an objective visual field testing device that measures a patient's pupillary light reflex to determine retinal health. Flashing red and blue LEDs stimulate pupil contraction, and an infrared camera tracks changing pupil diameter to evaluate a patient's vision at different points on the retina. Halma's device is simpler to administer and as accurate as the current visual field test. However, it is bulky and lacks sufficient adjustability features, making testing uncomfortable for patients.

Our device is a compact, portable visual field testing device that addresses the ergonomic, adjustability, and mobility challenges of Halma's prototype. It features a headset with a miniaturized perimeter and allows us to test up to 30˚ of the visual field in all directions.



A schematic of a VR headset with a miniaturized perimeter embedded with RGB LEDs and an infrared camera to measure the visual field. Physicians will diagnose patients using the resulting visual field map.

HALMA

TEAM
Victoria Chitwood, BME/Art
Tori Qualls, BME
Amy Rushing, BME

ADVISER
Deborah Ariosto, Ph.D., MSN, RN, Director of Nursing Analytics, Vanderbilt University Medical Center

SPONSOR
Vanderbilt University Medical Center, Patient Care Informatics

BIOMEDICAL ENGINEERING

Integrating Post-op Ambulation Data to the EHR-PHR

Early postoperative ambulation is essential to positive health outcomes because it reduces patient risk of deep vein thrombosis, peristalsis, pneumonia, and other significant health complications. As such, it is important to actively motivate patients to walk and track their progress. Currently, clinicians, particularly nurses, manually record subjective ambulation parameters.

Our solution is an insole for a hospital non-skid sock that accurately records parameters such as distance traveled, time and speed walked, and the degree to which a patient limps. This information is integrated with a mobile health application that helps nurses, physical therapists, and other clinicians prioritize which patients need the most assistance. Eventually, this data will be integrated with an electronic health record. Additionally, a mobile application is available to patients so they can track their own progress and be motivated to walk as part of a fun, interactive, goal-achieving experience.

An ambulation tracking device fits into the insole of a sock and around the patient's foot, as shown. Data will be communicated via student-designed mobile application.

VANDERBILT UNIVERSITY MEDICAL CENTER

BIOMEDICAL ENGINEERING

TEAM
Taylor Combs, BME
Megan Holmberg, BME
Seiver Jorgensen, BME
Samantha Kultgen, BME

ADVISER
Joseph Schlesinger, M.D., Assistant Professor of Anesthesiology and Critical Care Medicine

SPONSORS
Vanderbilt University School of Medicine Department of Anesthesiology
Vanderbilt University School of Medicine Department of Critical Care Medicine

Direct Multisensory Alarm Delivery for Clinicians

Clinicians and patients in intensive care units (ICUs) are bombarded constantly with auditory medical alarms. Nonspecific alarm sounds make it difficult to distinguish what is wrong, which can impair the quality of care. More than a simple nuisance, frequent alarms make clinicians prone to alarm fatigue and desensitization. They also can cause some patients to develop delirium and PTSD during ICU stays.

To improve the ICU environment for patients and clinicians, the team developed a novel system to trigger alarms in a meaningful, multisensory, and non-fatiguing way. The system eliminates threshold medical alarms from the free field by sending them directly to clinicians via both an earpiece and a haptic actuator. It addresses the poor predictive value of existing alarms with a multisensory combination of haptic feedback and a unique soundscape that changes timbre for different physiological parameters, replacing one general alarm for multiple problems. Alarm differentiation is easier for clinicians, and the alarm system creates a quieter ICU that reduces the risk of overstimulation for both clinicians and patients.

The multisensory alarm system utilizes both an auditory stimulus from sonification of physiologic data and a haptic (vibrotactile) stimulus on the clinician's ankle.

SCHOOL OF MEDICINE
VANDERBILT UNIVERSITY

BIOMEDICAL ENGINEERING

TEAM
Jason Blohm, BME
Nicholas Diehl, BME
Joseph Jeffrey, BME
Sheng-Yau Lim, BME

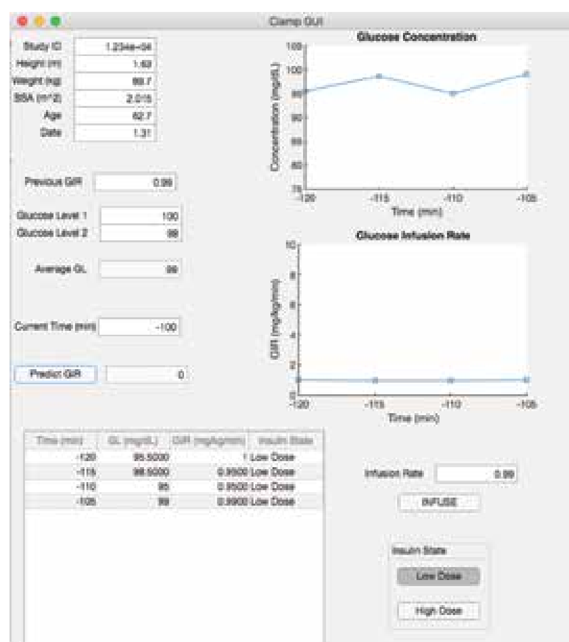
ADVISERS
Matthew Walker III, Associate Professor of the Practice of Biomedical Engineering
James M. Luther, M.D., Assistant Professor of Medicine, Assistant Professor of Pharmacology

SPONSOR
Vanderbilt University Medical Center Department of Pharmacology

Insulin Infusion Algorithm

The team's goal was to develop a more controlled method for investigators to study insulin sensitivity and insulin resistance that works with existing equipment. The team designed an algorithm for a hyperinsulinemic clamp that adjusts the infusion rate of glucose to 200 mg/dL and maintains it at that rate in the subject for 2.5 hours.

The research of the team adviser focuses on the role of a specific hormone system on glucose regulation, using both human and animal models. The team also developed a proof of concept for the algorithm that interfaces with a syringe pump, which could be used in future animal studies.



From the user interface, the physician can input demographic data and predict glucose infusion rates that the algorithm shows in two graphs. Infusion begins via the "INFUSE" button.

VANDERBILT UNIVERSITY
MEDICAL CENTER

TEAM
James Ford, BME
Rachel Howell, BME
Ivy Lee, BME
Annalee Schuck, BME
Caroline Stiles, BME

ADVISERS
Donald Lee, M.D., Professor of Orthopaedics and Rehabilitation
Sumit Pruthi, M.D., Associate Professor of Radiology and Pediatrics, Chief of Pediatric Neuroradiology

SPONSOR
Vanderbilt University Medical Center

BIOMEDICAL ENGINEERING

3-D Printed Bones

The team created exact models of bones from 10 distal humerus fracture surgeries performed at Vanderbilt University Medical Center to determine the efficacy of 3-D bone models for pre-operative planning. In a retrospective study of complex distal humerus fractures, the team asked three surgeons to examine an X-ray, 2D CT scan, 3-D rendering, and the 3-D printed bone model for each procedure. The survey included quantitative questions about the size of plate to be used and qualitative questions about how confident the surgeon was in his or her pre-op decisions. With the 3-D bone modeling process, a surgeon can visualize all angles of the bone, accurately fit and contour plates, and manipulate the fractured pieces to prepare for the operation. The team will publish the findings of its retrospective analysis. 3-D bone modeling could improve operating room efficiency and patient outcomes for complex distal humerus fracture cases.

3-D printed replica of patient's bone from a CT scan

VANDERBILT UNIVERSITY MEDICAL CENTER

TEAM
Candace Grisham, BME
Shashank Manjunath BME/Mathematics
Ben Perlin, CompE/Neuroscience
Anthony Russo Jr., BME
Nick Wigginton BME/Political Science

ADVISERS
Adam B. Hicks, D.P.M., Senior Associate in Orthopaedics and Rehabilitation, Vanderbilt University Medical Center
Matthew Walker III, Associate Professor of the Practice of Biomedical Engineering

SPONSOR
Vanderbilt University Medical Center, Department of Orthopaedics

BIOMEDICAL ENGINEERING

LumaSil: Low Light Therapy Device for Diabetic Foot Wounds

One in four Americans with diabetes will develop a diabetic foot ulcer (DFU) in their lifetime, and the current treatment protocol relies entirely on passive methods such as standard wound dressing and off-loading casts. As a result, DFUs are notoriously prone to infection and frequently result in amputation of the affected limb. In 2010 alone, more than 70,000 diabetic patients had some level of amputation due to such complications. The team developed LumaSil for physicians, technicians and patients who seek a more active DFU therapy to improve outcomes.

LumaSil is a low profile, durable wound therapy device that delivers dose-specific, low-intensity light therapy to significantly reduce bacterial presence and infection risk in DFUs. The therapy system utilizes wavelengths of light with proven efficacy in preventing proliferation of infectious and antibiotic resistant bacteria. LumaSil is integrated directly into a patient's cast and automatically delivers light therapy to the wound site. Our design process incorporates primary feedback from industry to prioritize the device's automation, ease of implementation, and patient comfort. Finally, LumaSil's custom circuitry and programming actively and autonomously adjust therapy parameters to ensure optimal device performance, therapy efficacy, and patient safety.

3-D design of LumaSil, a low-level light therapy device to aid diabetic foot ulcer healing by reducing the presence of infectious and antibiotic-resistant agents. Light generated in an external module on the cast is delivered to the wound via LEDs in a circular silicon design.

VANDERBILT UNIVERSITY MEDICAL CENTER

BIOMEDICAL ENGINEERING

TEAM
Oscar Benavides, BME
Xavier Idriss, BME
Sarin Murlidar, BME
Benjamin Terrones, BME

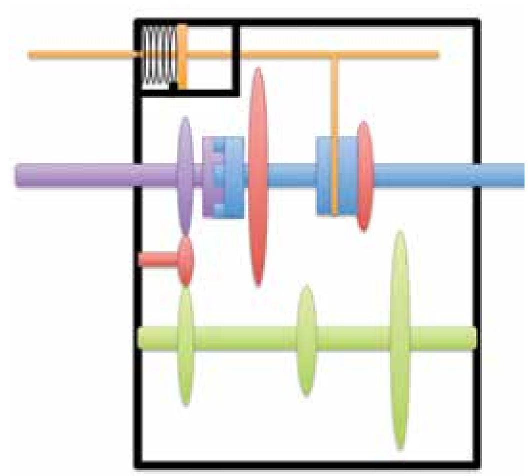
ADVISER
Salim Nasser, Chief Technical Officer

SPONSOR
RoWheels Incorporated

Reverse Drive Gear Hub to Enhance Alternative Wheelchair Row Motions

Use of conventional wheelchairs can place undue pressures on shoulder joints and muscles over long periods of time. RoWheels aims to design a wheelchair that allows the user to pull or "row" and create forward propulsion. The rowing motion is more biomechanically advantageous than pushing.

The team was tasked with creating a gear hub for a wheelchair that not only reverses this direction of motion but also includes high and low gears to give users more options and advantages. This will allow wheelchair users to either move faster in high gear or ascend inclines and traverse uneven terrain easier in low gear. In addition, the design should strain and reduce risk of injury among users of the wheelchair.



The gearbox allows for wheelchair users to shift between low and high gears. The main drive shaft is split into two sections, allowing for disengagement of the shafts and a one-to-one direct drive mode.

BIOMEDICAL ENGINEERING

TEAM
Dionne Black, BME
Devin Chang, BME

ADVISERS
Kyle Hocking, President
Colleen Brophy, M.D., Chief Medical Officer

SPONSOR
Volumetrix

NIVA: Wristband for Venous Flow Monitoring

Cardiovascular failure is the leading cause of hospitalizations globally. The earliest symptom of cardiovascular failure is an increase in vascular volume, and optimization of treatments for heart failure relies on the ability to detect this symptom early. The only device on the market capable of detecting this change is a costly invasive, implanted device called CardioMEMS ™.

Our solution is the NIVA (non-invasive venous waveform analysis) device. This device facilitates real-time diagnosis of patient vascular volume by incorporating a band the patient wears on the wrist and a small handheld component that provides a NIVA score to clinicians. This NIVA score has been proven to be an equivalent of pulmonary wedge pressure, which itself is directly related to total blood volume. NIVA is capable of generating real time diagnostic information directly relevant to patient vascular volume for early treatment of heart failure.

The NIVA band is a non-invasive diagnostic medical device that evaluates patient total blood volume based on a proprietary index. An increase in the baseline index would indicate the earliest symptoms of cardiovascular failure and allow for early intervention to prevent hospitalization.

TEAM
Joshua Anderson, CE
David Greaves, CE
Derek Gloudemans, CE
Kevin Kawabata, CE
Dillon Randolph, CE
Carrie Rybecky, CE

ADVISERS
Rich Teising, Staff Engineer, Civil and Environmental Engineering
Ravindra Duddu, Assistant Professor of Civil and Environmental Engineering

SPONSORS
American Society of Civil Engineers
American Institute of Steel Construction

CIVIL AND ENVIRONMENTAL ENGINEERING

ASCE Steel Bridge Competition

In the world of civil engineering capstone projects, the ASCE/AISC Steel Bridge competition is a classic. This year, the model bridge was imagined to span the entrance to a suburb and was required to be assembled at the competition site out of 3-foot sections without touching the river bordering the community-to-be. This bridge was designed and fabricated to be as light as possible, as stiff as possible, and assembled as fast as possible. To achieve this, the location of truss nodes and sizing of truss elements were determined by numerical optimization.

Connections were designed to minimize the number of bolts and assembly time. Conceptual 3-D modeling and finite element analysis were used to verify design adequacy. The bridge competed in the ASCE Southeast Conference on March 2 and placed first in lightness, fourth in efficiency, fifth in construction speed, and fifth overall.

The steel bridge is a 1:10 model of the imagined final bridge. Eighty separable, custom-fabricated pieces comprise the 18-foot span.

TEAM
Jack Cohn, CE
Gabriel Darmon, ME
Farhan Hanafi, ME
Beth Hardy, CE

ADVISERS
Brock Smethills, Sterling Ranch
Claire Smrekar, Associate Professor of Public Policy and Education
Justin Southwick, Project Manager, Wilmot, Inc.

SPONSOR
Sterling Ranch Colorado

CIVIL AND ENVIRONMENTAL ENGINEERING

Sterling Ranch Model Home

Sterling Ranch is a master development in Douglas County, Colorado. Its mission is to develop a 3,400-acre meadow to create a sustainable community of about 12,000 homes. The development promotes a responsible, environmentally friendly style of living that includes energy conservation, efficient water use, passive solar design and creative landscaping.

Working alongside Sterling Ranch and Vanderbilt's School of Engineering and Peabody College, the team strives to educate others on sustainable living practices. The team has accomplished this goal by designing a model home and constructing hands-on, interactive exhibits for both adolescents and adults to learn about sustainable home design. By further publicizing Sterling Ranch as a community and promoting sustainability, the team seeks to make others more conscientious of the need to better protect the environment in which we live.

Two team members visit a local middle school with an interactive exhibit to educate the youth on best yard design and home landscaping practices to inexpensively conserve water.

CIVIL AND ENVIRONMENTAL ENGINEERING

TEAM
Weston Brzostovski, CE
Miguel Gomez, CE
Jerom Theunissen, CE

ADVISERS
David Grisham, Architect, Deus Ex Design
Jacob Holloway, Structural Engineer, Ross Bryan Associates

SPONSORS
Vanderbilt Green Fund
Vanderbilt Campus Planning

Vanderbilt Campus Bike Shelter

Vanderbilt's existing bicycle infrastructure satisfies only the most basic parking needs for the campus community. Most bike racks are uncovered, and Vanderbilt wants to create bike shelters with environmental, aesthetic and practical benefits. The team designed a sustainable shelter with unique attributes such as gothic arch-shaped bike racks, a maintenance station, and a green roof. The green roof will serve as a habitat for native plants, absorb atmospheric CO_2, and reduce the amount of rainwater runoff.

It will be located directly in front of the Black Cultural Center, providing much needed parking in a high-traffic area. The team worked closely with Vanderbilt's FutureVU land use initiative, which aims to provide facilities that support efficient storage, security, and maintenance of student and faculty bicycles. If successful, similar bike shelters will be used to connect elements of the future greenway that will link campus neighborhoods.

Curved arches that pay homage to the adjacent Buttrick Hall are featured in the structural steel design.

VANDERBILT UNIVERSITY

CIVIL AND ENVIRONMENTAL ENGINEERING

TEAM
Amber Arquitola, BME/EE
Grant Forsee, ME
Ben Garcia, CE
Chris Michel, CompE
Mark Rumage, CompE
Natasha Quattro, EE

ADVISERS
Lori Troxel, Professor of the Practice of Civil and Environmental Engineering
Ralph Bruce, Professor of the Practice of Electrical Engineering
Jacob Verdin, Mechanical EIT, SSR

SPONSOR
Urban Housing Solutions

Urban Housing Solutions Race to Zero

Urban Housing Solutions provides permanent, affordable housing opportunities for Nashville's homeless, low-income, and workforce populations. With a goal of net-zero energy use, the team redesigned an existing Urban Housing Solutions' multi-family residential building to improve energy inefficiencies without sacrificing affordability. The main design strategy was to shift the 23-unit building from mixed gas and electric utilities to an all-electric design. This allowed placement of a solar array designed with energy modeling software on a carport adjacent to the building that met all of the building's energy demands. In addition, this design modified the building envelope, insulation, and windows to help reduce the energy load for heating and cooling.

A 23-unit Urban Housing Solutions multi-family building was redesigned to produce as much energy as it consumes.

urban housing solutions
innovation • opportunity

TEAM
Megan Barrett, CE
Jack McDowell, CE
Nick Siragusa, CE

ADVISERS
Travis Todd, Principal/Regional Director, Thomas & Hutton
Kelsey Oesmann, Design Initiatives Manager, Urban Housing Solutions
Brent Elrod, Director of Planning & Development, Urban Housing Solutions

SPONSOR
Urban Housing Solutions

CIVIL AND ENVIRONMENTAL ENGINEERING

Urban Housing Solutions—Madison, Tennessee, Site Design

One design iteration emphasizes a transition from multi-family to single-family housing, provides greenspace, and retains storm water to reduce site runoff.

The cost of living in Nashville continues to rise, creating a pressing need for more affordable housing. Urban Housing Solutions (UHS) has partnered with several affordable housing developers to create an innovative, mixed-use living community in Madison, Tennessee. The 14-acre site is well situated, with nearby parks, transit access, and frontage along Old Hickory Boulevard.

The team designed a civil site plan with placement of roads, residential lots and buildings, parking facilities, pedestrian ways and greenspaces. Considering topography, hydrology, existing easements, and other site characteristics, the layout creates minimal disturbance to the natural features of the land. To accommodate Metro Planning's vision of a transition from urban to suburban space, the site plan offers residential density options that include townhomes, multi-family apartment buildings, single-family homes, shared living units, as well as commercial space.

TEAM
Susan Cobb, CE
Julie Hornsby, CE
Thomas Rice, CE
Ashley Rivera, CE
Ryan Shea, EE

ADVISERS
Kevin Colvett, Project Manager, CH2M Hill
Wes Allen, retired Civil Engineer from NES
Steve Cochran, former manager of Christ's Gift Academy
Ben Nelson, Design Engineer, SDL Structural Engineers

SPONSOR
Christ's Gift Academy

CIVIL AND ENVIRONMENTAL ENGINEERING

Kenya Rainwater Collection System

Christ's Gift Academy is a school in the small village of Mbita, Kenya, that has been getting its water from individual rain barrels connected to classroom building roofs and from a government tank that can go months without releasing any water. Our goal was to create a larger, more reliable, and easily accessible supply of water for cooking and cleaning. The new system uses a pipe network to transport rainwater collected from the roofs to a central in-ground storage tank and a solar pump that drives the stored water to the kitchen. Now, students and staff won't need to carry buckets of water from different rain barrels to the dining area and will be better able to focus their attention on the educational mission.

The team's design increased the volume of collected rainwater, which also will serve the school's new fruit trees project, reduce surface runoff, and decrease the pollutants flowing into Lake Victoria. Significantly, the team's model can be replicated by other nearby communities.

Team members Julie Hornsby and Thomas Rice with a worker from Christ's Gift Academy at the bottom of a hole dug out for the in-ground rainwater storage tank.

CHEMICAL AND BIOMOLECULAR ENGINEERING

TEAM

Emily Bishop, ChemE
Sara Hoerrner, ChemE
Ariana Pérez, ChemE
Lily Williams, ChemE

ADVISERS

Russell F. Dunn, P.E., Professor of the Practice of Chemical and Biomolecular Engineering
Bryan Beyer, Adjunct Instructor of Chemical and Biomolecular Engineering
Dan Rahill, Chemical Engineering Consultant
Robert Marshall, Chemical Engineering Consultant
Nick Augspurger, Chemical Engineering Consultant

SPONSOR

Chemical Engineering Design Advisory Board

Software for Designing Systems to Recycle Water with Multiple Contaminants

With increasing environmental awareness and regulations, concerns have risen over long-term availability of clean water. The need for improvements in wastewater reduction is driving industries to create more efficient process designs. Our goal is to create spreadsheet-based software to design optimal systems for direct recycling and reuse of wastewater streams across several processes and industries. Because industrial wastewater is likely to contain several contaminants, the software is designed for multi-component wastewater streams, improving upon previous software that could design systems only for single-component streams. Additionally, the software takes into account utility systems such as heaters and coolers, and purification of streams to give the highest volumes of possible recycling. Included with the software is an economic analysis that provides real cost and savings data associated with the designed optimal networks.

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

CHEMICAL ENGINEERING DESIGN ADVISORY BOARD

CHEMICAL AND BIOMOLECULAR ENGINEERING

TEAM

Zain Ali, ChemE
Danielle Cole, ChemE
Mariah Wakefield, ChemE

ADVISERS

Russell Dunn, P.E., Professor of the Practice of Chemical and Biomolecular Engineering
Bryan Beyer, Adjunct Instructor of Chemical and Biomolecular Engineering
Karl B. Schnelle, Professor of Chemical and Biomolecular Engineering, Emeritus
Justin Corney, Chemical Engineering Consultant

SPONSOR

Chemical Engineering Design Advisory Board

Software for the Recovery of Volatile Organic Compounds for Air Pollution Control

Volatile Organic Compounds (VOCs) are important chemicals used in the process industry. This class of pollutants is present in many gaseous and aqueous emissions in a variety of industrial situations and represents a loss of potential product and an environmental hazard. In addition, strict environmental regulations make operation costly. It is imperative to find cost-effective ways to reduce or eliminate VOCs from emission streams. Current industrial initiatives aim to prevent pollution and recover VOCs before release into the atmosphere by various methods, including adsorption, condensation, and filtration. However, there is no single accepted method and strategies vary by state and industry.

Our team has designed a software package that analyzes the performance and economic efficiency of each method to identify the most cost-effective method of VOC recovery for a given situation. The program – designed in Microsoft Excel –streamlines and centralizes the process of comparing VOC recovery methods by eliminating the need for outside sources and cost information. The software uses an algorithm to calculate and display performance and economic efficiency data, organized in clear summary tabs.

VOCs react with nitrogen oxides emitted from power plants as well as other industrial sources to form ozone, which leads to the formation of fine particulates. Accumulation of these particulates and other pollutants results in smog that reduces visibility and can irritate the eyes as well as exacerbate heart and respiratory problems.

CHEMICAL ENGINEERING DESIGN ADVISORY BOARD

TEAM MEMBERS

John Biffl, ChemE
Leah Ehler, ChemE
Melanie Magdun, ChemE
Jonathan Turner, ChemE
Nathan Wawer, ChemE

ADVISERS

Russell Dunn, P.E., Professor of the Practice of Chemical and Biomolecular Engineering
Bryan Beyer, Adjunct Instructor of Chemical and Biomolecular Engineering
Ken Debelak, Professor of Chemical and Biomolecular Engineering, Emeritus
Dan Rahill, Chemical Engineering Consultant
Robert Marshall, Chemical Engineering Consultant
Nick Augsburger, Chemical Engineering Consultant

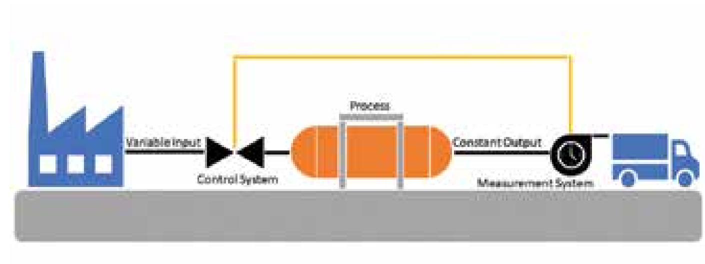
SPONSOR

Chemical Engineering Design Advisory Board

CHEMICAL AND BIOMOLECULAR ENGINEERING

Design of a Process Control Laboratory Module

Chemical production systems generally operate with exact and well-controlled process parameters such as temperature, stream composition, and pressure. These conditions tend to vary from batch to batch throughout a process due to fluctuations in ambient conditions or as a result of unexpected variations. To combat these fluctuations and achieve desired operating parameters, the design of a chemical process includes process control.



A simplified graphic of a process control loop maintaining a steady output from a varying input

Process control currently is taught as a strictly theoretical subject with no practical application in the unit operations lab, unlike other principles of the chemical engineering. Our project provides a means to demonstrate process control in a practical manner, giving students a more comprehensive grasp of the subject and its importance.

We improved upon a defunct process control lab module – a dated flash vaporization setup – by implementing modern microcontroller technology and incorporating widely used Matlab Simulink software. This brought accessibility and ease of use up to the standard of other lab experiments, and yielded a simplified data collection and interpretation process, which allows for future expansion and customization of the lab module.

Chemical Engineering Design Advisory Board

CHEMICAL AND BIOMOLECULAR ENGINEERING

TEAM

Franklin Gong, ChemE/Chem
Frank Luo, ChemE
Kristen Mancini, ChemE
King-Hur Wu, ChemE

ADVISERS

Russell Dunn, P.E., Professor of the Practice of Chemical and Biomolecular Engineering
Bryan Beyer, Adjunct Instructor of Chemical and Biomolecular Engineering
Tony Davis, Chemical Engineering Consultant
Del Pruitt, Chemical Engineering Consultant
Matt Lang, Professor of Chemical and Biomolecular Engineering

SPONSORS

Polymer and Chemical Technologies, LLC

Chemical Engineering Design Advisory Board

A New Dimension: Material Selection and Prototyping of a 3-D Printed Device

Ultimaker³ 3-D Printer

Traditional manufacturing fails to give innovators a quick, easy, and cost-effective way to bring their ideas to life. Three-dimensional printing solves this problem by enabling rapid prototyping of devices, which can be applied to a wide variety of applications, including carbon capture, biomedical implantation, and process design.

We used 3-D printers to economically design a prototype column packing. We chose construction materials based on optimal chemical and mechanical properties and their compatibility with the available printers. Fourier Transform Infrared Spectroscopy (FTIR) provided an analysis to aid material selection. 3-D Computer-Aided Design (CAD) software optimized our device for printing. Economic analysis of the design was performed based on the cost of printing each polymer type in each printer. The 3-D manufacturing method differs from existing methods by shortening development time, decreasing costs, mitigating risks, and increasing ability to prototype and continuously improve the desired product.

CHEMICAL AND BIOMOLECULAR ENGINEERING

TEAM

Abdul Hamid Mustafa, ChemE
Afza Zulfaka, ChemE
Eric Chiang, ChemE

ADVISERS

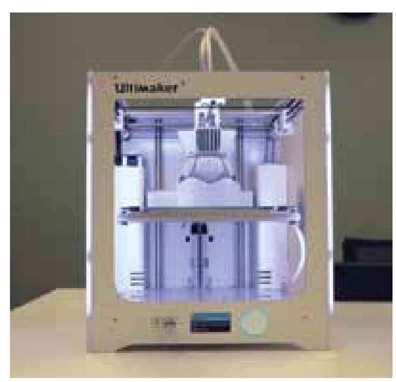
Russell Dunn, P.E., Professor of the Practice of Chemical and Biomolecular Engineering
Scott A. Guelcher, Professor of Chemical and Biomolecular Engineering
Bryan Beyer, Adjunct Instructor of Chemical and Biomolecular Engineering
Karl D. Schnelle, Chemical Engineering Consultant
Gerald McGlamery, Chemical Engineering Consultant
Matt Lang, Professor of Chemical and Biomolecular Engineering

SPONSOR

Polymer and Chemical Technologies, LLC

Chemical Engineering Design Advisory Board

3-D Printing in Chemical Engineering Applications



Ultimaker printers are a commercially available solution for 3-D prints.

Our goal was to explore the technology for application in chemical engineering to gain critical application data and provide innovative solutions. 3-D printers have a variation in filament properties, which introduces limits on fabrication for specific operations. The printed parts made from the same material through different 3-D printers can exhibit dramatic variation in chemical stability, mechanical properties, and print failure risk. In spite of this drawback, the technology paves the way for fabrication usable in a vast range of applications.

Our main approach included the analysis of mechanical, chemical and thermal properties of the printer filaments in raw form and in a finished product. The plan was to fabricate and test multiple "basic" shapes, taking into account variations of internal properties between batches. These data sets will create a set of heuristics for 3-D printing applications for various chemical engineering related products.

TEAM

Michaela Copp, ChemE
Dalton Gullett, ChemE/Econ
Andrew Hunt, ChemE
Crystal Loehman, ChemE
Zita Prutos, ChemE

ADVISERS

Russell Dunn, P.E., Professor of the Practice of Chemical and Biomolecular Engineering
Bryan Beyer, Adjunct Instructor of Chemical and Biomolecular Engineering
Dan Rahill, Chemical Engineering Consultant
Robert Marshall, Chemical Engineering Consultant
Nick Augsburger, Chemical Engineering Consultant

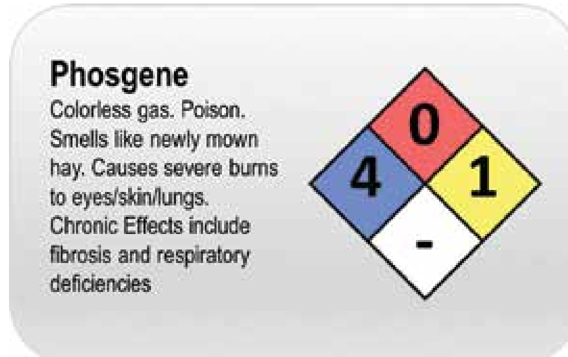
SPONSOR

Chemical Engineering Design Advisory Board

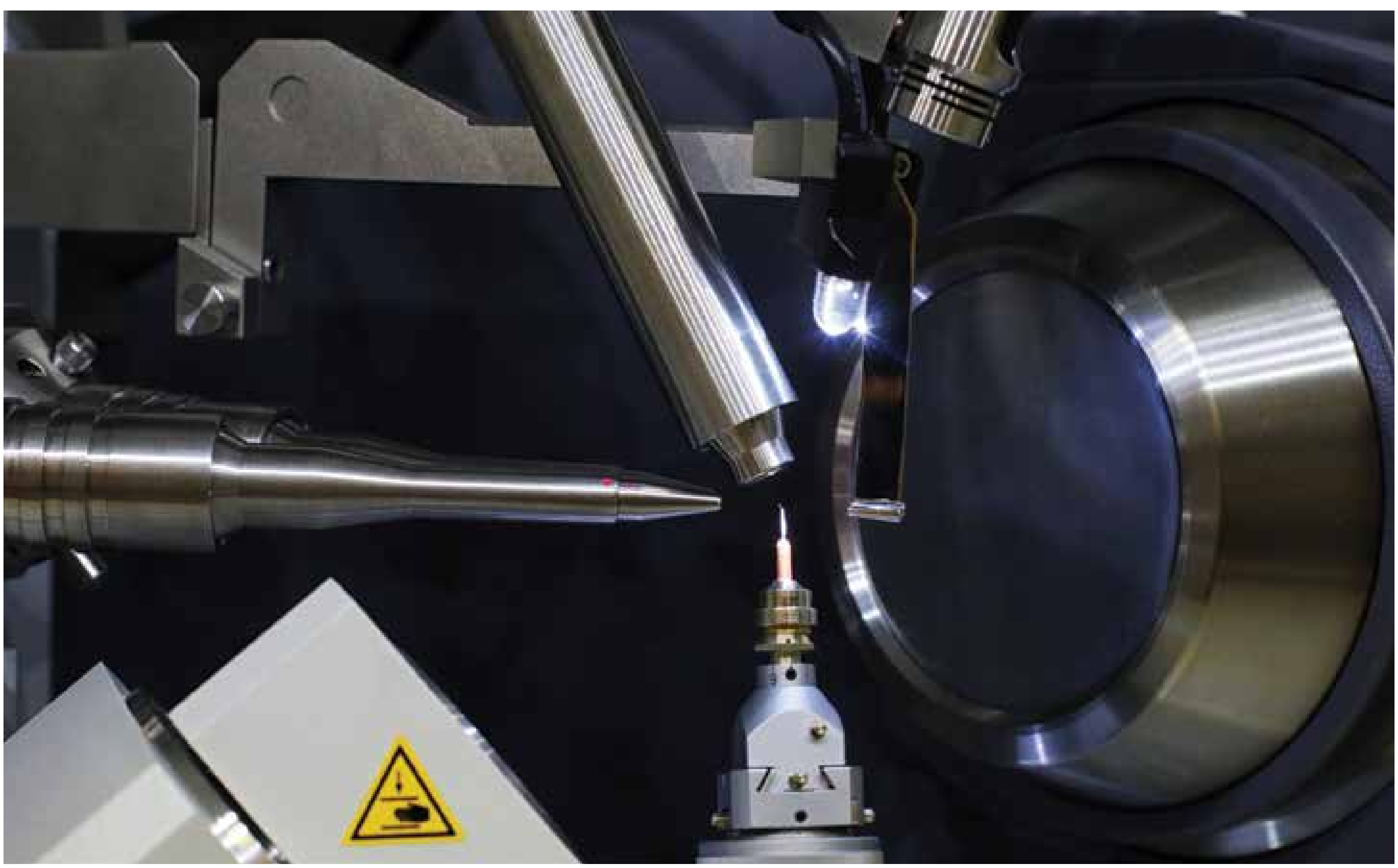
CHEMICAL AND BIOMOLECULAR ENGINEERING

Phosgene-Free Route to Polycarbonate Production

Polycarbonate plastics are valuable due to their natural transparency, impact resistance, and heat resistance. These qualities lend the plastics to many applications such as bulletproof glass, plastic lenses in eyewear, and medical devices. An important intermediate in the production of polycarbonates is diphenyl carbonate (DPC). Traditional industrial processes manufacture DPC using phosgene, a highly toxic reagent. At room temperature, this chemical is a poisonous gas previously used in chemical warfare and it contributed to more than 90,000 deaths throughout World War I. The inherent dangers of working with phosgene make developing an alternative method critical for producing polycarbonates in an environmentally friendly and safe manner. One potential way to create DPC uses a palladium halide catalyst with nitrogen-containing heterocyclic co-catalysts for the direct oxidative carbonylation of phenol to DPC. Our goal involved determining the most economical co-catalyst to be used in design of a plant capable of synthesizing 100 million pounds of DPC per year. Ultimately, the final plant design would eliminate the use of phosgene as an intermediate, minimize environmental impacts, and maximize profits.



The NFPA hazard diamond indicates the high toxicity of phosgene, underscoring the importance of removing it from the production process of polycarbonates.



CHEMICAL AND BIOMOLECULAR ENGINEERING

TEAM

Grace Comerford, ChemE
Aayush Gupta, ChemE
Frank Phillips, ChemE
Andrew Zaninovich, ChemE

ADVISERS

Russell Dunn, P.E., Professor of the Practice of Chemical and Biomolecular Engineering
Bryan Beyer, Adjunct Instructor of Chemical and Biomolecular Engineering
Alan Crawford, Chemical Engineering Consultant
David Steckler, Chemical Engineering Consultant

SPONSOR

Chemical Engineering Design Advisory Board

Mobile System to Treat Fracking Wastewater

Mobile wastewater treatment unit reduces the costs and environmental impacts associated with hydraulic fracturing waste.

The process of hydraulic fracturing, or fracking, is a technique for accessing subterranean reservoirs of natural gas and oil. Fracturing fluid is pumped at high pressure into wells over a mile below the surface, creating fissures through which the gas or oil can be recovered. The vast majority of the fracturing fluid is water, but it also contains several functional additives such as surfactants, friction reducers, gelling agents, scale and corrosion inhibitors, anti-bacterial agents, clay stabilizers, sand, and additional proprietary chemicals. It is estimated that 15-80 percent of the injected fluid returns as a mixture of the injected fluid and naturally occurring minerals from the Earth, which is typically is shipped off-site or stored in containment ponds until it can be properly treated and disposed. Stricter government regulations and increased shipping costs impact these current wastewater management solutions. We designed a mobile treatment system that can successfully prepare the resurfaced fracturing fluid for reuse through chemical and physical processes. The design minimizes the freshwater utilities required by fracking operations, thus lowering costs and reducing environmental impacts.

CHEMICAL AND BIOMOLECULAR ENGINEERING

TEAM

Kenneth Anderson, ChemE
Jordan Bair, ChemE
Jesse Benedict, ChemE
Kelly Couget, ChemE

ADVISERS

Russell Dunn, P.E., Professor of the Practice of Chemical and Biomolecular Engineering
Bryan Beyer, Adjunct Instructor of Chemical and Biomolecular Engineering
Tony Davis, Chemical Engineering Consultant
Del Pruitt, Chemical Engineering Consultant

SPONSOR

Polymer and Chemical Technologies, LLC

Chemical Engineering Design Advisory Board

Reducing Chemical Plant Operating Costs by Energy Conservation

A chemical plant with multiple reactors may not be recycling thermal energy at its full potential or reducing operating costs by maximizing internal heat exchange.

Utilities account for a majority of factory operating costs, so reducing the use of external utilities could result in significant cost savings. In chemical facilities, underutilization of internal resources such as steam, cooling water, or other process streams decreases overall energy efficiency and drives the need for external utilities. External energy demand can be reduced by determining advantageous stream pairings and by using heat exchangers to facilitate energy transfer between the streams. Using existing streams in this manner provides the heating and cooling utilities that would otherwise come from external sources. Accurate determination of the problem requires analyzing proprietary information, including plant diagrams; stream data such as flow rates, enthalpies, and inlet and outlet temperatures; and heat pinch and composite curves created from computer software. The team's goal is to discover favorable stream pairings to facilitate heat exchange and provide utility savings. Implementing the chosen heat exchange network will provide energy efficiency and decrease operating costs for the company.

TEAM
Imran Anoar, ChemE
Putri Desmawardi, ChemE
Victoria Yao, ChemE

ADVISERS
Russell Dunn, P.E., Professor of the Practice of Chemical and Biomolecular Engineering
Bryan Beyer, Adjunct Instructor of Chemical and Biomolecular Engineering
Karl D. Schnelle, Chemical Engineering Consultant
Gerald McGlamery, Chemical Engineering Consultant

SPONSOR
Chemical Engineering Design Advisory Board

CHEMICAL AND BIOMOLECULAR ENGINEERING

Sulfuric Acid Plant with Waste Heat Recovery

Sulfuric acid is one of the most highly produced commodity chemicals globally. It plays an integral role in fertilizer, water treatment, and battery industries, so high levels of sulfuric acid production in a country often indicate a strong national economy. We evaluated the feasibility of a sulfuric acid plant in Tennessee capable of producing 500 tons of sulfuric acid per day. The purest method of producing sulfuric acid reacts elemental sulfur with oxygen to produce sulfur dioxide gas, which is converted to sulfur trioxide through a catalyst bed reactor. Sulfur trioxide is further hydrated into sulfuric acid. Because this process is extremely exothermic, it generates large amounts of heat as a side product. Our design captures the produced energy in steam, which the plant can use internally or sell to neighboring processing plants. Recovering waste heat not only improves the economics of the plant, but also decreases environmental impact due to reduced fuel emissions. Our final design incorporates the profitability of all aspects needed to construct an actual sulfuric acid production plant.

A typical sulfuric acid production facility

TEAM
Terry Choi, ChemE
Hunter Rube, ChemE
Dawson Salter, ChemE

ADVISERS
Russell F. Dunn, P.E., Professor of the Practice of Chemical and Biomolecular Engineering
Bryan Beyer, Adjunct Instructor of Chemical and Biomolecular Engineering
Karl D. Schnelle, Chemical Engineering Consultant
Gerald McGlamery, Chemical Engineering Consultant

SPONSOR
Chemical Engineering Design Advisory Board

CHEMICAL AND BIOMOLECULAR ENGINEERING

Design of a 500-Ton-per-Day Sulfuric Acid Plant

More than 250 million tons of sulfuric acid are produced globally each year. Sulfuric acid is used in a wide range of industries, including fertilizer, batteries, water treatment, and metal processing. Because it has such a wide range of uses, sulfuric acid production generally can be used as a measure of a country's economy. Our goal was to design a plant that can produce 500 tons of sulfuric acid per day using elemental sulfur as a starting reactant. Since sulfuric acid production generates heat, excess energy can be harnessed to optimize our plant or sold to neighboring plants. An optimized steam network could give our plant an advantage over other sulfuric acid plants. Moreover, selling steam to neighboring plants would allow our plant to use their treated boiler feed water. We hope to produce the required amount of sulfuric acid in both 98 percent and 93.5 percent purities in the most economically viable method while meeting the sulfur dioxide emission requirements.

A typical sulfuric acid plant

CHEMICAL AND BIOMOLECULAR ENGINEERING

TEAM
Emily Cavalaris, ChemE
Emily Daley, ChemE
Savannah Thomas, ChemE

ADVISERS
Russell F. Dunn, P.E., Professor of the Practice of Chemical and Biomolecular Engineering
Bryan Beyer, Adjunct Instructor of Chemical and Biomolecular Engineering
Alan Crawford, Chemical Engineering Consultant
David Steckler, Chemical Engineering Consultant

SPONSOR
Chemical Engineering Design Advisory Board

Production of Semiconductor Grade Silane for Polysilane Synthesis

An industrial silane plant currently operating in the United States

The rapidly growing semiconductor industry depends largely on the production of silane, which is an essential component in the technologies developed by this sector. Recently, new applications for high order polysilanes, including silicon wafer and flat panel display technologies, have created increased demand for its main reaction component, silane. To supply the growing demand, the team designed an optimal industrial silane production route to produce 50 tons per year of silane to feed an in-house polysilane production process.

Research was conducted on different silane production methods and the specific requirements of silane for polysilane production. After choosing the optimal process for production goals, a plant design was created to meet the volume and product specifications, balancing the cost and complexity associated with the process. The design produced 50 TYPsemiconductor grade silane in a safe, economical, and efficient manner. Silane supply for polysilane synthesis is expensive and difficult to obtain. This design provides the best solution for allowing a company to venture into polysilane production.

Chemical Engineering Design Advisory Board

CHEMICAL AND BIOMOLECULAR ENGINEERING

TEAM
Elijah Aude, ChemE
Andrew Naclerio, ChemE/Math
Neel Ramachandran, ChemE

ADVISERS
Russell Dunn, P.E., Professor of the Practice of Chemical and Biomolecular Engineering
Bryan Beyer, Adjunct Instructor of Chemical and Biomolecular Engineering
Tony Davis, Chemical Engineering Consultant
Del Pruitt, Chemical Engineering Consultant

SPONSOR
Chemical Engineering Design Advisory Board

Controlling and Preventing Nitrogen Trichloride Buildup in the Chlor-Alkali Industry

In the chlor-alkali industry, brine water is electrolyzed to form sodium hydroxide and chlorine gas, two commodity chemicals with applications in nearly every chemical industry. When trace amounts of ammonia contaminants are present in the brine, a dangerous byproduct, nitrogen trichloride, is formed during electrolysis. Chemically similar to dynamite, nitrogen trichloride will auto-detonate at relatively low concentrations and cause serious damage to equipment, toxic chlorine gas leaks, and injury to workers. Thus, it is vital to control nitrogen trichloride concentrations throughout the chlor-alkali process. We are developing solutions to measure and remove nitrogen compounds upstream and downstream of the electrolysis process to prevent the potentially catastrophic buildup of nitrogen trichloride. Our system creates a safer working environment and minimizes the chance of explosion while maintaining economic viability for retrofitting existing chlor-alkali processes.

To prevent explosions and gas leaks, nitrogen trichloride must be controlled in chlor-alkali processes.

Chemical Engineering Design Advisory Board

TEAM

Nicholas Crowther, ChemE
Brian Doney, ChemE
Emily McRen, ChemE
Theresa Miller, ChemE

ADVISERS

Russell Dunn, P.E., Professor of the Practice of Chemical and Biomolecular Engineering
Bryan Beyer, Adjunct Instructor of Chemical and Biomolecular Engineering
Karl B. Schnelle, Professor of Chemical and Biomolecular Engineering, Emeritus
Justin Corney, Chemical Engineering Consultant

SPONSOR

Chemical Engineering Design Advisory Board

CHEMICAL AND BIOMOLECULAR ENGINEERING

Designing a Multi-Product Brewery

Bent End Brewery, established in 2017

In the United States, the beer industry sees most present-day growth in craft beer. Smaller-scale production allows for increased quality and specificity, which often gives rise to a variety of unique flavors, textures, and ingredients.

Our team designed the brewing process for 100,000 barrels per year of five year-round, four seasonal, and four limited edition brews. We undertook home brewing to understand initial production and then applied scale-up techniques to model a full manufacturing process to create Bent End Brewery. We evaluated the economic viability of production at a new facility versus production under contract at a large regional facility. While large-scale production often can result in significant waste and emissions, our team focused on minimizing waste and maximizing environmental efficiency by establishing a zero-emissions operating design. Bent End Brewery offers a unique combination of quality, taste and environmental responsibility.

Chemical Engineering Design Advisory Board

TEAM

Faruq Qawiem Bin Ahmad Faizi, ChemE
Ilie Arisha Ashraff, ChemE
Irfan Iskandar Jasmi, ChemE
Syazwan Danial Bin Zailan Azhar, ChemE

ADVISERS

Russell F. Dunn, P.E., Professor of the Practice of Chemical and Biomolecular Engineering
Bryan Beyer, Adjunct Instructor of Chemical and Biomolecular Engineering
Karl B. Schnelle, Professor of Chemical and Biomolecular Engineering, Emeritus
Justin Corney, Chemical Engineering Consultant

SPONSOR

Chemical Engineering Design Advisory Board

CHEMICAL AND BIOMOLECULAR ENGINEERING

Producing Linear Alpha Olefins from Ethylene with Improved Selectivity

Typical petrochemical plant for linear alpha olefin production

Linear alpha olefins (LAO) are straight chain alkenes where the double bond is on the primary carbon atom and they are produced primarily using ethylene as the raw material. Industrially, LAOs are important feedstocks for consumer products such as detergents, synthetic lubricants, and plasticizers. LAOs also are co-monomers in polyolefins manufacturing. However, the current oligomerization of ethylene results in low yield of the commercially more valuable 1-hexene (C6=) and 1-octene (C8=). Our team designed a plant to incorporate a specialized trimerization and tetramerization catalyst that has high C6= and C8= selectivity.

Our approach included modeling and simulating those plant designs using ASPEN Plus software. Economics evaluation and safety analysis were implemented to ultimately select the best design. The designed plant is capable of producing 100MM lb/yr of LAO with adjustable C6= and C8= mass split to meet the current market demand. All unwanted products and unused raw materials are recycled to minimize materials waste. In addition to increased sales, the plant is expected to be environmentally friendly and comply with the federal and state regulations.

Chemical Engineering Design Advisory Board

CHEMICAL AND BIOMOLECULAR ENGINEERING

TEAM

Marie Armbruster, ChemE
Jessica Banasiak, ChemE
Matthew Bedard, ChemE
Nicole Jenkinson, ChemE

ADVISERS

Russell Dunn, PE, Professor of the Practice of Chemical and Biomolecular Engineering
Bryan Beyer, Adjunct Instructor of Chemical and Biomolecular Engineering
Alan Crawford, Chemical Engineering Consultant
David Steckler, Chemical Engineering Consultant

SPONSOR

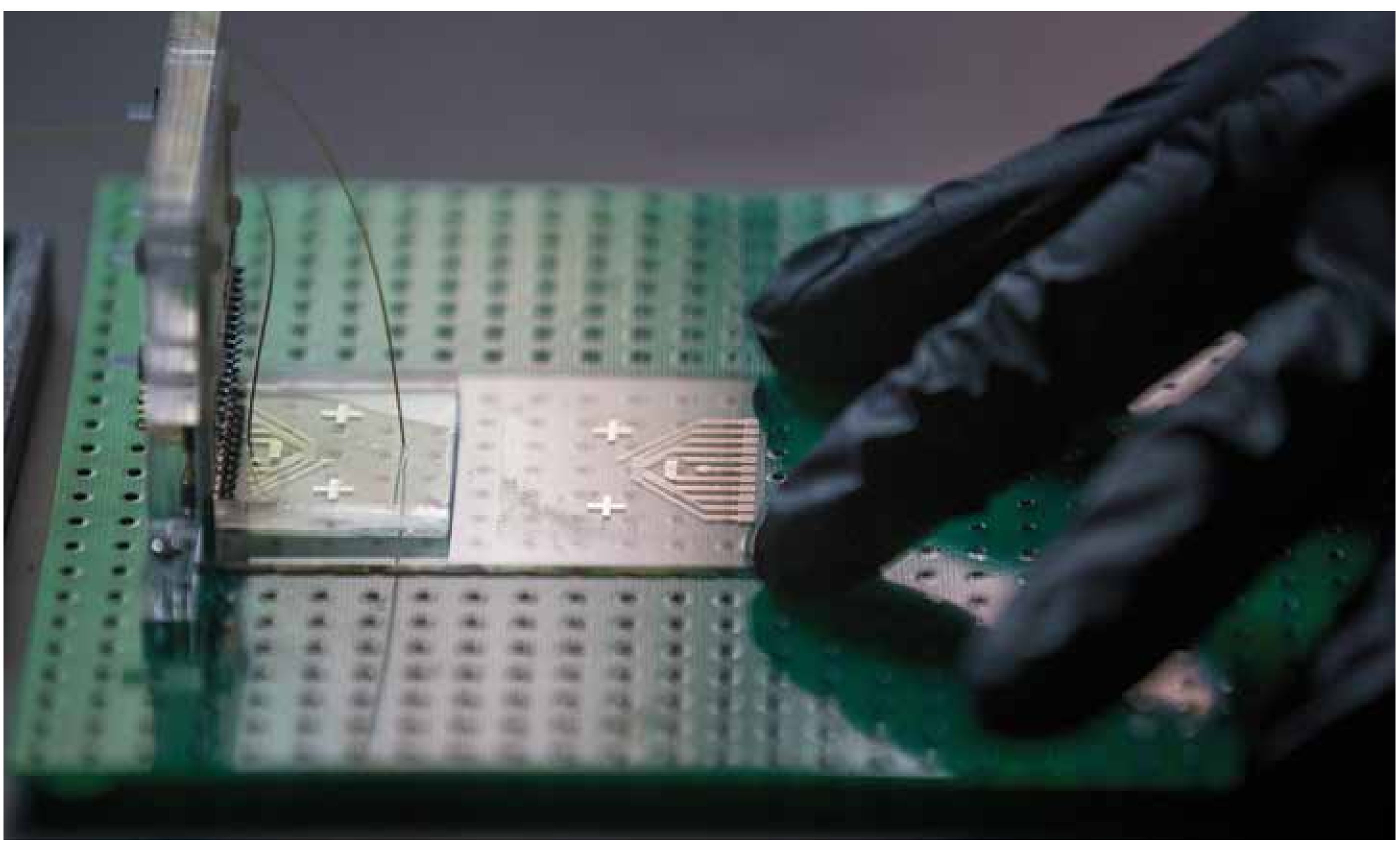
Chemical Engineering Design Advisory Board

Grassroot Plant for Conversion of Natural Gas to Aromatics

Natural gas often is wasted at fracking sites, but it can be converted into the p-xylene molecule, shown above. P-xylene is of high value as a feedstock for PET – a polymer used to produce plastics and textiles.

Conventional methods for the production of aromatics, which require crude oil, are unpopular due to the increasing cost, diminishing availability, and negative environmental impact of crude oil. Aromatic compounds such as benzene, toluene, and p-xylene (or BTX), are key components in a variety of chemical processes. Most notably, p-xylene is a basic raw material for polyester terephthalate (PET) polymers, which are used to produce beverage containers, fabrics, and packaging for processed foods.

Natural gas from fracking is an inexpensive alternative to crude oil, but an economical process to convert this natural gas into BTX does not currently exist. We propose a cost-effective plant to produce highly valuable aromatics from the natural gas that is often burned off as flare. The design of this grassroot facility includes two major sections: (1) dehydrocyclization using a zeolite catalyst to form C_6 and C_{10} and (2) selective alkylation of C_6 aromatics into p-xylene. The team analyzed critical economic factors to assess the profitability of the plant and to determine the value of constructing the plant. Compared to previous processes for production of p-xylene, this use of natural gas offers a more economical and sustainable approach than conventional methods.



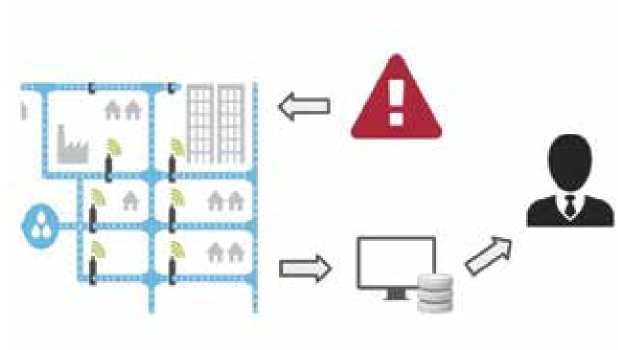
TEAM
Hannah Braun, CompE
Kenny Frye, CE
Steven James, CompE
Kenny Wang, CompE

ADVISERS
Jonn Kim, Founder and CEO
Ralph Bruce, Professor of the Practice of Electrical Engineering
Lori Troxel, Professor of the Practice of Civil and Environmental Engineering

SPONSOR
Geeks and Nerds

ELECTRICAL ENGINEERING AND COMPUTER SCIENCE

Cybersecurity Testbed for Critical Infrastructure



A generic water system model with a software testing suite identifies cybersecurity threats and reports them to administrators.

As developing resilient infrastructure becomes a national security priority, cybersecurity will play a larger and larger role. That goal requires testing but “testing” infrastructure and critical systems in the real world is impractical as well as unwise. Robust, secure testbeds sidestep this limitation by creating safe environments for collaboration, research and testing. The team designed a scalable open-source testbed for use with critical infrastructure systems to identify potential cybersecurity vulnerabilities.

Working with the project sponsor, the team modeled a water system and related communications that can be tested to identify and exploit vulnerabilities. The design includes a Programmable Logic Controller (PLC) based network, a middleware communication protocol, and a software suite for testing. This testbed seeks to analyze such a network, determine where security-related issues may arise, and prompt administrators to address them. The testbed can be a prototype for larger, generic, and extensible models designed to be used in real-world systems. Such testbeds and models will make it easier for geographically dispersed research teams to communication and collaborate on best practices.

TEAM
Derek Johnstone, EE
Boadjom MacCarthy, EE

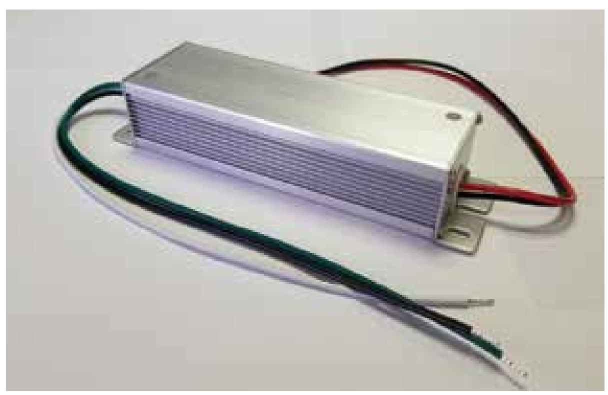
ADVISERS
Joseph Polt, Product Development Manager
Brian Sierawski, Research Assistant Professor of Electrical Engineering

SPONSOR
SFEG

ELECTRICAL ENGINEERING AND COMPUTER SCIENCE

IoT LED Driver

LED drivers are commonly used and they have reached a plateau in terms of efficiency. There is a need to differentiate current LED driver models by introducing useful functionality with newer technologies. The objective is to add specific Internet of Things functionality to LED drivers that could improve the experience for users and manufacturers. The added component is a microcontroller whose function would effectively replace the current integrated circuit. A microcontroller would run all current processes of the IC with additional features as determined by a user.



LED power supply operated by an integrated microcontroller with the capacity for built-in IoT-based functionality

ELECTRICAL ENGINEERING AND COMPUTER SCIENCE

TEAM
Colburn Wagner, EE
Dongchen Liu, CompE
Syafiq Abdur Rahman, ME

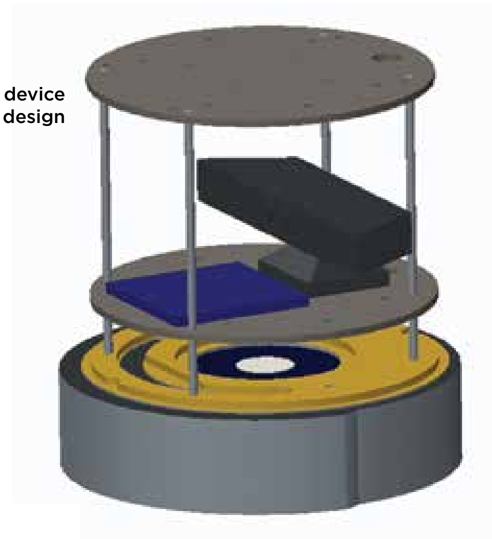
ADVISER
Richard Alan Peters, Associate Professor of Electrical Engineering

SPONSOR
Metova

Metova Autonomous Utility Robot II

The autonomous utility robot devised for Metova strives to automate asset tracking by continuously updating the location of, and searching for, important company assets within an office setting. The robot creates a map of the office and navigates itself to certain locations on the map. From an end-user perspective, the location of a designated item can be queried, with a response generated based on the robot's ability to effectively locate the object. This allows employees to save valuable time when searching for an asset. Instead of hunting for the item, they will view the map and query the AUR about the object's location, which results in increased efficiency for office-wide asset tracking. An immediate commercial application is the use of AURs in similarly-sized single-floor offices, workspaces, homes, and classrooms. Additional dimensions of scalability involve environment size and maximum number of trackable assets.

Final device design



ELECTRICAL ENGINEERING AND COMPUTER SCIENCE

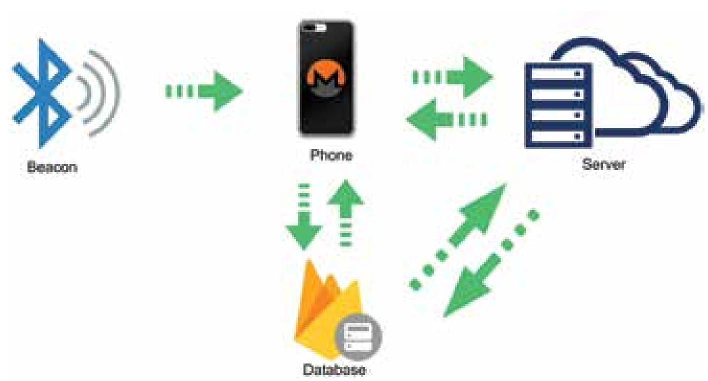
TEAM
Christopher Acker, EE
Connor Goggans, EE
Husain Ruhama, EE

ADVISER
Michael Etherley, Software Engineer, Metova

SPONSOR
Metova

Indoor Positioning System

The need for context-aware data is growing as software we use daily becomes more complex and integral to our lives. The goal of the Metova IPS project is to create a smarter office space by integrating employees' location data with a company's software suite. Employees' locations are tracked via beacons that emit a Bluetooth signal, which employees' smartphones analyze to determine their position in the office space. An employee's location data is sent to a server, which interacts with the software tools used by the company. For instance, if an employee walks into a meeting, the platform can automatically set their status to "busy" and turn off notifications on their phone. Through such automation, the platform will serve to make interaction between employees and the software they use more seamless and may improve company efficiencies.



Metova IPS control flow

TEAM
Allan Boudreau-Fine, EE
Sam Hurd, EE/CS
Tristan Le Veille, EE

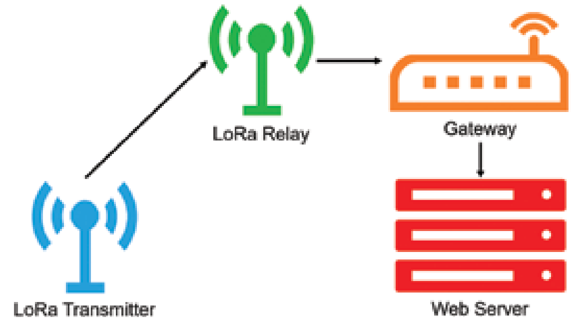
ADVISER
Ralph Bruce, Professor of the Practice of Electrical Engineering

SPONSOR
Metova

ELECTRICAL ENGINEERING AND COMPUTER SCIENCE

Metova LoRa Single-Hop Mesh Network

In a LoRa network, the nodes traditionally are arranged in a star format with each node directly communicating with the gateway. This format works well for a limited range but in some remote applications the transmitters need to be farther from the gateway. The goal is to build a single-hop mesh network using LoRa devices. In this network, nodes that are out of range of the gateway can use other nodes in the network to relay packets back to the gateway. The single-hop mesh network includes four main components. An out-of-range transmitter node sends data to a node acting as a relay. The relay node sends the packet to a gateway. Finally, the gateway uses a network connection to send the packet to a server. This solution extends the potential range of a LoRa network running with a single gateway. The node-to-node communication also allows LoRa devices to share data without requiring a gateway so the nodes can be used to create a powerful Internet of Things network.



The overall system for the single-hop mesh network using LoRa transmitter devices

TEAM
Case Cooper, EE
Noah Gertler, ME

ADVISERS
Ralph Bruce, Professor of the Practice of Electrical Engineering
Ibrahim Ahmed, Electrical Engineering Graduate Student
Brock Smethills, Chief Technology Officer, Sterling Ranch Development Company
Andre Gouin, Business Technology Consultant, Xcel Energy

SPONSORS
Vanderbilt University School of Engineering

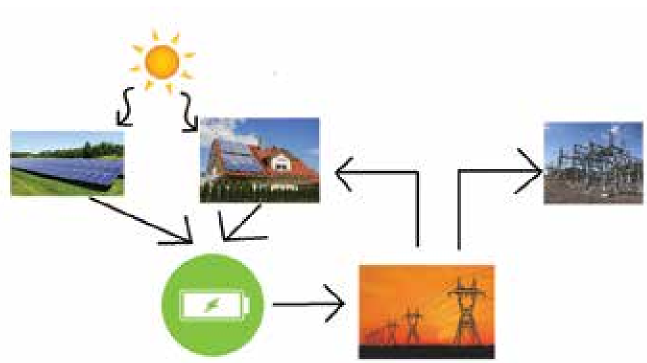
Sterling Ranch Development Company
- Tesla and Siemens

Xcel Energy

ELECTRICAL ENGINEERING AND COMPUTER SCIENCE

Sterling Ranch Energy Storage

Sterling Ranch is a sustainable community development south of Denver, Colorado. With a goal of having at least 40 percent of its homes use rooftop solar panels, Sterling Ranch is looking to photovoltaics to trailblaze a greener society. Our goal is to determine both the projected load the Sterling Ranch community will put on Xcel's grid, as well as modeling potential energy production and storage efficiencies via rooftop and community solar. Brock Smethills, Sterling Ranch CTO, and Andre Gouin, business technology consultant at Xcel Energy, supplied data, and we have corresponded with individuals at Tesla and Siemens. In a viability assessment, we determined the potential loads from Sterling Ranch residences, commercial properties, electric vehicle penetration, and hospital requirements. We will develop more precise estimates for Xcel Energy to help them determine when the company needs to add a new substation to the Denver grid.



Solar energy is captured via rooftop solar panels and community solar gardens and stored in a central battery unit. Stored power can be redistributed to Sterling Ranch homes or other needs within Xcel's full grid.

ELECTRICAL ENGINEERING AND COMPUTER SCIENCE

TEAM

Ghassan Alduraibi, EE/Math
Shamita Nagalla, CompE
Emir Rodzi, CompE
Betsy Weber, CompE

ADVISERS

Marty Skolnick, Account Manager, Siemens
Brock Smethills, Chief Technology Officer, Sterling Ranch Development Company
Kevin Brown, Steward App Developer
Rene Herrera, Technology Integration Officer & Program Manager, Siemens
Ralph Bruce, Professor of the Practice in Electrical Engineering

SPONSOR

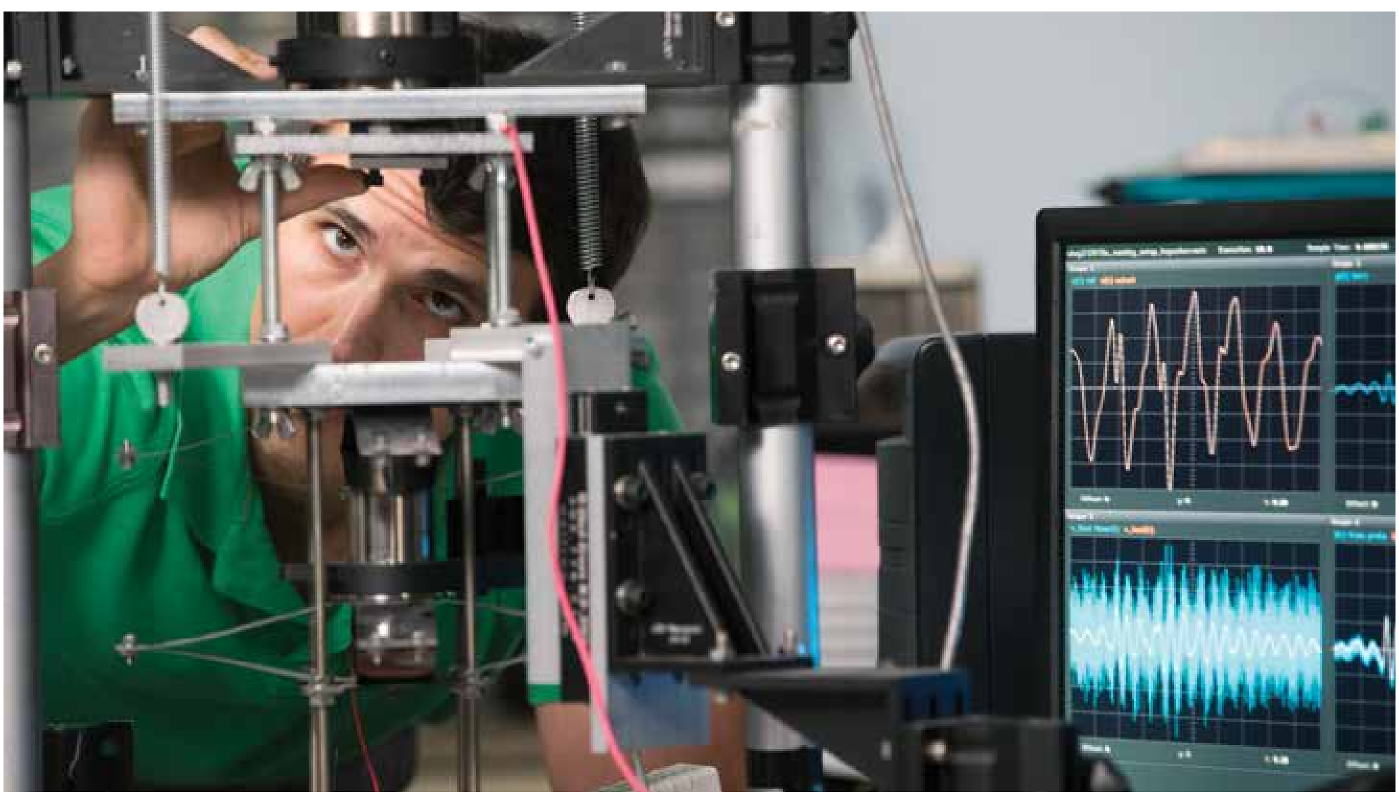
Sterling Ranch Development Company

Siemens

V Smart Light Poles

Sterling Ranch is a technologically advanced net zero community near Denver, Colorado. Sterling Ranch residents will be able to control in-home appliances with Steward, a smartphone app. The functions of Steward also are being expanded to outside the homes for safe passage at night throughout the community, and to reduce noise pollution from light poles. The project objective is to create a feature for the Steward app that detects phones approaching via Bluetooth beacons. Steward will then signal community light poles to brighten from the default dim state. The smart light poles, developed by Siemens, are connected by a single network, which is controlled by an central server. By communicating with the Steward app, the server is able to control the light poles remotely.

Steward Application Home Page Interface



TEAM
Michael Brown, ME
Suhardi Hablee, ME
Nur Hanis Hamidzul, ME
Bethanie McCrary, ME
Eiman Rozman, ME

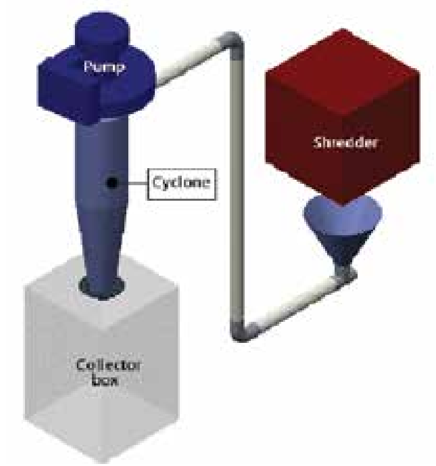
ADVISERS
Mark Larson, Manager Engineering, Integrated Factory Automation
Joel Wotruba, Senior Engineer, Integrated Factory Automation

SPONSOR
Nissan North America

MECHANICAL ENGINEERING

Nissan Cardboard Conveyance Project

Nissan's vehicle assembly plant in Smyrna, TN needs to manage 12 million pounds of waste cardboard, which enters the plant as packaging for parts from overseas. Getting rid of this cardboard from the assembly line is crucial to ensure a smooth production process. Currently, cardboard is thrown into dumpsters at 23 different locations around the plant. Workers then transport and bale this cardboard. To convey the cardboard efficiently, Nissan needs a new system that is safe, ergonomic, efficient, and low maintenance. The team set up a pneumatic conveyance system using a vacuum pump and PVC pipes. After an initial feasibility test, the team did mathematical modeling to calculate the energy loss, conveyance minimum air velocity and the pressure drop. A cyclone was designed to ensure that shredded cardboard particles would settle into a large container due to the change in pressure throughout the cyclone. The design will allow cardboard to be conveyed successfully without clogging, with minimal maintenance, and it is expected to give Nissan a return on investment within two to five years.



This pneumatic conveyance system design conveys cardboard efficiently from a shredder through a vacuum system to a cyclone, which then funnels the particulate into a collection box.

TEAM
Aiman Azani, ME
Chandler Barnes, CompE
Aishah Sofea Hanifa, ME
Aisar Mat Hassan, ME
Fatin Inani Rosdi, ME
Dennis Sohn, ME

ADVISER
Joshua Kojot, Research Biochemist

SPONSOR
Naval Surface Warfare Center, Panama City Division

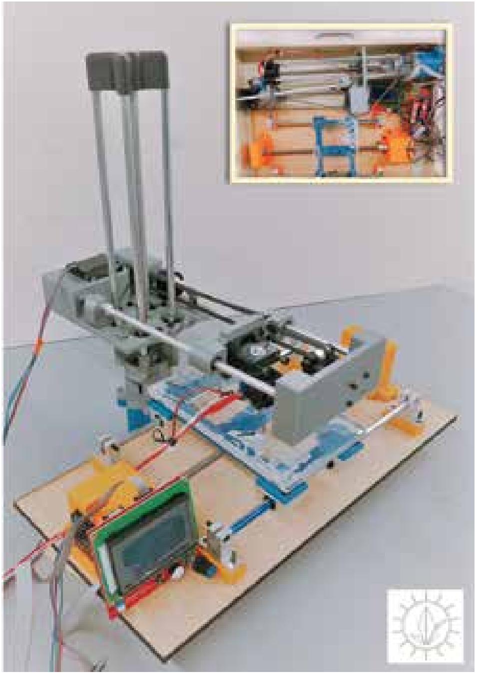
MECHANICAL ENGINEERING

Collapsible, Solar Powered 3-D Printer

3-D printing is revolutionizing the design and manufacturing fields — from medical equipment to space travel. Typical 3-D printing machines are characterized by a large, bulky size and must be operated in a controlled environment. The next innovation in the 3-D printer evolution is extreme portability which will allow for more dynamic uses in various environments.

The team's goal was to develop a collapsible 3-D printer that can fold into a compact size for transit. This compact design must fit into a briefcase, weigh under 10 pounds, and be solar powered. These features will give the device advantages over current 3-D printers, which are difficult to move and must have a dedicated power source.

The final product is a fully functioning 3-D printer that can successfully fold into a 43cm x 51cm x 16cm traveling case, operate on solar power with a rechargeable battery, and produce a build volume of 18cm x 10cm x 20cm with a resolution quality comparable to current 3-D printers. This transportable, compact design will impact the next generation of 3-D printers and the way they are used.



A collapsible, portable, and solar-powered 3-D printer shown is easy to use and move.

MECHANICAL ENGINEERING

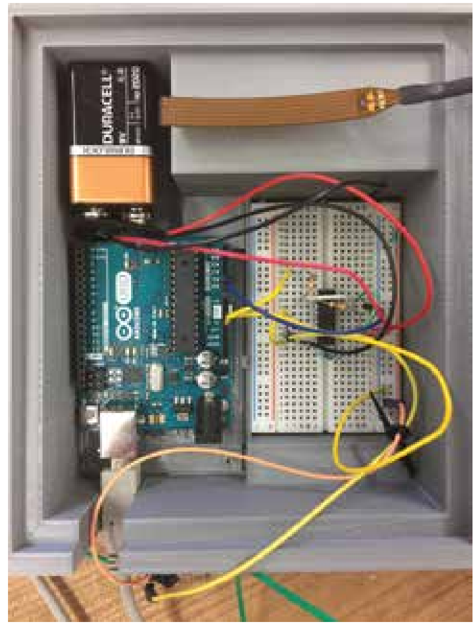
TEAM
Robert Balistreri, ME
Kamalia Hisham, ME/Math
Timothy Jiang, ME
Jessica Matos, ME
Rohan Rao, ME

ADVISER
Robert Ridley, Section Leader, North American Production Engineering Department

SPONSOR
DENSO Manufacturing Tennessee, Inc.

Denso Sensor Development Project

The objective of the project is to determine high fidelity and economic opportunities for Denso's new heat flux sensor, and evaluate their applications. This sensor has a competitive edge over other sensors on the market due to its high sensitivity and unique flexibility, which allows for more potential applications. This project aims to develop fully functional and safe prototypes to evaluate the feasibility of using Denso's sensor in a variety of fields, ranging from medical equipment to commercial HVAC. Applications investigated include insulation R-value prediction, heat fin performance evaluation, and clothing insulation effectiveness. The result is a portfolio to Denso that details the experimental setup and procedures of 10 potential applications. This portfolio also will include economic feasibility for each application, such as market size, current competitors, and overall profit potential.



Denso's new heat flux sensor with circuitry used for testing potential applications

DENSO

MECHANICAL ENGINEERING

TEAM
Sam Elkins, ME
Marc Fleming, ME
Brandon Paikoff, ME
Jack Schaefer, ME
William Sox, ME

ADVISERS
Jason Mitchell, Research Assistant Professor of Mechanical Engineering
Brett Byram, Assistant Professor of Biomedical Engineering

SPONSOR
U.S. Navy Supervisor of Salvage (SUPSALV)

Developing Technologies for Near Field Visualization for Divers in Zero Visibility Environments

Ultrasound was used to produce high quality images of various tools submerged in water at distances of a few centimeters up to a meter. Such images will allow divers to "see" in their zero visibility environment.

Navy divers frequently work in water with enough suspended particulate to make floodlights useless. Divers must move around such environments based purely on their sense of touch. The team worked with the Navy's Supervisor of Salvage to develop sensor technology for the Divers Augmented Visual Display project. The goal was to investigate innovative sensing technology, which would allow divers to visualize their nearby surroundings. Most options based on electromagnetic waves suffer from water's high absorptivity in the EM spectrum, eliminating modalities such as infrared and lasers. Sound waves transmit well through water with suspended particles. Low frequency sonar is good for the far field but cannot image up to the face of the transducer, and its resolution is limited. Higher frequency, shorter wavelength ultrasound is ideal as shorter wavelengths allow for higher resolution and can image up to the face of the transducer. We have collected images at a variety of distances and water conditions, validating ultrasound to successfully image tools and other objects under water at distances up to 1 meter to supplement the visual feedback available to Navy divers.

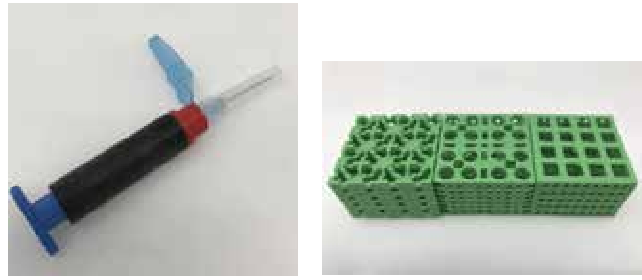
TEAM
Perry Bakas, ME
Mar Battistella, ME
Sanjay Ramaprasad, ME
Joshua Tacca, ME

ADVISERS
Tracie Prater, Aerospace Engineer, Materials and Processes Laboratory, NASA
Niki Werkheiser, Project Manager for the In-Space Manufacturing Project, NASA
Frank Ledbetter, Technical Adviser, Wheelhouse Consulting

SPONSOR
NASA

MECHANICAL ENGINEERING

In-Space Manufacturing: Additive Manufacturing for Long Duration Space Flight



Left, 3-D printed syringe prototype. Right, three plant growth substrates 3-D printed from starch-based materials.

The International Space Station carries about 29,000 pounds of spare storage, though 95 percent of it is never used. This practice is unsustainable for long duration missions because it is a waste of vital storage space. Additive manufacturing provides a promising solution, as on-demand 3-D printing of tools and supplies reduces the amount of spares and consumables.

The team designed and printed medical devices and plant growth substrates to support NASA's "make it, don't take it" philosophy. Consumable medical devices, including otoscope specula, nasal trumpets, and syringes were printed and analyzed. For the plant substrates, the key parameters of pore size, filament material, and lattice structure were varied to optimize plant yield and printability as well as minimize use of material. Our work contributes to NASA's capabilities for in-space manufacturing.

TEAM
Michael Byrd, EE
Elizabeth Lee, ME
Thomas Metke, ME
Gabriel Rios, ME
Jonathan Tari, ME
Samvrutha Tumuluru, EE/BME
Andrew Wang, EE

ADVISERS
Jonn Kim, CEO

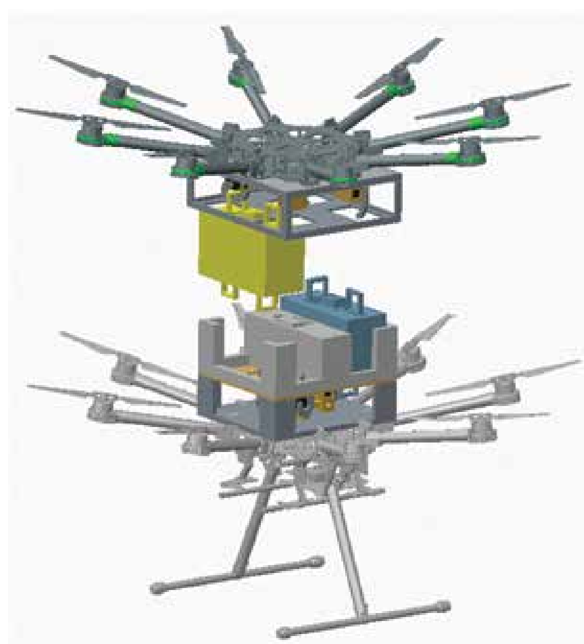
SPONSOR
Geeks and Nerds

MECHANICAL ENGINEERING

Mid-Flight Drone Refueling

Multirotor drones have become popular in the last ten years. Their ability to record data and film video from the air have made them ubiquitous in government and industry. Still, a key deficiency affects their usefulness. Rechargeable batteries power nearly all multirotors, which limit flight time to less than 30 minutes. The team solved this issue by creating a system that autonomously refuels drones in mid-air, allowing for increased flight time.

The project began with an assessment of requirements and existing technologies, followed by design options for adaptation, then feasibility testing. The best design was fabricated and tested. The team created the Touch-n-Go™ mechanism in which a refueling drone meets an airborne drone from below and swaps out a fully charged battery for the discharged battery. The prototype demonstrated the success of the Touch-n-Go™ mechanism through a multi-stage proof of concept refueling of an airborne 8-rotor drone.



A payload octocopter (top) has its battery swapped by a refueling drone (bottom) to demonstrate the Touch-n-Go™ mechanism.

MECHANICAL ENGINEERING

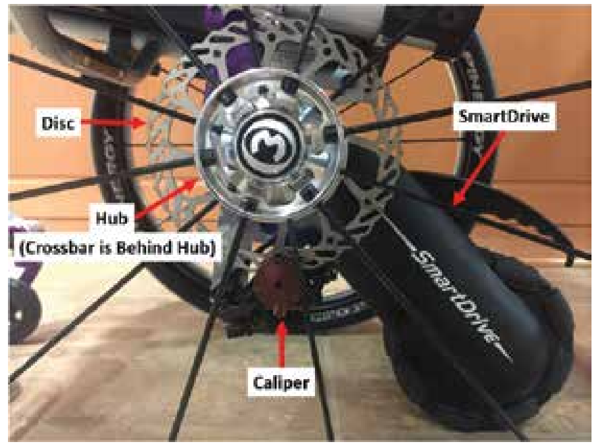
TEAM
Ajwad Roslee, ME
Baffour Osei, ME
Chase Janikowski, ME
Christine Brandewie, EE
Jon McGahee, ME
Nurasyikin Abdul Latif, ME

ADVISERS
William Emfinger, Chief Technology Officer
Dexter Watkins, Research Engineer
Ken Shafer, Mechanical Design Engineer

SPONSOR
MAX Mobility, LLC.

Power-Add-On for Manual Wheelchairs Enabling Steering and Braking

MAX Mobility maximizes the mobility of those with physical disabilities through innovative, accessibility-inspired technology. The company's leading product is SmartDrive, a motorized wheel that can be attached to the crossbar of any manual wheelchair. The SmartDrive provides forward motion, which alleviates shoulder strain (and resulting injury) from constantly pushing their chair. The team designed another add-on to work in tandem with the SmartDrive, to provide braking and steering functionalities. After several iterations, the team chose a disc brake system to provide wheelchair braking and steering through variable braking of the wheels. Variable braking emulates the way wheelchair users typically brake – grasping one wheel to slow it and turn the wheelchair in that direction. The discs are attached rigidly to the rear wheels of the wheelchair, while the braking calipers are fixed to the crossbar of the wheelchair. A handheld controller allows the user to control the brakes with minimal hand function, differentiating this system from the leading wheelchair disc brake system on the market. The wheelchair retrofitted with the disc braking system will be used for feasibility testing of disc brakes in the company's future products.



An automated disc brake system for a manual wheelchair used in conjunction with MAX Mobility's SmartDrive

max mobility

MECHANICAL ENGINEERING

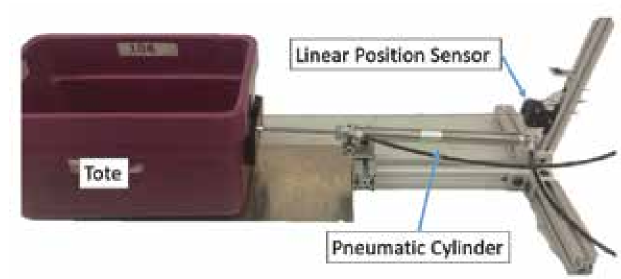
TEAM
Danial Luqman Ain, ME
Fitri Nabila Shafien, ME
Fletcher Prouty, ME
Matthew Bacon, ME/Math
Muhammad Aliff Aiman Abdul Rahman, ME

ADVISER
Lie Tang, Ph.D, Control Specialist

SPONSOR
Quality Manufacturing Systems, Inc.

QMSI Tote Pusher Design Project

Automated pharmacies fill thousands of mail order prescriptions daily. Liquid medication and inhaler orders are placed in plastic containers known as totes and are transported around these facilities via conveyor systems using pneumatic air cylinders. Because the current pneumatic systems do not include feedback mechanisms, the lighter totes are pushed with the same force as the heavier one. With tote weight varying between two and 20 pounds, lighter totes occasionally are pushed with too high a velocity and improperly transferred between conveyors, which causes a failure in the automation system. The team designed a velocity controlled pneumatic cylinder system that ensures all totes are pushed at an appropriate speed. The design uses simple solenoid valves to regulate the velocity by turning off the supply air for a specified time interval, an action that reduces tote velocity. To determine that time interval, the system employs a feedback algorithm with velocity data calculated by leveraging the output of a high-resolution linear position sensor. This system is a low-cost solution that effectively regulates tote velocity, allowing for future implementation in automated pharmacies.



Design solution highlights the pneumatic cylinder, the linear position sensor and the tote being pushed.

QMSI

TEAM
Andrew Jordan, ME
Dannielle Hendon, BME
Iliya Mohamad Lokman, ME
Joshua J. Fleck, ME
Kamal Hisyam Kamal Azmi, ME
Matthew C. Johnson, ME
Seonghoon Noh, ME/Math

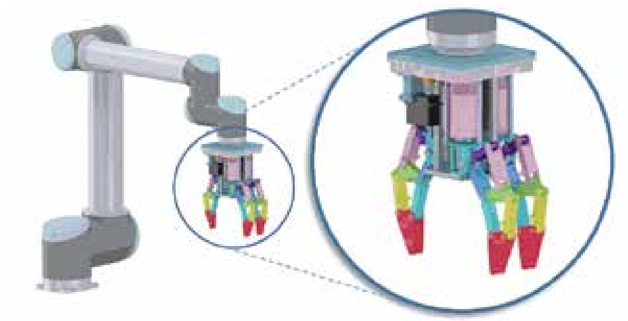
ADVISERS
Mark Larson, Manager, Integrated Factory Automation Engineering
David Blaylock, Engineering Supervisor, Integrated Factory Automation
Joel Wotruba, Engineer, Integrated Factory Automation
Maston Lyons, Senior Design Engineer
Kevin Amos, Manufacturing Engineer

SPONSOR
Nissan North America, Inc.

MECHANICAL ENGINEERING

Nissan Robotic End-of-Arm Tooling

Part picking is a repetitive and labor-intensive process in a vehicle production line where production associates select parts and place them in bins for later assembly. The Integrated Factory Automation team at the Nissan Smyrna, Tenn. plant seeks to automate part picking with a collaborative, industrial robotic arm manufactured by Universal Robotics. The goal was to develop the corresponding end-of-arm tooling and integrate the tooling with a computer vision system for a fully autonomous operation.



Three-fingered, 10DOF end-of-arm tooling mounted on Universal Robotics' industrial robot

The team developed an underactuated, 10 degrees of freedom (10DOF) end-of-arm tool with variable grasp configurations through a rotatable, three-fingered design. The end-of-arm tool incorporates force-controlled grasping to ensure safe and effective execution. An externally mounted Cognex camera and computer vision system command the movement of the robot arm. The robotic hand is less expensive to produce by an order of magnitude than comparable commercial solutions, and it can grasp a wider variety of parts. It is lightweight, 3-D printable, and easily scalable for diverse applications.

TEAM
Thomas Curnin, ME
Tyler Ritter, ME
Jimmie Sanders, ME
Eric Speer, ME

ADVISERS
Tonia Rex, Associate Professor of Ophthalmology
Robert Webster, Associate Professor of Mechanical Engineering

SPONSOR
Vanderbilt Eye Institute, Vanderbilt University Medical Center

MECHANICAL ENGINEERING

Simulation of IED Blast for Optical Trauma

The increased use of improvised explosive devices (IEDs) on modern battlefields has increased explosive-related injuries. In particular, overpressure created by a passing shock wave causes many soldiers and veterans severe optical trauma. The team set out to fabricate a system to replicate the pressure gradient of a blast for use on mouse test subjects. Constraints included producing a pressure gradient wave similar to that of a Friedlander curve (a step function with exponential decay), controlling the amplitude and timing of the wave, and allowing space for a mouse to experience the impact of the wave. The team designed a shock tube system using an air-tight driver (pressurized) section, a driven (testing) section, a membrane, and a membrane-puncturing actuator. Once the driver section is pressurized, the linear actuator punctures the membrane and produces a shock wave that travels along the driven section to the test specimen. The shock tube more accurately and consistently generates blast characteristics than even the fastest valve, which is dynamically unable to create the sharp step pressure rise.

Shock tube system to simulate blast-related injuries to the eye

VANDERBILT HEALTH

VANDERBILT UNIVERSITY MEDICAL CENTER

MECHANICAL ENGINEERING

TEAM
Alexander Roed, ME
Chris Savoca, EE
Doug Manogue, ME
Eric Noonan, ME
Kevin Barrow, ME
Lindsey Nestor, ME

ADVISERS
Alexander Langerman, Associate Professor of Otolaryngology, Director of Surgical Analytics Lab, Faculty of the Center for Biomedical Ethics and Society
William Rodriguez, Medical Image Processing Lab

SPONSOR
Surgical Analytics Lab

Surgical Video System Design Project

The team designed, built, and tested a wearable video system that captures high-quality video of open surgical procedures. The project sponsor, an otolaryngologist who specializes in surgical oncology, seeks to capture more visual data during surgeries. While most modern operating rooms contain video recording systems, the current standard for open-case capture is an overhead boom-mounted camera whose video stream is obstructed constantly by the heads of the surgical staff. The team's system features a camera at the top of a gown aimed at the surgical field. Laser, computing and power systems are located under the gown and a power button is accessible through the gown.

This fully developed surgical video system will allow physicians to review their procedures, enable an immersive educational experience, provide clarity in malpractice cases, and formulate normative surgical practices.

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

MECHANICAL ENGINEERING

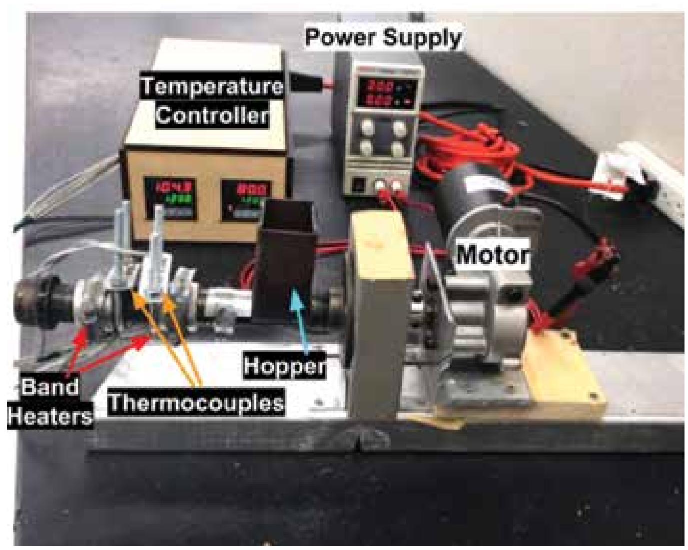
TEAM
Collin Garcia, ME
Brenden Glover, ME
Sawyer Lawrence, ME
Fiqah Mahamud, ME
Sam Monroe, ME

ADVISER
Joshua Kojot, Research Biochemist

SPONSOR
Naval Surface Warfare Center, Panama City Division

The Additive Re-Manufacturing of Plastic for 3-D Printer Filament

Converting plastic waste into 3-D printer filament will reduce logistical needs by lowering waste disposal as well as eliminating filament transportation needs. The primary design elements are the motor, heating system, and barrel. The motor uses a digital power supply to control motor speed, and it operates the auger bit through a worm gear train to translate material through the barrel. The heating system uses band heaters operated using PID temperature controllers with thermocouples as temperature monitors. The barrel contains an input hopper for plastic material to be added to the system, an enclosure to heat the plastic inside, and a nozzle for sizing the output. There are currently filament extruders on the market, but these require highly processed resin pellets with small and regular dimensions and cannot recycle raw plastics. General extrusion devices that can process recyclable plastic lack the precision needed for 3-D printer filament. The additive re-manufacturing of 3-D filament device will convert shredded PETE and HDPE plastics into 3mm and 1.75mm 3-D printer filament and will occupy a new niche in the market.



The additive re-manufacturing of 3-D filament extrusion device

TEAM
Morgan Byrd, ME
Nicholas Galioto, ME
Dominic Ghilardi, ME
Katie Hornbeck, ME
Spencer Kallor, ME
Taylor Parra, ME

ADVISERS
Amrutur Anilkumar, Professor of the Practice of Mechanical Engineering

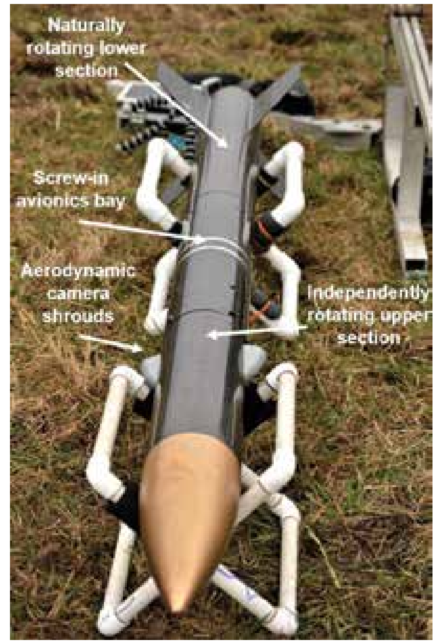
SPONSOR
Vanderbilt Aerospace Design Laboratory

NASA Marshall Space Center

MECHANICAL ENGINEERING

Spacecraft Sectional Roll Control During Flight

The Vanderbilt Aerospace Design Lab (VADL) has designed, built, and tested a rocket that optimizes an imaging payload. The flight vehicle was built to satisfy and exceed requirements of the NASA Student Launch Initiative. It is designed to fly to one mile (5,280 feet) in altitude, to be recoverable and reusable, and to perform a target detection experiment via the imaging payload. In support of the payload, the rocket precisely controls its rotational position to maximize camera exposure to the targets. Motor control best offered the needed precision but necessitated the key innovation for the project: the novel concept of sectional roll control (SRC). The forward section of the rocket, which carries the payload and is controlled by the motor, rotates independently of the aft section. As there are no records of such a rocket being created, a unique mechanism utilizing dual thrust bearings was designed and built to facilitate Sectional Roll Control. This concept was validated through extensive ground-based testing and various test flights throughout the year. The project culminated in early April with flight at the NASA Student Launch in Huntsville, Alabama.



The rocket in a flight-ready configuration with callouts for key details

TEAM
Daniel Schneller, ME
Jered Dominguez-Trujillo, ME
Kurt Lezon, EE
Peyton Fite, ME
Will Pagano, ME
Xavier Williams, EE

ADVISER
Amrutur Anilkumar, Professor of the Practice of Mechanical Engineering

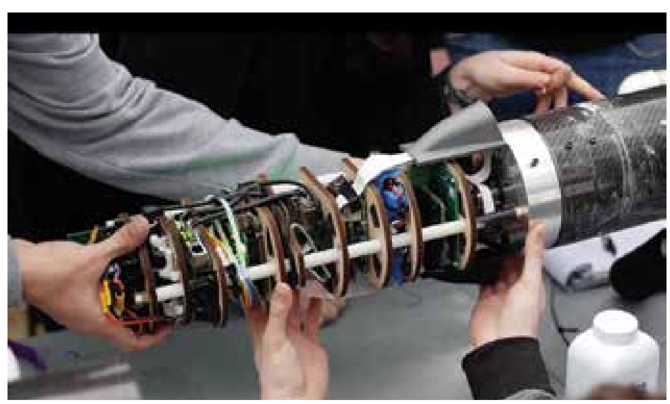
SPONSORS
Vanderbilt Aerospace Design Laboratory

NASA Marshall Space Center

MECHANICAL ENGINEERING

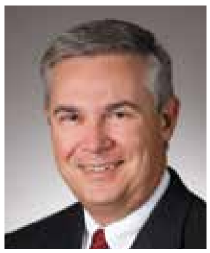
Real Time Target Detection on Rocket Flight

Vanderbilt Aerospace Design Lab was tasked by the NASA Student Launch Initiative with designing a fully enclosed imaging system for the purpose of identifying ground-based targets during the course of rocket flight. Using cutting-edge hardware and software, the team built a fully integrated camera system to allow for target detection by means of HSV color filtration. In conjunction with the imaging system, the VADL also designed and integrated a dynamically controlled electric motor system called the sectional roll control (SCR) subsystem. This subsystem uses positional input from the real-time image detection data to reorient the independently controlled top section of the rocket, which allows ground-based targets to remain in view of the onboard cameras. The SRC and imaging subsystems work in parallel to aim the airborne camera system at targets during rocket flight in order to maximize aerial image quality. This concept was validated through extensive ground-based testing and various experimental flights throughout the year. The project culminated in early April at the NASA Student Launch in Huntsville, Alabama.


The fully assembled VADL real-time target detection payload attached to the rocket body prior to launch

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 2018 and have transformed our Class of 2018 into your professionals.

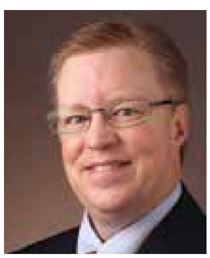


BRYAN BEYER
Adjunct Instructor of Chemical and Biomolecular Engineering

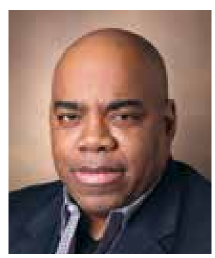
JASON MITCHELL
Research Assistant Professor of Mechanical Engineering

RALPH BRUCE
Professor of the Practice of Electrical Engineering

LORI TROXEL
Professor of the Practice of Civil and Environmental Engineering

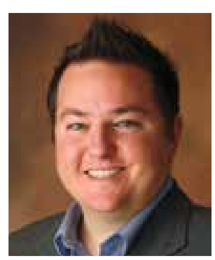


RUSSELL DUNN
Professor of the Practice of Chemical and Biomolecular Engineering

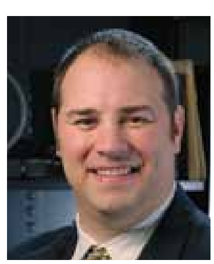


MATTHEW WALKER III
Associate Professor of the Practice of Biomedical Engineering

SCOTT GUELCHER
Professor of Chemical and Biomolecular Engineering

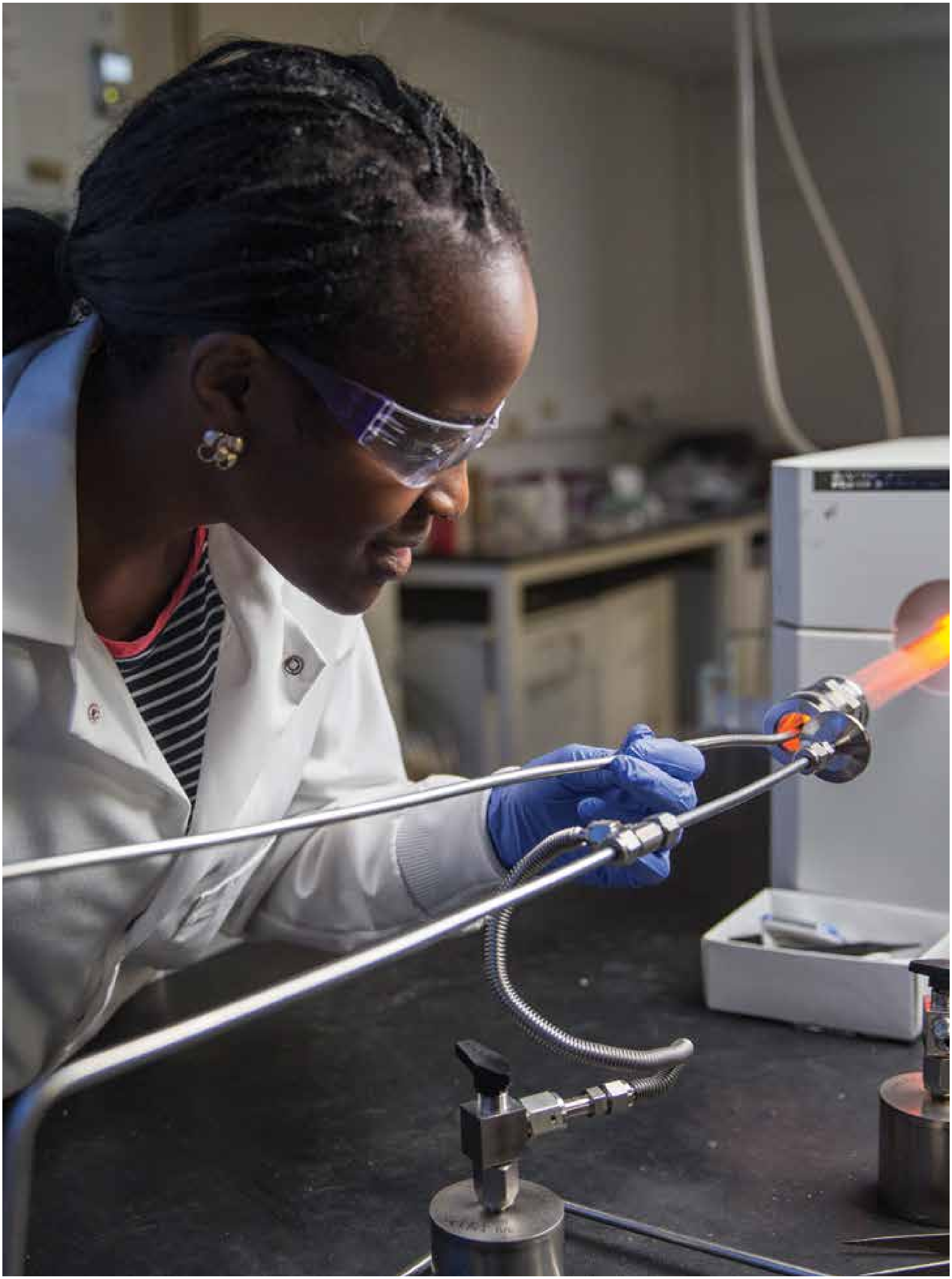


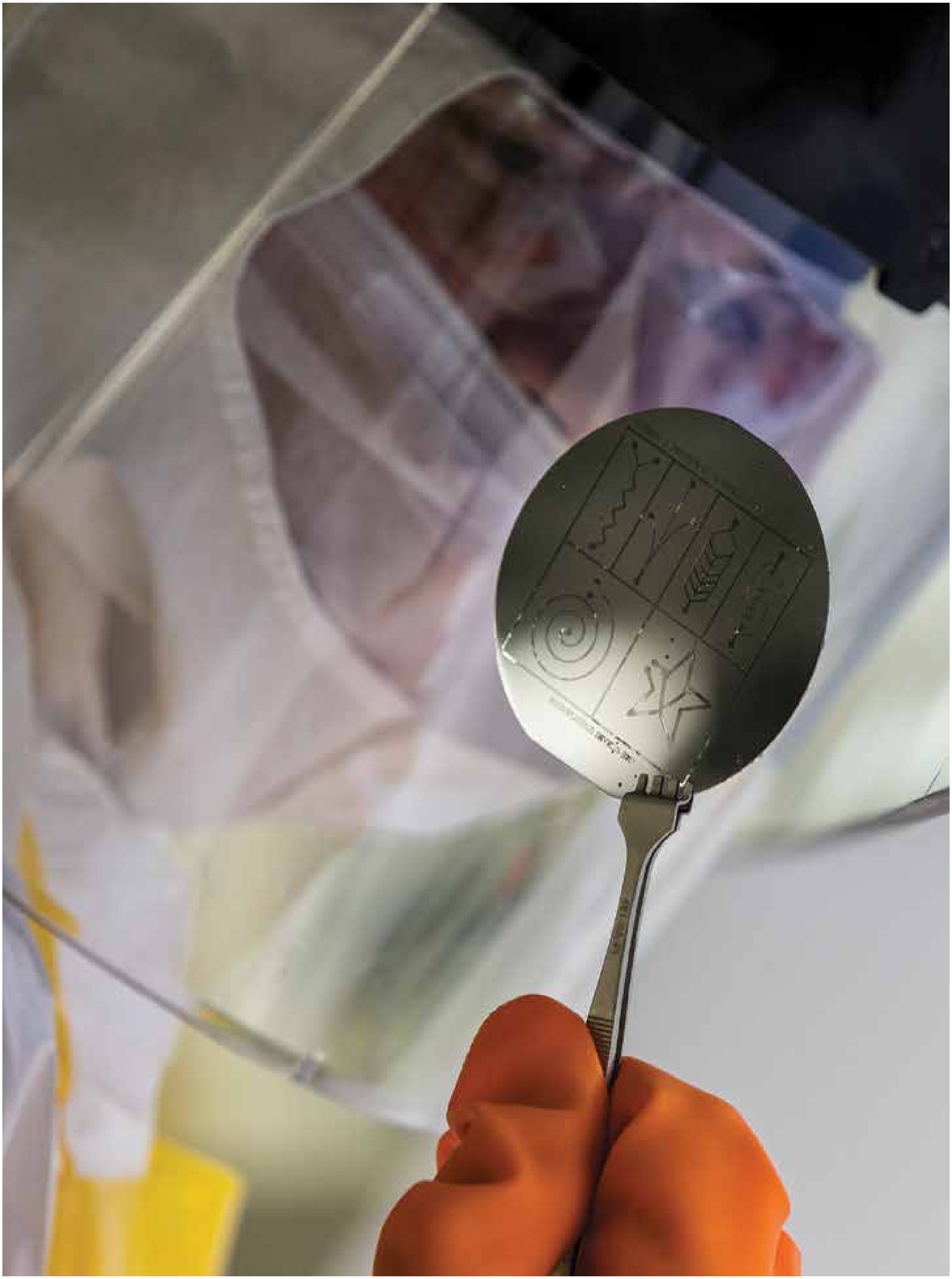
JULES WHITE
Assistant Professor of Computer Science and Computer Engineering



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

VANDERBILT
School of Engineering





VANDERBILT School of Engineering

INSIGHT • INNOVATION • IMPACT®

Connect with us:

vanderbiltengineering

@VUEngineering

@VanderbiltEngineering

YouTube youtube.com/vanderbilt

Web: engineering.vanderbilt.edu

FPO