



Solutions

Dear Readers:

Many of you have indicated the senior design projects and other design-related activities in the School of Engineering are of particular interest. In recent years, we've collected them in our spring *Designing the Future* publication. They will continue to be in the spring publication, but we have renamed and redesigned it as *Solutions, The Design Issue* to group our print publications under a single masthead.

This magazine will be delivered to you after the spring semester as a companion piece to the *Solutions* issue you receive in October.

We want to showcase the important work of our outstanding students and faculty while raising the school's visibility among our peer institutions and other national audiences.

I hope you enjoy reading the stories and browsing this year's senior design project descriptions. As always, your feedback is important as these publications are created with you in mind. For a more regular stream of stories, please subscribe to Dean Fauchet's weekly e-newsletter at engineering.vanderbilt.edu/news/weekly-subscribe. We're also on Twitter @vuengineering, Instagram @vanderbiltengineering and Facebook at facebook.com/vanderbiltengineering.

Best regards,

Christopher Rowe

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VANDERBILT
SCHOOL OF
ENGINEERING

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Getting robotic surgical tools from the lab to the operating room

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THE PATH from university lab to commercialization is especially complex in the biotech industry. Challenges range from long lead times, sometimes measured in decades, to the costs of transforming ideas into innovations, as well as issues of intellectual property, patenting and licensing.

Yet Nabil Simaan, a mechanical engineering professor who specializes in designing robots to help surgeons perform operations in areas of the body that are hard to reach, does not deter easily. He has years of experience working collaboratively with commercial entities while collecting numerous patents—three in 2017 alone.

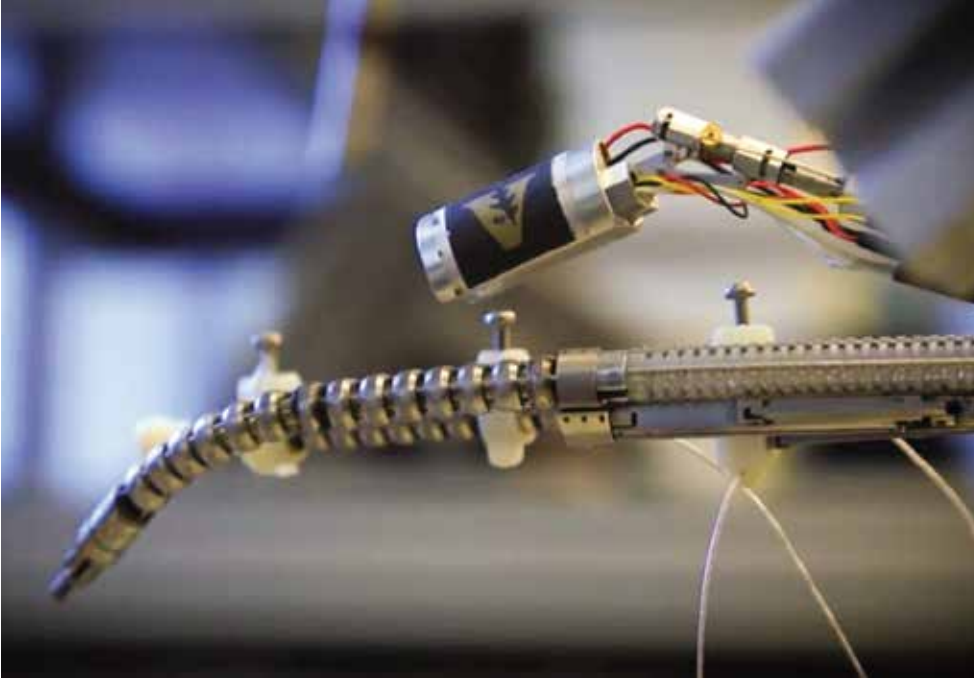
Simaan's Advanced Robotics and Mechanism Applications Laboratory at Vanderbilt leads the way in advancing several robotics technologies for medical use, including miniature robots for single small-incision, cochlear implant and minimally invasive throat surgeries.

"A key focus of the research is the design of intelligent robotic devices that can sense and reg-

ulate their interaction with the anatomy," Simaan said. "These robots can be used collaboratively with a surgeon to safely excise or ablate tissue."

Simaan is co-inventor of the Insertable Robotic Effector Platform. IREP—a portfolio of multiple patents—is believed to be the world's smallest robotic system and was hailed as a medical science breakthrough in 2013. It is licensed to Titan Medical and led to the development of the Titan SPORT system for single-port access surgery.

The minuscule robotic surgical tool enters the body through a remarkably small incision—six-tenths of an inch, or 15 millimeters. Once inside the body, it unfolds to reveal a camera system for 3D visualization and imaging feedback,



and two snakelike arms that perform the surgery.

IREP has gone through several development stages. First, Columbia University computer scientist Peter Allen devised an insertable camera that tilted, panned and followed the movements of surgical instruments from inside the abdomen, and projected its vision onto a computer screen. Surgeon Dennis Fowler at Columbia performed a number of appendectomies, nephroscopies and other operations on porcine models using the technology.

At Vanderbilt, Simaan equipped IREP with two snakelike arms built from a series of push-pull flexible beams that can bend and twist the arms in the required directions. Simaan also gave IREP wrists and grippers to manipulate objects.

“Typically, as a research lab, we try to be at least 10 years ahead of industry to help usher in new approaches to surgery via new technologies,” he said. “But university researchers and industry are catching up.” Simaan moved the ARMA lab to Vanderbilt when he joined the engineering faculty in 2012.

The latest ARMA tech—a prototype robot system to remove bladder tumors—shows great promise, having proved successful in animal studies. The research, recently published by the *Journal of Endourology*, earned a best paper award at the 2018 Engineering and Urology Society conference.

Among all cancer diagnoses, the incidence of bladder cancer ranks fourth in the United

States and seventh worldwide in males. “Bladder cancer also is very expensive to treat. It requires repeat resections because surgeons remove a bladder tumor ‘piecewise’ and that often results in recurrence and more surgeries,” Simaan said.

Simaan and his team developed a transurethral robot platform called TURBot. It is the first endoscopic robotic system to provide full surgical cover-

age—with visibility—of the bladder, including the neck and dome, and the first to have been evaluated during in vivo animal experiments.

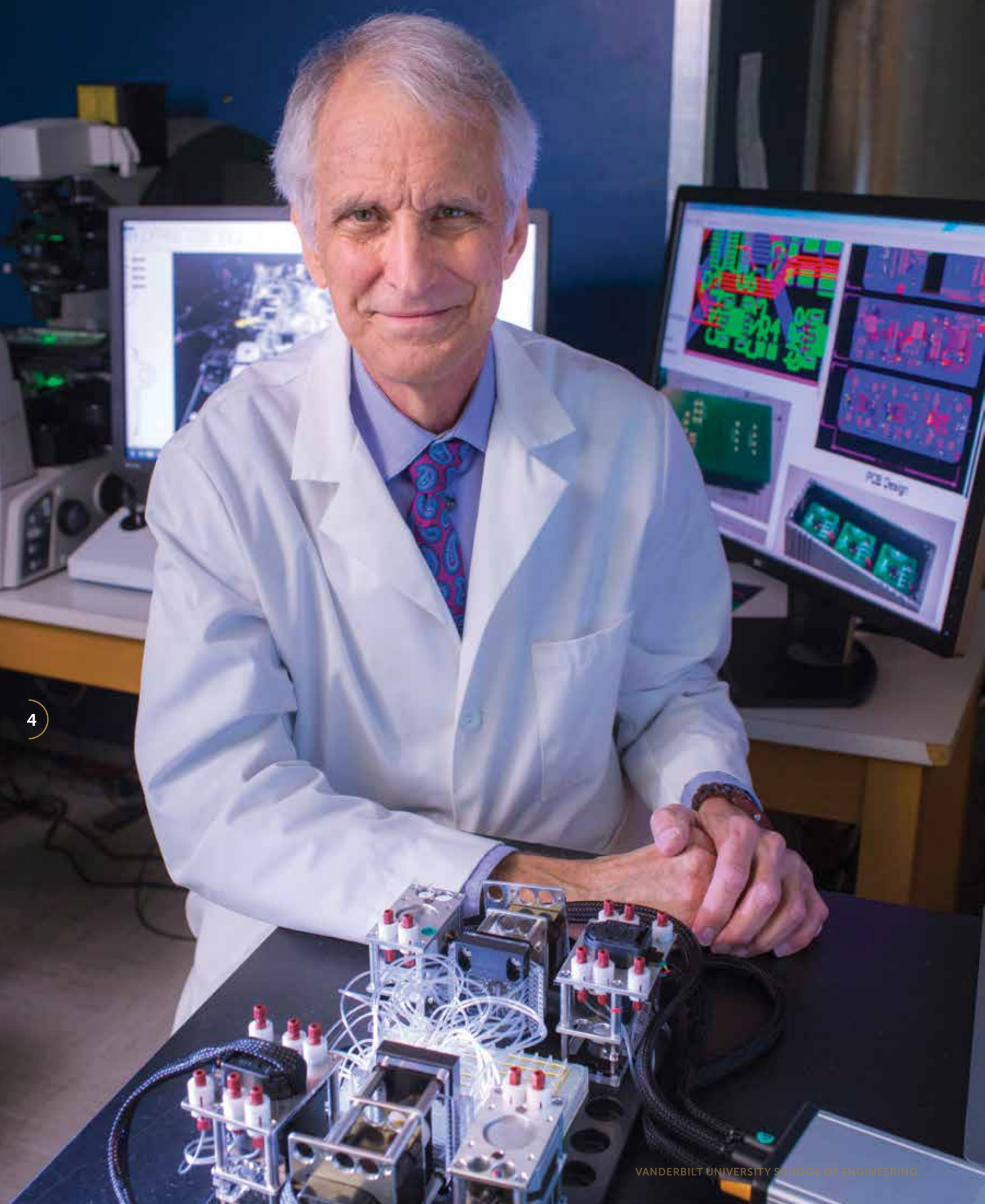
Three 1.8 mm working channels of TURBot’s miniature multibackbone continuum robot use graspers, custom flexible cameras, and other

Simaan’s research with collaborators within and outside Vanderbilt has resulted in a number of patents and patent applications. Here are five patents awarded since Simaan arrived at Vanderbilt:

- Systems and Methods for Robot-Assisted Transurethral Exploration and Intervention; U.S. patent 9,687,303, granted 5/1/2018.
- Dexterous Wrists for Surgical Intervention; U.S. patent 9,687,303, granted 6/27/2017.
- Robotic Device for Establishing Access Channel; U.S. patent 9,549,720, granted 1/24/2017.
- Systems and Methods for Safe Compliant Insertion and Hybrid Force/Motion Telemanipulation of Continuum Robots; U.S. patent 9,539,726, Granted 1/10/2017.
- Method and system for contact detection and contact localization along continuum robots; U.S. patent 9,333,650, granted 5/10/2016.

imaging probes to reach all regions of the bladder. Simulated bladder lesions were successfully ablated by laser.

Simaan and two former students have co-founded a startup to develop such technologies for robot-assisted transurethral resection of bladder tumors. **V**



MANY DRUGS under development may be tested in a new device created by Vanderbilt biomedical engineers and commercialized by a biotechnology spinoff from Oxford University.

The MultiWell MicroFormulator, in effect, allows researchers to conduct 96 different experiments at the same time. The device's revolutionary potential to speed up drug development as well as "organs-on-chips" research earned an R&D 100 Award last year for its creators. Gordon A. Cain University Professor John Wikswo and his team at the Vanderbilt Institute for Integrative Biosystems Research and Education plus CN Bio Innovations Ltd., which licensed the technology from Vanderbilt, shared in the honor in late 2017.

"This is an excellent example of translational research," Wikswo said. "Our work on pumps

The VIIBRE pump and valve technologies and the software that controls them have wider applicability, which research partners and sponsors quickly realized. The MultiWell MicroFormulator, for example, also can simulate the function of organs that may be missing from multi-organ-chip systems, such as those that secrete vital hormones.

The National Center for Advancing Translational Sciences, which was among the early sponsors, provided additional funding through a Small Business Innovation Research grant to adapt the technology for use in 3D bioprinted

Pumping up standard well plate revolutionizes drug testing and tissue printing

and valves began as an undergraduate research project, was then funded by the Department of Defense and the National Institutes of Health, and is now moving into pharma."

The technology upgrades the 96-well plate, a standard and widely used research tool, into an efficient, reliable and automated miniature lab of its own. A series of computer-controlled valves and pumps can mix and deliver minuscule amounts of drugs or other compounds into each of the plate's 96 wells, which act as separate, tiny test tubes.

"In contrast to bringing lots of well plates to a large and expensive high-throughput screening robot, we are bringing a small and low-cost robot to each well plate," said Wikswo, also a professor of biomedical engineering and A. B. Learned Professor of Living State Physics.

tissues. The idea is to provide highly controlled incubation conditions that automatically deliver fresh nutrients and remove waste as tissues to be used for drug testing mature efficiently and under less stress.

"Biology, pharmacology and toxicology experiments that require long-term control of cultured cells can all benefit from this technology," Wikswo said. **V**

The development of the MicroFormulator has been supported in part by NIH/NCATS (grant TR000491 to Vanderbilt University and contracts HHSN271201600009C and HHSN271201700044C to CFDR) and through a research agreement with AstraZeneca UK Limited.

I-Corps training supports commercialization of NSF-funded research



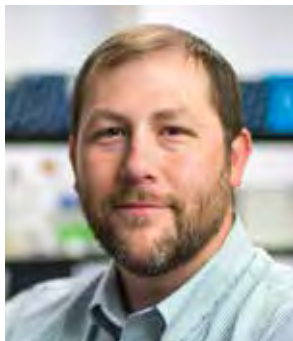
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Even as an undergraduate majoring in chemical engineering, Lara Jazmin, PhD'15, had a deep interest in applying math and science to real-world problems. She found a golden opportunity to do just that as a graduate student when she started working in the laboratory of Jamey Young, associate professor of chemical and biomolecular engineering at Vanderbilt.

About 10 years ago, Young's research mapping the metabolic pathways within living cells began generating a lot of interest from pharmaceutical and biotechnology companies.

The use of cells as microfactories to produce food, drugs and fuels has a long history. Researchers traditionally have treated cells as tiny black boxes, studying what goes into cells and what comes out, but there was very little information about what was happening inside.

"Our research has given us a technology that reveals what's going on within cells," said Jazmin. "It is similar to the information that X-rays provide about what is going on within the body. By mapping the pathways of biochemical reactions



Jamie Young

within cells, researchers get detailed information they can use to bioengineer microorganisms to improve the efficiency and reduce the cost of producing drugs, biofuels, perfumes and a wide range of other products.”

In 2015, Jazmin and Young founded the company Metalytics to commercialize the technology with the aid of The Innovation Corps (I-Corps™), a National Science Foundation program that helps researchers learn what is involved in turning their NSF-funded research into commercial products, encourages innovation and drives economic development.

“The idea to start a company came before I-Corps, but I think the contacts we made and the lessons we learned through the I-Corps program gave us the confidence to pull the trigger,” said Young. “I-Corps forced us to make a ‘go or no go’ decision and provided us with a path forward.”

Jazmin and Young are one of seven Vanderbilt teams—each composed of a faculty member, entrepreneurial lead and business mentor—who have gone through the six-week I-Corps program. Four of the teams decided to form companies and create commercial products based on their ideas. Another five teams have been invited to participate, and an additional 18 have expressed interest.

Last year the Wond’ry, the university’s center for innovation and entrepreneurship, in collaboration with the Vanderbilt Institute for Surgery and Engineering, won a five-year, \$500,000 NSF grant to become an I-Corps site. The designation puts Vanderbilt in elite company and allows the university to teach some I-Corps courses on commercialization. It also gives participants small grants to support their initial entrepreneurial efforts and works hand-in-glove with the Center for Technology Transfer and Commer-

cialization, which provides professional commercialization services to the Vanderbilt community.

“What’s really great about the program is that it forces the researchers to get out of the lab and talk to people—to business students, angel investors, industry representatives—and this helps them identify the ‘value-added’ aspects of their research ... in addition to the cool science that they report in academic papers,” said I-Corps site coordinator Byron Smith, MS’12, who has been involved in a number of projects. “It also puts them in touch with the extensive local and national accelerator network that can kick-start their commercialization efforts.”

Smith was the entrepreneurial lead on the first team at Vanderbilt to go through the I-Corps program. He formed a company to develop a disposable CO₂ system for inflating the colon during colonoscopies, so the doctors could view the areas



Lara Jazmin

between the folds. Although the system would reduce pain and shorten recovery times, it turned out to be more expensive than existing systems.

“Although it didn’t work out, the experience gave me a thorough understanding of the commercialization process and the tools you need to succeed,” Smith said. “No matter how great a discovery is, if it’s not profitable it’s not going to help patients.”

Another company that (continued on page 31)

Advice from a venture capitalist



BRUCE R. EVANS, BE'81, senior adviser and chairman of Boston-based growth equity and venture capital firm Summit Partners, shared details about his journey from Vanderbilt to the venture capital industry at a talk on campus in February 2018. Key takeaways for working with VC companies:

AVOID COMMON MISTAKES AMONG FIRST-TIME ENTREPRENEURS.

Top errors include targeting too small a market, say \$20 million, with a great idea but poor growth potential; failing to properly control the nuts and bolts of the business, including lack of spending and management discipline; and having hubris and inflated egos.

UNDERSTAND THE VC TIMELINE.

Because most VC funds have a 10-to-12-year life span, investors will be patient for five to seven years but then will want to see real performance. That means a return of three or four times what was invested. Why? After paying fees and absorbing losses from other investments, a VC fund needs to double its money or more to keep investors engaged.

CAREFULLY WEIGH PROPOSED INVESTMENT AND EXIT OPTIONS.

All “money” is not equal. A cash for equity deal gives you flexibility but could mean significant ownership dilution if you need more money in the future. Most VCs would rather own convertible debt because it earns interest and is a senior debt on the balance sheet. If the situation goes south, it acts as a stock loss for the investor. VC funds will ask to be represented on your board, but if the investor wants to run the business, it is not likely a good fit.

RESPECT THEIR TIME.

Come up with your storyline, which is a succinct statement of the opportunity, to make investors stop and consider your proposal over others. Be able to quickly convey the strengths of your product or service with respect to technical risk, market size and competition, team qualifications, and projected financial performance. Remember, venture capitalists have more money than time.

GO AS FAR AS YOU CAN WITHOUT TAKING ON INVESTORS.

The further you can go without needing outside capital, the more of your company you will own. Use your own resources, your own capital, your own sweat equity.

Evans, who is now chairman of the Vanderbilt Board of Trust, delivered the Chambers Family Entrepreneurial Lecture to a packed audience that included students, faculty and top administrators from throughout the university.

Network membership boosts engineering entrepreneurship

Vanderbilt has joined the Kern Entrepreneurial Engineering Network, a collaborative community of more than 30 U.S. engineering schools, and doubled down on efforts to enhance entrepreneurship and innovation.

Launched by the Kern Family Foundation, the network brings together engineering universities and faculty dedicated to instilling new engineers with entrepreneurial skills and thinking. Network members, or partners, have the flexibility to shape their own KEEN programs but they also build shared curriculum resources and meet regularly to foster best practices and engage the broader engineering education community.

KEEN's mission is to "graduate engineers with an entrepreneurial mindset so they can create personal, economic and societal value through a lifetime of meaningful work." The mindset involves not only entrepreneurship in the traditional case of startups, but also taking a more holistic view of a technology or organization by understanding its operations, analyzing data and working from within to add value for employees and customers.

Network membership comes at an opportune time. Design as an Immersive Vanderbilt Experience is in place and the Wond'ry at the Innovation Pavilion, the campus hub for innovation and entrepreneurship, is in full swing. Both are components of the university's Strategic Plan.

Network membership "aligns beautifully with both the culture and work already being done at Vanderbilt's School of Engineering, including existing multidisciplinary senior design projects," said Christopher Rowe, professor of the practice of engineering management and campus liaison to the foundation. "Our immersion program calls for all undergraduates to immerse themselves

in creative, independent projects that give them the opportunity to engage, question and forge change. Our home city of Nashville is experiencing a boom in growth, too, with more and more startups and entrepreneurial-minded people moving here every day."

Curriculum enhancements are expanding design activities throughout all four years of the curriculum in all majors. Joining the KEEN network accelerates that process by allowing faculty to add to the first-year introduction to engineering course. The module-based course has been successful in allowing students to choose or confirm their choice of major in their first semester.

"In addition to that original purpose, introducing the concepts of making and entrepreneurship rounds out a powerful first-year engineering experience," Rowe said.

Two pilot sections were converted to the new format last year with the remaining ones coming online in subsequent years. Membership in the network provides collaboration and funding for future projects.

"Vanderbilt is excited to work with the network members. The diversity of schools allows us to study existing best practices, create new ones, and work with colleagues across the country interested in similar things," Rowe said.

Other network members include Georgia Tech, Colorado School of Mines, Rose-Hulman Institute of Technology, and Lehigh University, among others. ▽

Design connects us

by Philippe Fauchet

It shapes our homes, how we get clean water, how we get to work, and how we interact. Design advances us, too, by enhancing individual ability to address societal imperatives, contribute to better health, and create user-centered outcomes.



Engineers know this well, and our engineering undergraduates learn this early in their academic careers. Immersion Vanderbilt, launched with the 2018–19 incoming class, is the cornerstone of the university's academic strategic plan. Now, students across all disciplines will be asked to explore a subject in depth and with passion.

The School of Engineering embraces immersive experiences and in many ways has helped pave the way for them. The university's Design as an Immersive Vanderbilt Experience program was primarily authored by engineering students and faculty. Our senior design capstone requirement is the most obvious example of immersion, and I believe a truly immersive engineering education should involve design throughout each year of the undergraduate experience. We've already begun revamping our first-year introduction to engineering course to involve more hands-on design, and the academic departments are submitting plans to continue that experience through the second and third years. A civil engineering course on sustainable design was an instant hit, and now two new courses, How to Design (Almost) Anything and Design Thinking–Design Doing, already are so popular that students are on waitlists.

Engineers live by a rigorous tradition of research, design, prototyping, and testing. Far from deterring potential students, however, this disci-

plined mindset draws undergraduates as well as graduate students here. We see it in the Innovation Realization course, an interdisciplinary graduate course that matches engineering doctoral candidates with business and law students to create a commercialization plan for their innovations; participation in entrepreneurial training through our NSF-funded iCorps site with the Wond'ry, as you will read about in these pages; and the Medical Innovators Development Program that plots a path to train engineering Ph.D.'s to become practicing M.D.'s, creating a new type of physician.

Design has transformative power, and in the stories contained in these pages you see how an emphasis on design connects classroom learning with real-world challenges and elevates extracurricular activities to life-changing experiences.

Engineers are relevant from music to medicine and art to education. At Vanderbilt School of Engineering this way of thinking is embedded in our culture. Our graduates are distinguished by their ability to contribute early, think creatively, add value, and work collaboratively. Whether they join Nissan North America's factory automation program, design next-generation thrusters for SpaceX, plunge into a startup venture, or contribute through a humanitarian organization, our graduates come out of the gate with a "let's make this happen" mindset that sets them apart from many of their peers.

It is an exhilarating time for engineering researchers and educators, and as supporters of our mission I look to you as our partners to do what you do best: bring us your problems, involve our students, and celebrate their success. ▼

New master's degrees advance engineers in critical areas

Two new interdisciplinary master's degrees will help answer workforce needs in advanced engineering skills. The 12-month programs—in Cyber Physical Systems and Risk, Reliability and Resilience—will put graduates on the fast track in careers related to the Internet of Things and risk assessment and mitigation, respectively. Both areas are critical to U.S. innovation, competitiveness and security.

Beyond courses in computer science and engineering, students in both programs will acquire leadership skills by taking graduate engineering management courses and completing capstone projects in Vanderbilt institutes and laboratories.

Industry and government agencies have keen interest in both fields. RRR engineering, for instance, has broad application across the aerospace, automotive, maritime, manufacturing, oil, chemical, power transmission, medical device, infrastructure planning, and emergency response sectors. The field covers a wide range of questions, such as assessing a given system's capacity to meet demand, predictive modeling, collecting and analyzing data for better decision-making, and evaluating the trustworthiness of those models.

CPS has widespread application, too. CPS technologies employ sensors, processors and actuators to enable computers to perform dynamically in the physical world. From autopilot systems in aircraft and controls in prosthetics to medical devices, energy-efficient structures and advanced manufacturing, such systems have become ubiquitous. They also are driving advancements in connected or “smart” cities.

The School of Engineering already is an international leader with recognized experts in both areas. Xenofon Koutsoukos, professor of computer science, computer engineering and electrical engineering, is director of the CPS master's program,

which will be tied to the Vanderbilt Institute for Software Integrated Systems. The RRR program is co-directed by John R. Murray Professor of Engineering Sankaran Mahadevan and Mark Abkowitz, professor of civil and environmental engineering.

The programs are suited to recent graduates in engineering or the math and physical sciences who aspire to jobs and leadership positions in industry and government, as well as industry-based professionals who want to pursue careers in these vital, high-profile fields. **V**



Sterling Ranch vision takes shape with first residents and community center



With at least 60 homes occupied, regulatory approvals secured for Colorado's first rainwater collection system, and a community center almost complete, Sterling Ranch is taking shape.

12 The ambitious project on a former meadow southwest of Denver is distinctive for more than its focus on sustainability, including smart management systems for water and energy. Sterling Ranch is, in effect, a living lab where Vanderbilt School of Engineering undergraduates, graduate students, researchers and faculty members help design and implement the newest innovations.

Sterling Ranch officials said about 200 homes had been sold by mid-April with 450 total targeted to be sold by the end of 2018. Sterling Center, the community's civic center, is expected to open in late summer. It will feature 20,000 square feet of business space—UCHealth has claimed nearly half of it—and an exhibit hall.

Civil engineering major Beth Hardy and mechanical engineering major Gabe Darmon, both BE'18, saw the changes up close in January 2018 during what has become known as "Vanderbilt Week" at Sterling Ranch.

"I had a friend intern at Sterling Ranch when it was just a plot of land," Hardy said. "It is exciting to see the progress."

Senior design projects at work

Hardy and Darmon were among a group of students, staff and professors who made this year's excursion. They also were on one of three senior engineering design teams that tackled Sterling Ranch projects and presented their work in April.

Their project involved designing a low-energy-use home and an interactive exhibit for education about sustainable home design.

"One of the things that drew me to Vanderbilt was the civil engineering department's focus on sustainability," said Hardy, who already is studying for her LEED certification. She will be a project manager for Whiting Turner in Atlanta.

Darmon is off to New York where he will be a project engineer with a firm working on the LaGuardia Airport redesign.

"What impressed me most about Sterling Ranch was how the homes are designed for wide appeal," he said. "You don't have to be 'green' to see yourself in one."

A separate team of electrical engineering and computer engineering students enhanced Steward, a smartphone app, with the ability to communicate with Siemens-designed smart light poles via



Bluetooth beacons. When dimmed as a default state, the poles will detect the approach of someone walking with a phone and brighten.

The configuration increases safety, decreases energy use and minimizes noise and light pollution from the poles.

A third design team calculated potential energy loads from homes, commercial properties, electric vehicle penetration and a community hospital to inform Xcel Energy's timing for adding a new substation to its Denver grid. In addition to a community solar garden, Sterling Ranch aims to have rooftop solar panels on 40 percent of the homes—the load models need to account for energy storage and integration into the existing grid.

Real-time monitoring and long-range vision

The development also creates internship opportunities in several departments. Two undergraduates, for example, worked with Cornelius Vanderbilt Professor of Engineering David S. Kosson to create water use simulations for model homes, map interactions between Sterling Ranch and the regional water supply system, and devise strategies to provide near real-time homeowner feedback on water usage.

"Sterling Ranch provides an unprecedented test bed for understanding the impact of home design

features and interactions with behavior on actual water and energy usage," said Kosson, a professor of civil and environmental engineering.

At the end of 20 years, the community is expected to have about 12,000 homes, multiple elementary schools, a middle school, a high school, three parks, and 2 million square feet of commercial space. Like the School of Engineering, Vanderbilt's Peabody College of education and human development is a project partner.

The development already is home to Colorado's first sanctioned rainwater harvesting effort, which will collect, transport and store runoff for use in irrigating parks, gardens and greenways.

Vanderbilt engineers will track the system's impact, just as they were instrumental in studying the potential effects rainwater collection would have on nearby communities. It took a change in state law to pave the way for the pilot program at Sterling Ranch.

"Water," said Brock Smethills, BE'13, the chief technology officer for Sterling Ranch, "in the West is gold."

His family has worked to bring the community to life for more than a decade. Harold Smethills, his father and the company's founder and CEO, was inducted into the School of Engineering's Circle of Distinguished Friends in March. **V**

7 questions with Amazon's David Limp – senior vice president for devices & services



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David Limp, BS'88, is senior vice president of Amazon Devices and Services. He has overall responsibility for development, retail sales and operational aspects of Amazon devices and the services behind them, including Alexa, Echo, Kindle, Fire TV, Fire tablets, Amazon Appstore, Dash buttons, and the Dash Replenishment Service. Limp has a bachelor of science in computer science and mathematics from Vanderbilt and a master of management from Stanford University's Graduate School of Business; he also is on the School of Engineering's Board of Visitors, and we sat down with him for a few questions in March 2018.

What skills and experiences at Vanderbilt do you think most contributed to your career development?

To me the fundamentals I learned here, the rigors around the scientific method and the willingness to experiment, were the most important and are the most important to my career now.

We know design is a complex process and hardly linear. What are some recurring design questions you and your team face that require the most focus and discipline?

We use a design process called working backwards. For every new product or feature we start with a press release and FAQs, which are centered around the features and experiences that we think will be the most delightful for our customers. These documents drive the vision throughout the development of a product—and when a green-lighted project veers away from that document and loses sight of the customer focus, you have to intervene. Sometimes you hit a dead end and have to back up and go back to the process—sometimes you have to be the chief slowdown officer and say this thing isn't ready yet.

How do you start the workday?

Our culture at Amazon is “customer first,” and I have a routine first thing in the morning to put me in the customer frame of mind. When I get to my office I pick out one of our products at random and look at the most recent one-star and five-star reviews. It helps me focus on what we've done right and what we can do better. Then I look at feedback in emails, which can have anecdotes that lead to other features or ideas. To follow leads you have to be curious.

What are you curious about?

I do think we are in a Golden Age of computer science right now and problems we thought to be unsolvable can be solved. We can solve things that have really stymied us—low cost space exploration, health care, the environment, transportation. The new types of things we can invent because we have at our fingertips, tool sets we didn't have even a decade ago—that gets me excited to get up in the morning.

Can you separate design and development?

I don't try to separate them. You write down the product you want to build (with the working backwards process). Next is research, design and development. The vision of some of those areas might require invention; some need time; some might need art. They all come together but not always on the same timelines. If the six-page working backward documents are written well, everyone is on the same page. All the data is available and clear. Keep your eye on the customer vision and then you can be much more tactical on the day-to-day execution.

What would you tell your 21-year-old self that you wish you'd been told?

Be much more patient. I felt like I needed to boil the ocean all the time. Many of my biggest mistakes were made because I was moving too fast—it was a combination of energy and sometimes stubbornness. Sometimes it is much better to take a step back and take a breath.

Amazon is partnering with auto companies and manufacturers of other consumer products. What should we watch for next?

We will continue innovating on behalf of customers. The themes we are focused on center around how we can take machine learning et al. and apply it to everyday lives, in the home, at the business, in the car. We will continue to ask ourselves what problems we can solve that make life more convenient or add fun to our customers' lives. **V**

3D printed arm bones could aid in surgery planning and surgeon training

Orthopaedic surgeons typically look at X-ray or CT images of a broken arm bone and hold up an old-school ruler to confirm the best plate type and size for repair.

But the process is not always that easy, especially in cases involving complex fractures. And without years of experience to inform their estimates, young surgeons may need more time in the operating room to get a good fit.

A team of biomedical engineering seniors set out to show how a replica of the damaged bone would streamline the process, creating 3D printed humerus bones from prior cases at Vanderbilt University Medical Center. The humerus is one of the longest bones in the human body, and arm fractures account for 50 percent of broken bones in adults.

The team asked three surgeons to examine four pre-surgery versions of 10 humerus fractures: an X-ray, a two-dimensional CT scan, a 3D rendering and a 3D printed bone model. The retrospective study used complex distal humerus fractures that surgeons had repaired at VUMC.

Engineering students James Ford, Rachel Howell, Ivy Lee, Annalee Schuck and Caroline Stiles, all in the Class of 2018, analyzed the results and hope to co-publish a journal article on their findings.

They worked with Dr. Donald Lee, professor of orthopaedic surgery and rehabilitation, and Dr. Sumit Pruthi, associate professor of radiology and radiological sciences and of pediatrics. Pruthi helped establish the new 3-D Printing Center at Monroe Carell Jr. Children's Hospital at Vanderbilt, which serves both pediatric and adult cases.

"The purpose of the study was to determine if 3D printing of distal humerus frac-

tures helps surgeons predict the appropriate operative approach and type of operative fixation of these fractures," Lee said. "Distal humerus fractures were picked since they were relatively common fractures with complex anatomy."

In a separate case, the group printed a complex scapula fracture before surgery.

"The surgeon was able to physically pick up the printed bone and move it around and fit the plates, even contouring them in advance before sterilizing it for surgery," Howell said.

All of the student team members were attracted to a senior design project with direct patient impact. Ford, who plans to attend medical school, said a small amount of data can show clear differences, particularly in medial fractures.

The 3-D Printing Center currently has three 3D printers that have the ability to create models that range in size from the width of a human hair to the length of a leg. A structured light-based 3D scanner is also part of the equipment, and all of the printers use Materialise Mimics Innovation Suite, the only FDA medically cleared 3D printing software.

"One of the goals at Vanderbilt is innovation, and 3D printing technology certainly is in keeping with that mission. This technology is innovative and part of the future of medicine," Pruthi said. "The models can be used for patient education, medical student and resident education/training, surgical planning and simulation." ▽



From cardboard moving to robotic grasping, Nissan values fresh eyes





Adding a three-fingered hand to a robotic arm may not seem to have much in common with managing millions of pounds of cardboard waste. Each presents a different engineering challenge. And yet they both share the goal of improving safety, traffic and efficiency at an automobile assembly plant.

For four years running, Nissan North America has sponsored engineering senior design projects such as these for potential use in its facility in Smyrna, Tennessee. Mark Larson, the manager for Nissan's Integrated Factory Automation Engineering, welcomes fresh eyes on a problem each year.

"Having folks with no experience in an automotive manufacturing environment and no preconceived ideas on what 'is and is not possible' may give us an outside-the-box solution we have not identified," said Larson, who has advised the teams.

One year a team created a small, automatic guided cart for areas in the plant where kits are assembled. Other carts on the market were too large for those spaces. The 2016–17 team designed an over-under parts handler that uses momentum and gravity—and needs no electricity. Nissan is considering using the concept in a long-term project under way, Larson said.

This year seven students took on the arm extension for an industrial robot manufactured by Universal Robotics. They developed an underactuated, 10-degrees-of-freedom tool with a rotating, three-fingered design and force-controlled grasping. Integrating multiple subsystems—linear control, computer vision, sensors, electrical, control force and the physical tool itself—was the most difficult aspect, said Iliya Lokman. He and five other students—Andrew Jordan, Josh Fleck, Kamal Azmi, Matt Johnson and Seonghoon Noh, all BE'18—are mechanical engineering majors. Interest in prosthetics and medical robotics led biomedical engi-

neering major Dannielle Hendon, BE'18, to round out the team.

Their 3D printed hand, which can grab parts weighing up to 15 pounds, is "super versatile" and can be scaled for other applications, Jordan said.

It also is significantly less costly and more adaptable than solutions on the market, students said.

The second team set up a pneumatic conveyance system using a vacuum pump and PVC pipes to move shredded cardboard. Currently, cardboard is tossed into dumpsters at more than two dozen locations throughout the plant, then moved, then baled before it is sent to a large shredder for recycling. The plant collects about two rail cars filled with shredded cardboard each day.

"We have a tremendous amount of cardboard," Larson said, explaining that most of it is packaging for parts shipped from overseas.

Mechanical engineering majors Michael Brown, Suhardi Hablee, Hanis Hamidzul, Bethanie McCrary and Eiman Rozman, all BE'18, proposed a series of smaller cardboard shredders that feed into containers through piping; a cyclone ensures pieces settle in the container and do not clog the system.

Larson said the teams did well.

"They learned and were successful at overcoming obstacles and roadblocks not recognized at the beginning of the projects," he said. "Their ideas may also lead us in a direction we had not previously studied." ▽



Undergraduates DIVE into design and maker events

Design shapes processes and experiences as well as physical products, and it is reshaping what it means to be a Vanderbilt University undergraduate.

The evidence is everywhere—in classes, student-organized events, volunteer efforts, design boot camps and campuswide challenges. Design is taking center stage, and engineering students and faculty often have leading roles.

Design as an Immersive Vanderbilt Experience, which launched during the 2017–18 academic year, engages students in learning human-centered design skills to solve complex, real-world problems on multidisciplinary teams guided by faculty mentors.

Engineering students know this well. Most engineering seniors spend their last two semesters on teams tasked with designing solutions for problems their sponsors posed, culminating in the annual Design Day extravaganza.

Creating community

The Wild Bunch Library Design Challenge is just one example. The contest, sponsored by the Wild Bunch alumni group, was open to all Vanderbilt students and asked teams to design ways to make the resources in university libraries more accessible and meaningful for users.

The winning team, “Leaders in the Quest for New Knowledge,” proposed integrating librarians into the Vanderbilt Visions programming for all first-year students and staging additional pop-up libraries across campus. Two of the three team members were chemical engineering students, and the teams that ranked second and third included

engineering undergraduates as well.

The challenge began with a design-thinking boot camp and discussion led by Kevin Galloway, director of making, faculty director of DIVE and research assistant professor of mechanical engineering; and Karina Gupta, an engineering student active with Design for America.

Multiple events in 2017–18 supported DIVE by inviting teams of students to develop solutions to problems they are either presented or discover for themselves.

Among them:

- **Distributed: Health Hackathon.** This 24-hour hackathon in September 2017 invited participants to use blockchain technology to create apps for health care, insurance, finance and identity protection.
- **VandyHacks IV.** This completely student-organized, 36-hour collegiate hackathon in October 2017 had record numbers of universities participating.
- **TOM Global Makeathon.** The name is derived from *tikkun olam*, Hebrew for “repairing the world,” and the makeathon spanned 72 hours in January 2018. The makers paired up with individuals living with disabilities, their caregivers or professionals in the field to address specific problems.

“With these maker events, the visitors and participants all get an immersive experience,” Galloway *(continued next page)*

said. “To grow as a maker, it’s important to step out of your comfort zone, to study the approaches others pursue, and to work on a wide variety of challenges. This not only builds experience and confidence, but opens up new networks, making connections that lead to impactful work.”

VandyHacks IV was notable for its outreach as well as team creations. The organization spent a significant part of its sponsorship money on four buses that brought students from the Illinois Institute of Technology and University of Illinois at Urbana-Champaign, Purdue University, Georgia Tech and the University of Florida to ensure those regions who wanted to come could do so.

The top three winners were Guardyn, an app that uses computer vision to detect and report active shooters more quickly than civilians are able to contact 911; Congressect, an app that gives residents an easy way to discuss the actions and votes of their members of Congress—and gives U.S. senators and representatives information on constituent viewpoints; and AmblyoCare, a virtual reality game using Oculus Rift for treatment of lazy eye, or amblyopia, which affects up to 3 percent of children.

Vanderbilt also teamed up with the Nashville Mini Maker Faire for the faire’s fifth annual event—the first held across two days and the first located on Vanderbilt’s campus. More than 100 maker booths, vendors and demonstrations in and around the Engineering and Science Building attracted hundreds of visitors from Vanderbilt and the greater Nashville community.

Making a difference

More courses and seminars have design at the center. Galloway launched a new DIVE course, How to Make (Almost) Anything, designed for all undergraduates regardless of major or technical training. Students gain experience with both hand tools and digital fabrication to quickly test ideas, clearly communicate concepts and solve problems. It

already is so popular that enrollment in the fall 2018 course will be decided by lottery.

In the first class, teams of sophomores and juniors took on “clients,” which included a young sports fan, two Vanderbilt students, and Thistle Farms, a Nashville nonprofit organization.

Their projects included a modified helmet for a young boy with cochlear implants who wants to play sports; a tray to attach to a student’s walker so she could get her own dining hall meals without help; and an adaptive tool for a student who uses a wheelchair to open doors and hold them open for a friend using a walker.

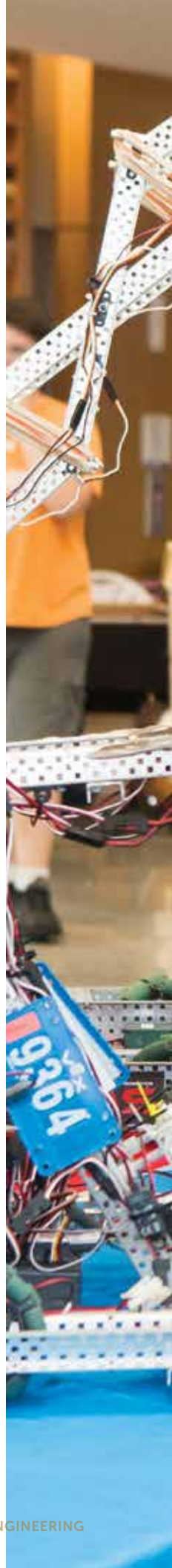
“The first idea rarely works,” Galloway said. “Part of it is learning to get over that quickly.”

Other School of Engineering faculty have stepped up to offer iSeminars, or Immersion Seminars, to first-year students, including three during the spring 2018 semester. Thomas Withrow, assistant dean for design and associate professor of the practice of mechanical engineering, led Build Your Skills: Designing Your Own Path, and Electric Power Generation: Energy Choices and Environmental Consequences was offered by James Clarke, professor of the practice of civil and environmental engineering and professor of earth and environmental sciences.

The third, Triumph of the City, explored the evolution of communities from agriculture to manufacturing to knowledge work; population density; infrastructure; socioeconomic mobility; health and sanitation; engineering and technology; and what the future of cities might look like.

Christopher Rowe, professor of the practice of engineering management and director of the Division of General Engineering, said the idea was to give students potential immersion topics for future study and “prepare them to pursue their passions through rigorous, compelling and unique projects.”

Ten of the 15 students enrolled were engineering students. **V**









New civil engineering Ph.D. grad combines engineering and storytelling

Farzana is a little girl from the mind of Chelsea Peters, but there are thousands of real children like her in Bangladesh, walking for miles to find clean water for their families.

They, like their counterpart in Peters' children's book *Farzana's Journey: A Bangladesh Story of the Water, Land, and People*, struggle to understand why they are surrounded by water they cannot drink, streaming down from the Himalayas and crashing into the coast. It is a question that Peters herself investigated for a project supported by the Office of Naval Research. As it turns out, both salt and arsenic, which has little taste, occur naturally high in the mountains.

"I was studying why the groundwater was salty and working on how people in Bangladesh make their decisions about drinking-water sources," said Peters, who worked with George Hornberger, University Distinguished Professor of Civil and Environmental Engineering, Craig E. Phillip Professor of Engineering and director of the Vanderbilt Institute for Energy and Environment.

Understanding how water conditions evolved and affected human migration was the original goal of her research project, but the scope expanded to look at the culture and factors that influence adaptations and decisions about what wells are used when. For instance, though tainted wells in Bangladesh are often identified with red paint, people still at times draw water from them rather than seek out a safer source.

It was scenarios like these that got Peters thinking about how best to educate youngsters in Bangladesh about water quality and community choices. She successfully defended her dissertation in March.

"In my book, animals talk to Farzana about her environment, with the focus being on water," she said. "Ultimately, she comes to the conclusion that, while she has to walk a long way to get safe water, she should be proud of the adaptations people have made to discover and drink that."

Peters wrote *Farzana's Journey*, which is illustrated by Vanderbilt undergraduates, following her selection as a 2017 Public Scholar by the Curb Center for Art, Enterprise and Public Policy at Vanderbilt. Scholars are Ph.D. students who propose to put their academic research to work solving problems through creative methods.

Jay Clayton, the Curb Center's director and the William R. Kenan Jr. Professor of English, said Peters' book was a natural choice for the program.

"It was a no-brainer to pick this brilliant engineering student for a program that hopes to combine creativity and the arts with other disciplines, particularly science and social science," Clayton said. "The book is absolutely gorgeous and should make a real impact on the lives of children in Bangladesh." **V**

Undergraduate experiences are designed into VINSE cleanroom

In a space where a single speck of dust can ruin a costly experiment, the importance of design cannot be overstated. For the new Vanderbilt Institute of Nanoscience and Engineering cleanroom, a five-person team from engineering and basic sciences disciplines worked for months with a consulting firm that specializes in academic cleanrooms.

The resulting 10,000-square-foot, commercial-grade cleanroom shines with pristine newness. It also stands out programmatically.

Student access to such specialized, delicate equipment is usually restricted, but this cleanroom hosts several undergraduate and graduate classes. Separately, a team of 10 undergraduates is tasked with maintaining the space and its equipment in what resembles an industry internship.

The combination creates unique opportunities for undergraduates.

Alice Leach, PhD'17, a research assistant professor of materials science and cleanroom immersion leader, puts together the lab components of cleanroom courses. In some laboratories, each student runs a process with a different set of instrument parameters, shares the data with others in the class, and then the other students identify the optimal parameters for the process, she said.

"In another lab, a plasma enhanced chemical vapor deposition tool is dismantled, giving students rare insight into the plumbing and electronics behind an advanced instrument," Leach said.

Thomas Stilson, a rising senior majoring in mechanical engineering, has not taken the courses but has prepped lab samples for them as a member of the "Tech Crew" that maintains the space.

Stilson, who is in an accelerated graduate program and plans to graduate with both a bachelor's and master's in mechanical engineering in 2019, started by providing support to users and wiping down surfaces. He has moved on to process development work, including implementing an edge bead removal process for a photoresist film, setting up a new plasma etching tool, and, most recently, duplicating a process for spinning and etching a silicone compound on wafers.

"The processes we run are conceptually very simple, which was surprising to me at first," Stilson said. "There are a lot of technical details that can trip you up, but the big picture of what we do is much clearer than what I thought it would be.

"I think working at VINSE has shown that nanoscience is much more accessible than I would have imagined," he said. **V**





EXIT



Designing engagement here and south of the border

 Carlos Silvera Batista and Julianne Vernon are creating a design for inclusion.

“We look at it as a design challenge,” Carlos said. The married co-creators of a targeted recruiting campaign in Latin America say Dean Philippe Fauchet’s focus on inclusion is part of what attracted them to Vanderbilt almost a year ago.

Carlos and Julie have extensive experience in service and outreach and they have proposed an innovative set of plans to bolster the engagement of the engineering school with schools and students in Latin America.

“Philippe’s passion for inclusion and retention was important to us. When he said, ‘We’re invested,’ we knew we ended up in the right place,” said Julie, research assistant professor of chemical and biomolecular engineering. She and Carlos, an assistant professor of chemical and biomolecular engineering, recently returned from a whirlwind recruiting trip to selected Latin American universities that yielded 40 students interested in Vanderbilt engineering programs.

This is familiar turf. Carlos was born in Cartagena, Colombia, and immigrated to New York City with his family. Julie was born in New York City to parents from Belize. Circuitous routes brought them together at City College of New York where she earned a B.E. in chemical engineering in 2004, and he did the same a year later. In 2006, they left New York for graduate school at the University of Florida.

Jacques Cousteau and the ‘Little Engineers’

As a kid, Carlos wanted to be a marine biologist and binged on the TV program *The Undersea World of Jacques Cousteau* hosted by the French filmmaker, researcher and marine explorer. “I think I was probably 11 when I actually wrote a letter to Cousteau,” he said and laughed. He got no reply. In high school, he fell in love with chemistry. “Atoms. Molecules. Pure magic,” he said. “Then, I discovered chemical engineering and that allowed me to stay in engineering.”

Julie, with little guidance through school but with a gift for mathematics, entered an upper-level math class as a high school freshman. “There were three of us young students in a class primarily for juniors. The teacher, who didn’t want us to feel lost, called us his ‘little engineers.’ He would say, ‘Come, sit in the front, little engineers.’ It must have planted a seed,” she said.

In 2011, armed with Ph.D’s from the University of Florida, they set off for postdoctoral fellowships. Julie returned to CUNY and worked for the NSF’s New York City Alliance-Louis Stokes Alliance for Minority Participation in (continued next page)

STEM as a project leader for international programs. Carlos worked for the National Institute of Standards and Technology for almost two years. Then, both went on to the University of Michigan to complete more training as postdoctoral fellows. Throughout their years in New York, Florida, Maryland and Michigan, the couple sought outreach activities and professional programs fostering inclusion, retention and innovative curriculum development projects.

In Michigan, Julie began to focus on first-year engineering programs, STEM education for underserved students, and an international summer research model. It was her summer research model, while a research project leader for the New York City LSAMP, that was used in Cartagena and Cali, Colombia; Quito, Ecuador; and Bahia, Brazil, for undergraduate and graduate students. Carlos hosted and led science activities during Girls in Science and Engineering summer camps. He particularly enjoyed mentoring undergraduates, and he continues that focus in his Vanderbilt lab. As an alumnus the New York City LSAMP programs, he has been active in those programs as well

Multiple draws to Nashville

A Vanderbilt engineering alumnus and good friend encouraged Carlos to look at the school. He plans to engage broadly with the Vanderbilt Institute for Nanoscale Science and Engineering. His nanoscale systems research is expected to advance applications in composites, energy conversion, bio-sensing and bio-imaging. He has eagerly invited undergraduates to work in his lab; he enjoys mentoring them.

Julie was impressed by innovative approaches to the engineering curriculum. She is an executive director of an NSF INCLUDES project at Vanderbilt: Southeastern Compact for Inclusive Student Transitions in Engineering and Physical Sciences. SCI-STEPS is a regional network among major research universities, Historically Black Colleges and Universities, comprehensive universities, community colleges, national labs, and major scientific organizations. The goal is to ensure underrepresented individuals in the physical sciences and engineering navigate through the higher education system, earn an appropriate terminal degree, and join the STEM workforce.

“It’s a great fit,” they say.

And, there’s Nashville’s milder climate, the friendliness of its residents and the restaurant scene.

“We’re foodies,” Carlos said. “Nashville is great.” **V**

iCorps (continued from page 7) benefited from I-Corps is VenoStent. Founded by Vanderbilt graduate students Timothy Boire, MS'13, PhD'17, and Geoffrey Lucks, MBA'17, it is applying shape-memory polymers to reduce failures of hemodialysis access sites, the main technique used to remove wastes from dialysis patients' blood. According to the latest statistics there are approximately 468,000 dialysis patients in the U.S. Access site failures are a major cause of mortality and morbidity, with 40–60 percent failing within the first year.

Boire had experience working for Genzyme, a large biotechnology company, before deciding to go back to school and get his Ph.D. with the idea of starting a company. Working in the laboratory of Hak-Joon Sung, an assistant professor of biomedical engineering at Vanderbilt, Boire developed a new class of biocompatible polymers with a remarkable quality: They can retain their shape at body temperature.

In collaboration with Vanderbilt Professor of Surgery Colleen Brophy, Boire and his colleagues determined that the material could be molded into a wrap and applied externally to vein-artery or vein-graft junctions. Initial testing in mice showed that these wraps could promote new blood vessel formation, which, in combination with the mechanical support that it provides, may suppress a biochemical reaction called neointimal hyperplasia, which is one of the major causes of access site failures.

“At first, we were thinking about applying it to heart bypass surgery,” said Boire. “In the course of the interviews with vascular surgeons that we conducted as part of the I-Corps program, however, we shifted our focus to dialysis when we learned that the clinical need was even more acute and the clinical trial and follow-up times are far shorter.”

Recently, VenoStent has been accepted into the J-Labs program, a biotechnology startup incubator in Houston sponsored by Johnson & Johnson Co. It is designed to provide entrepreneurs with promising new medical technologies with a “resource-rich environment” to help them successfully commercialize their ideas. **V**

Vanderbilt I-Corps Grants

Vanderbilt University I-Corps Site

Principal Investigator: Robert Grajewski; Co-Principal Investigator: Robert Webster; Start Date: 08/15/2017; Award Amount: \$99,937

Ultra-Minimally Invasive Surgical Tools

Principal Investigator: Robert Webster; Start Date: 08/15/2016; Award Amount: \$50,000

Barcode Embedded Rapid Diagnostic Tests for Point-of-Care Fertility Tests

Principal Investigator: David Wright; Start Date: 01/01/2018; Award Amount: \$50,000

Modular Toolkit for Rapid Prototyping of Capsule Robots

Principal Investigator: Pietro Valdastrì; Co-Principal Investigators: Christopher Harris, Ekawahyu Susilo; Start Date: 12/15/2014; Award Amount: \$50,000

Discovery for a Semi-Powered Transtibial Prosthesis

Principal Investigator: Michael Goldfarb; Start Date: 04/01/2018; Award Amount: \$50,000

Software and Services to Enable Metabolic Flux Analysis

Principal Investigator: Jamey Young; Start Date: 05/15/2015; Award Amount: \$50,000

CO₂ Insufflator for Minimally Invasive Procedures

Principal Investigator: Pietro Valdastrì; Start Date: 10/01/2013; Award Amount: \$50,000

Filtergraph – A Fast and Intuitive Data Visualization Interface for Massive Datasets

Principal Investigator: Keivan Stassun; Start Date: 07/01/2014; Award Amount: \$50,000

A Shape Memory External Stent for Vein Graft

Principal Investigator: Hak-Joon Sung; Start Date: 08/01/2014; Award Amount: \$50,000

A Community-Driven Precision GPS Service

Principal Investigator: Akos Ledecz; Start Date: 07/01/2014; Award Amount: \$50,000

2018 Senior Design Winners

Thomas G. Arnold Prizes

The Thomas G. Arnold Prizes for biomedical engineering systems design and Research are shared by **Lauren Holtslander**, Columbia, S.C. (research), and for design (LumaSil: Low Light Therapy Device for Diabetic Foot Wounds), **Candace Grisham**, Lakeland, Tennessee; **Shashank Manjunath**, Acton, Massachusetts; **Benjamin Perlin**, Nashville, Tennessee; **Anthony Russo Jr.**, Park Ridge, Illinois; and **Nicholas Wigginton**, Troy, Illinois.

Civil Engineering Design Award

The Civil Engineering Design Award goes to **Weston Brzostovski**, Roslyn, New York; **Miguel Gomez**, San Antonio, Texas; and **Jerom Theunissen**, Rye, New York; for their senior design project: Vanderbilt Green Fund Bike Shelter.

Mechanical Engineering Design Award

The Mechanical Engineering Design Award is shared by two project teams. The winning projects are the Surgical Video System Design Project and the Nissan Robotic End-of-Arm Tooling Project. The video system team members are **Alexander Roed** (ME), West Bloomfield, Michigan; **Christopher Savoca** (EE), Ridgefield, Connecticut; **Douglas Manogue** (ME), Sea Cliff, New York; **Eric Noonan** (ME), Wilton, Connecticut; **Kevin Barrow** (ME), Carlisle, Massachusetts; and **Lindsey Nestor** (ME), Malvern, Pennsylvania. The Nissan team members are **Andrew Jordan** (ME), Oklahoma City, Oklahoma; **Dannielle Hendon** (BME), Monroe, Georgia; **Iliya Mohamad Lokman** (ME), Sungai Buloh, Malaysia; **Joshua J. Fleck** (ME), Bradenton, Florida; **Kamal Hisyam Kamal Azmi** (ME), Shah Alam, Malaysia; **Matthew C. Johnson** (ME), Pasadena, California; and **Seonghoon Noh** (ME/Math), Chattanooga, Tennessee.

Walter C. Criley Prize

The Walter C. Criley Prize in electrical engineering is awarded to the Sterling Ranch V Smart Light Pole senior design team: **Ghassan Alduraibi** (EE), Riyadh, Saudi Arabia; **Emir Farid Mohd Rodzi** (CmpE), Kuala Lumpur, Malaysia; **Shamita Nagalla** (CmpE), Alpharetta, Georgia; and **Elizabeth Ann Weber** (CmpE), Bay Village, Ohio.

Kenneth A. Debelak Award for Excellence in Design

Winners of the Kenneth A' Debelak Award for Excellence in Design in chemical and biomolecular engineering winners are *First place*: Production of Semiconductor Grade Silane for Polysilane Synthesis, **Emily L. Daley**, Ashburn, Virginia; **Emily M. Cavalaris**, Lake Forest, Illinois; and **Savannah A. Thomas**, Ridgeland, Mississippi. *Second place*: Designing a Multi-Product Brewery, **Nicholas Crowther**, Suwanee, Georgia; **Brian Doney**, Westerville, Ohio; **Emily McRen**, Hendersonville, Tennessee; **Theresa Miller**, Lake Zurich, Illinois. *Third place (tie)*: Sulfuric Acid Plant with Waste Heat Recovery, **Victoria Yao**, College Station, Texas; **Putri Desmawardi**, Telok Panglima Garang, Malaysia; and **Imran Anoar**, Petaling Jaya, Malaysia; and Grassroot Plant for Conversion of Natural Gas to Aromatics, **Marie Armbruster**, Lexington, Kentucky; **Jessica Banasiak**, Scotch Plains, New Jersey; **Matthew Bedard**, Frisco, Texas; and **Nicole Jenkinson**, Sheperdstown, West Virginia. **V**

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,

A handwritten signature in black ink that reads "Thomas J. Withrow". The signature is fluid and cursive.

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Scott Guelcher, Professor of Chemical and Biomolecular Engineering

Bryan Beyer, Adjunct Instructor of Chemical and Biomolecular Engineering

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66 DESIGN AND PROJECT FACULTY

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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



TEAM

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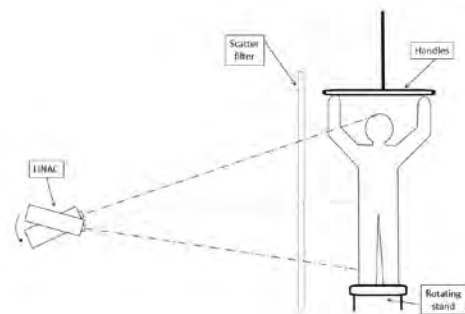
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Department of Radiation Oncology,
Vanderbilt University Medical Center

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.

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MEDICAL CENTER

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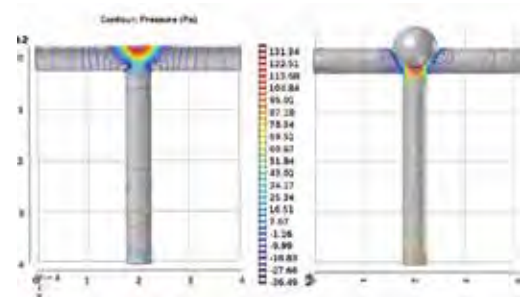
Vanderbilt University Medical
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**BIOMEDICAL
ENGINEERING**

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.

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Department of
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**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.

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MEDICAL 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.



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.

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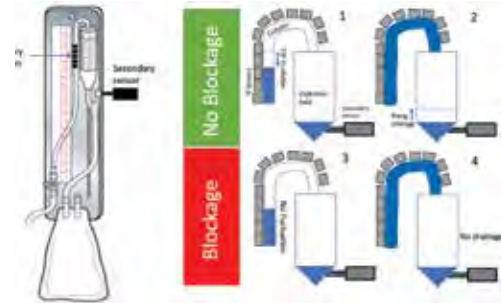
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SensiFlow: A Smart Blockage Detection Device for Extraventricular Drains

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.



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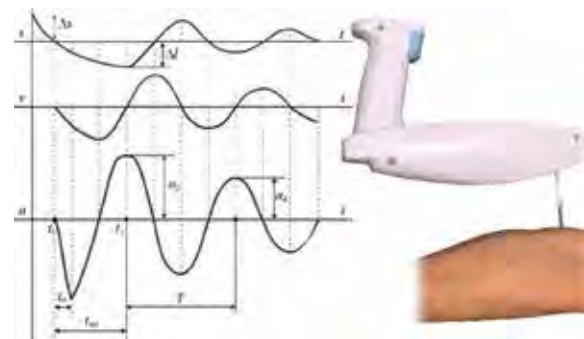
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Omniton: Device to Quantify Changes in Muscle and Skin Biomechanical Properties

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.

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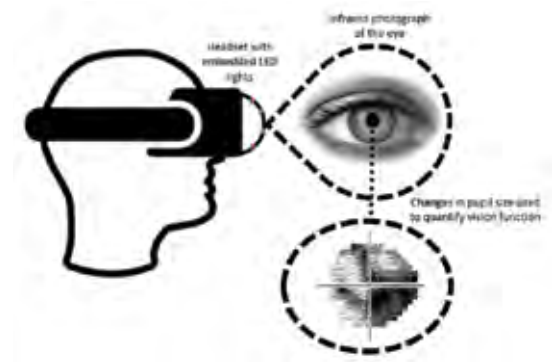
**BIOMEDICAL
ENGINEERING**

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

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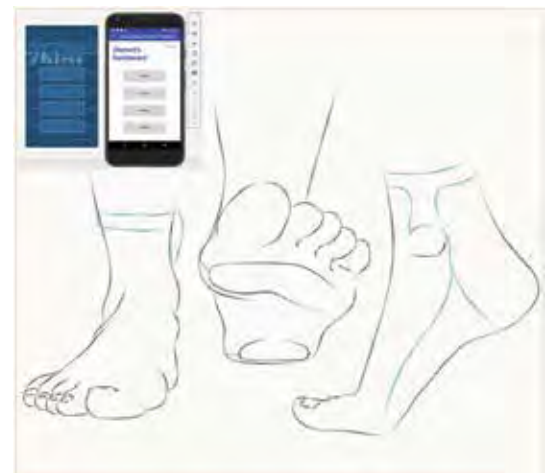
Vanderbilt University
Medical Center,
Patient Care
Informatics

**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.

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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.



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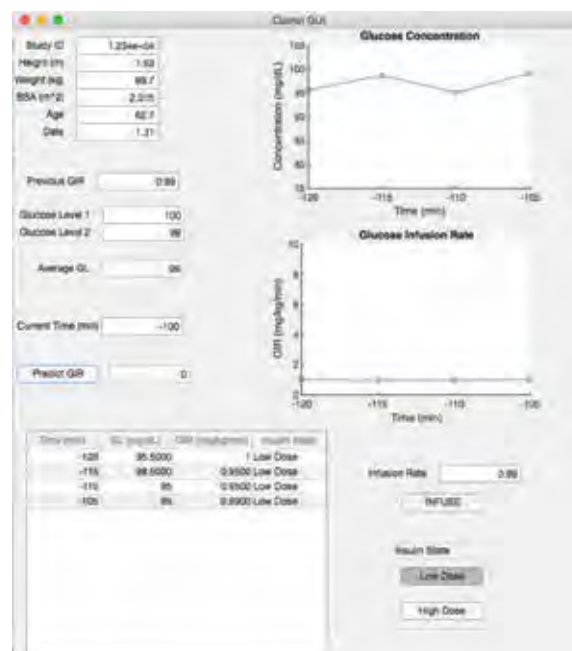
Vanderbilt University Medical Center
Department of Pharmacology

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 hyper-insulinemic 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.



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BIOMEDICAL ENGINEERING

3D 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 3D 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, 3D rendering, and the 3D 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 3D 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. 3D bone modeling could improve operating room efficiency and patient outcomes for complex distal humerus fracture cases.



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

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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.



3D 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.

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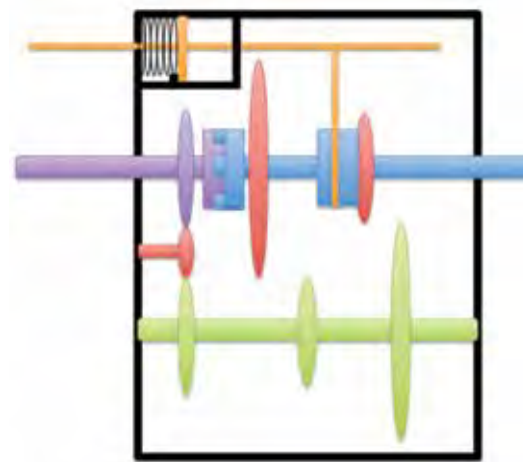
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RoWheels Incorporated

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.

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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.



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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 3D 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.

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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.



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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 CO₂, 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
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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.



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**CIVIL AND
ENVIRONMENTAL
ENGINEERING**

Urban Housing Solutions— Madison, Tennessee, Site Design

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.



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

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Ben Nelson, Design Engineer, SDL Structural Engineers

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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.



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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.



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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.



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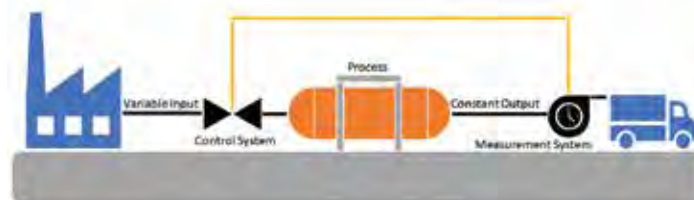
CHEMICAL AND BIOMOLECULAR ENGINEERING

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.

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.



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



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

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, bio-medical implantation, and process design.

We used 3D 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. 3D 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 3D 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.



Ultimaker³ 3D Printer



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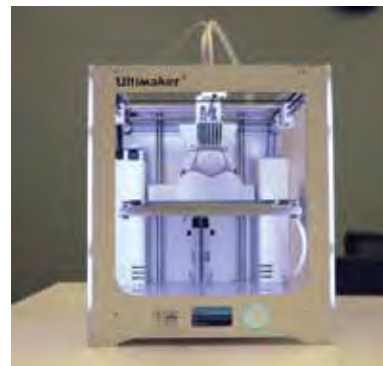
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3D Printing in Chemical Engineering Applications

Our goal was to explore the technology for application in chemical engineering to gain critical application data and provide innovative solutions. 3D 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 3D 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 3D printing applications for various chemical engineering related products.



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



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**CHEMICAL AND
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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.

Phosgene

Colorless gas. Poison.
Smells like newly mown
hay. Causes severe burns
to eyes/skin/lungs.
Chronic Effects include
fibrosis and respiratory
deficiencies



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



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Mobile System to Treat Fracking Wastewater

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.



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



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Reducing Chemical Plant Operating Costs by Energy Conservation

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.



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.

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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

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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



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Production of Semiconductor Grade Silane for Polysilane Synthesis

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 TYP semiconductor 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.

An industrial silane plant
currently operating in
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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.



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CHEMICAL AND BIOMOLECULAR ENGINEERING

Designing a Multi-Product Brewery

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.



Bent End Brewery, established in 2017

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CHEMICAL AND BIOMOLECULAR ENGINEERING

Producing Linear Alpha Olefins from Ethylene with Improved Selectivity

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.



Typical petrochemical plant for linear alpha olefin production



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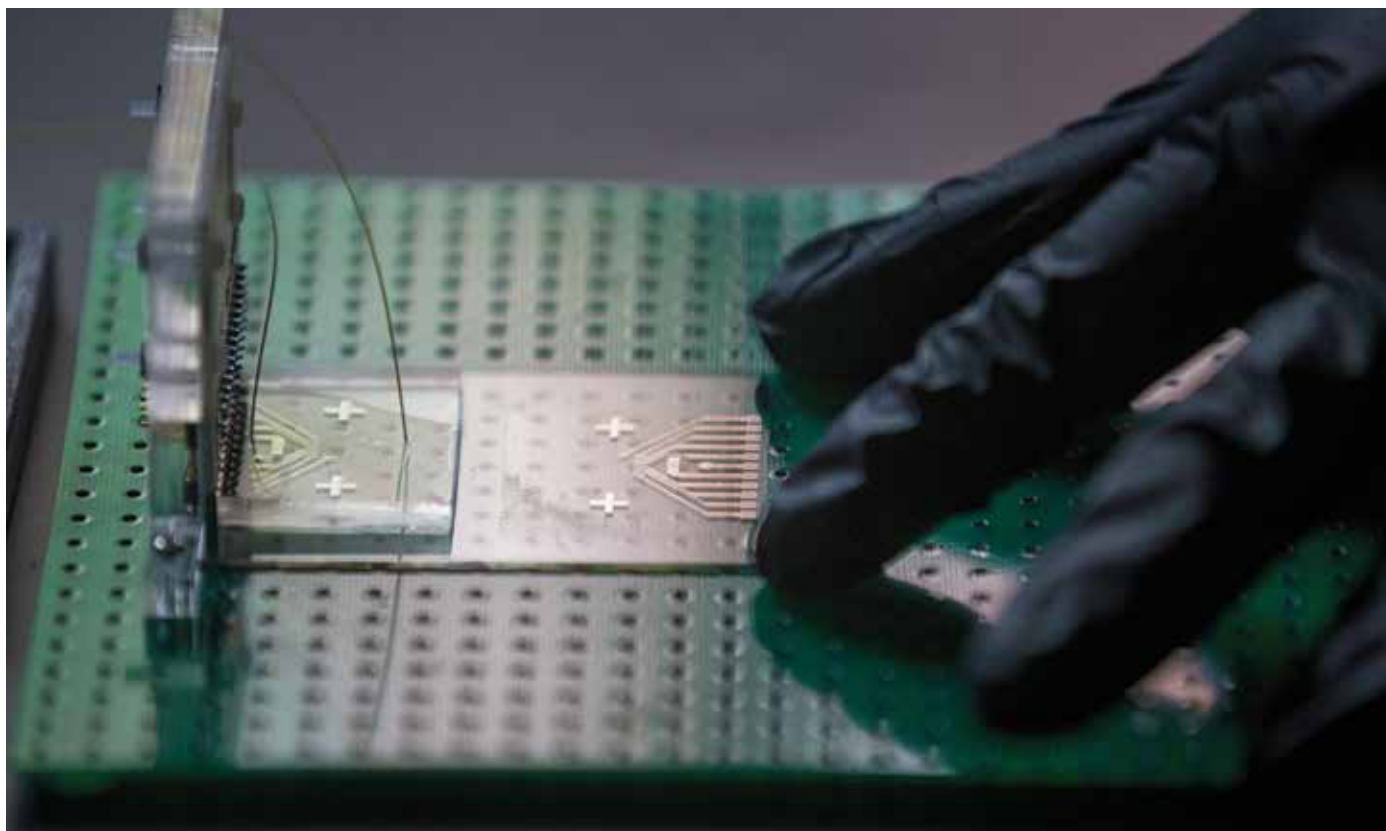
Grassroot Plant for Conversion of Natural Gas to Aromatics

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 grassroots 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.



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.



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Cybersecurity Testbed for Critical Infrastructure

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 communicate and collaborate on best practices.



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

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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



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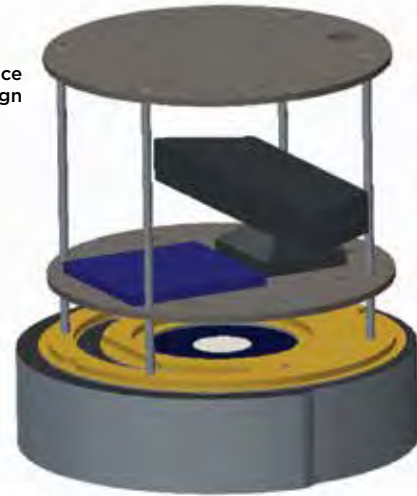
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Metova Autonomous Utility Robot II

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

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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



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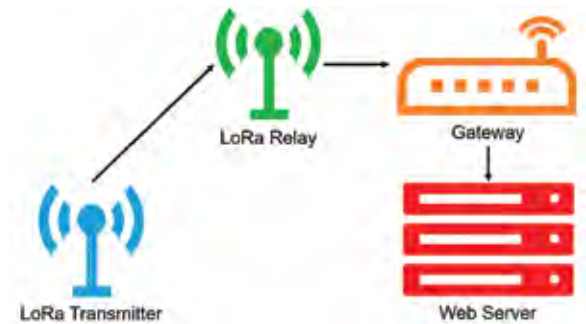
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Metova LoRa Single-Hop Mesh Network

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

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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.



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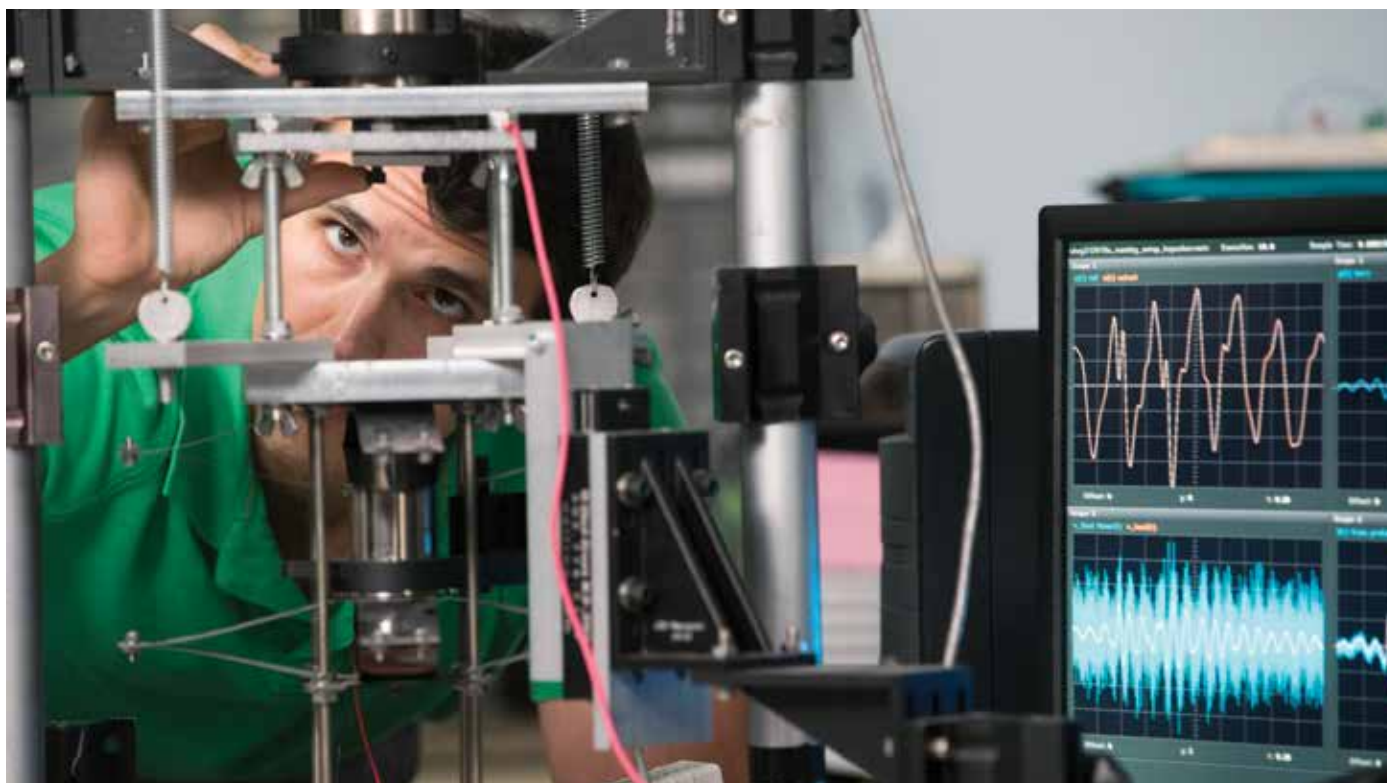
Sterling Ranch Development
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Siemens

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 a central server. By communicating with the Steward app, the server is able to control the light poles remotely.



**Steward
Application Home
Page Interface**



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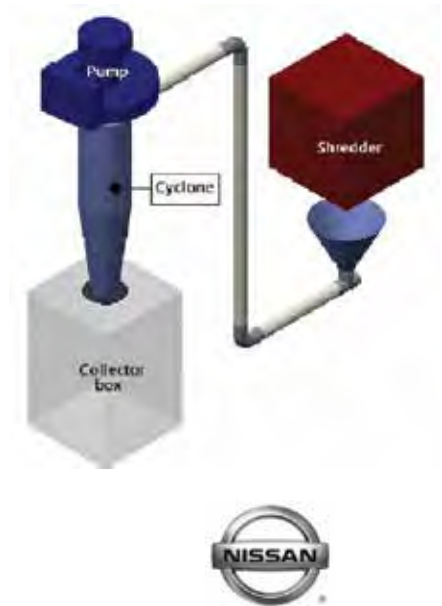
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Nissan Cardboard Conveyance Project

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.



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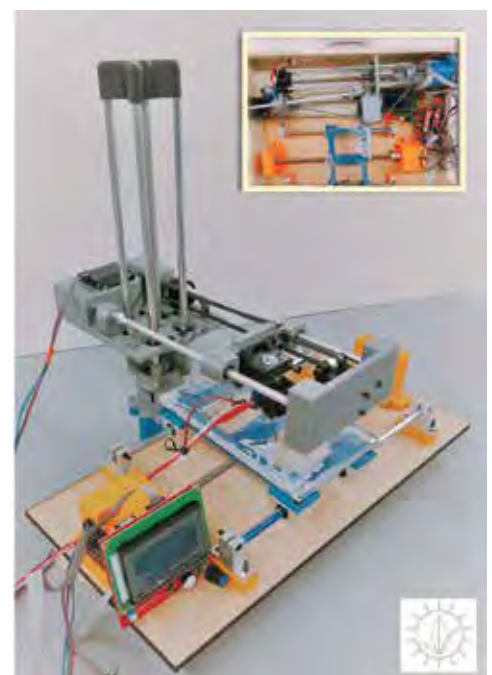
Collapsible, Solar Powered 3D Printer

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

The team's goal was to develop a collapsible 3D 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 3D printers, which are difficult to move and must have a dedicated power source.

The final product is a fully functioning 3D 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 3D printers. This transportable, compact design will impact the next generation of 3D printers and the way they are used.

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



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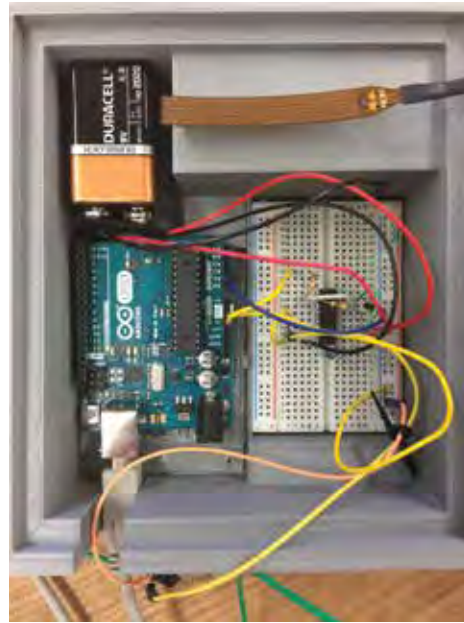
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Tennessee, Inc.

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

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U.S. Navy Supervisor of
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Developing Technologies for Near Field Visualization for Divers in Zero Visibility Environments

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.



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.



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MECHANICAL ENGINEERING

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

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 3D 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.



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



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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.

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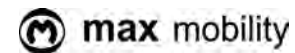
MAX Mobility, LLC.

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



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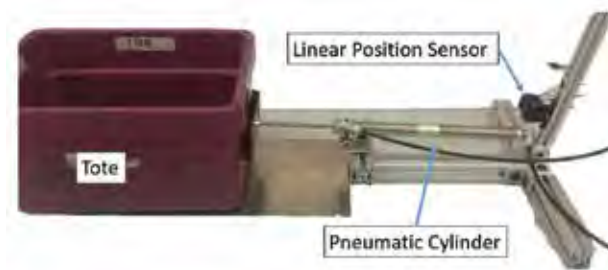
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QMSI Tote Pusher Design Project

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.



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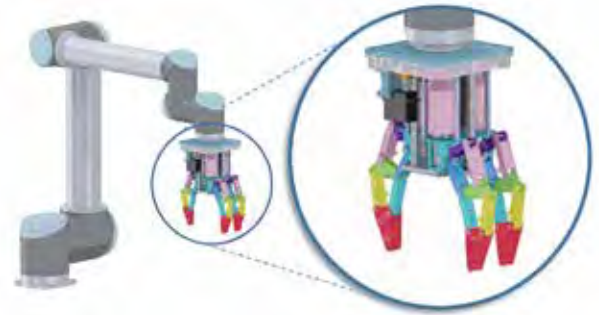
Nissan North America, Inc.

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.

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, 3D printable, and easily scalable for diverse applications.



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



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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

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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.

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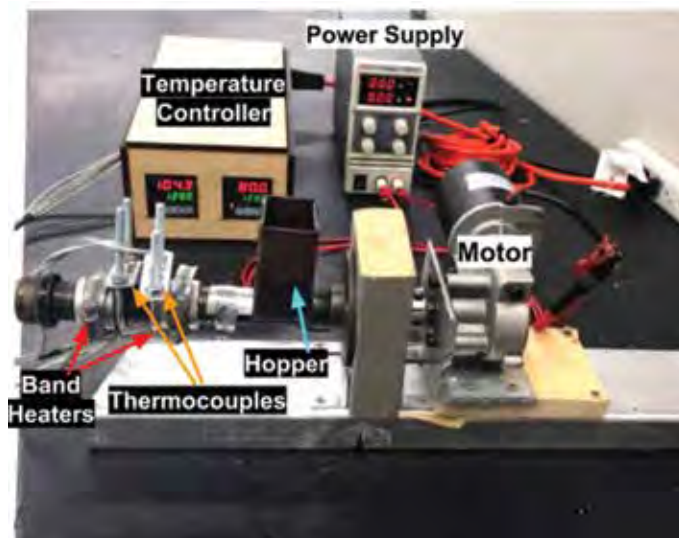
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The Additive Re-Manufacturing of Plastic for 3D Printer Filament

Converting plastic waste into 3D 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 3D printer filament. The additive re-manufacturing of 3D filament device will convert shredded PETE and HDPE plastics into 3mm and 1.75mm 3D printer filament and will occupy a new niche in the market.



The additive re-manufacturing of 3D filament extrusion device



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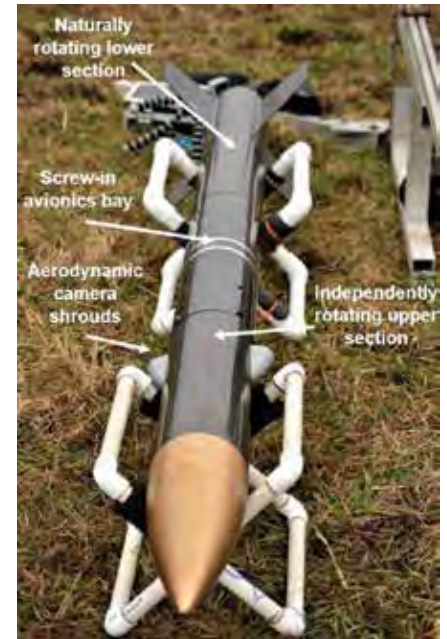
MECHANICAL ENGINEERING

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



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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



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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.



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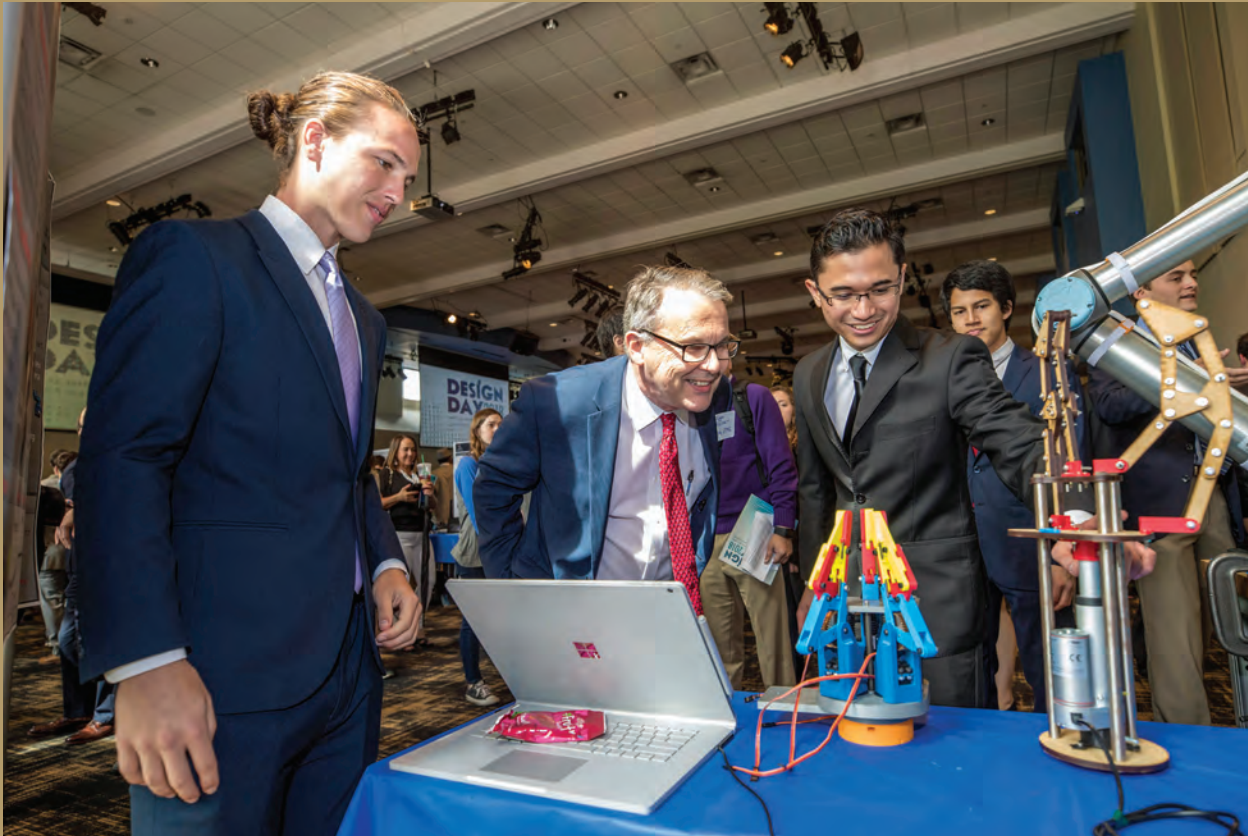
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