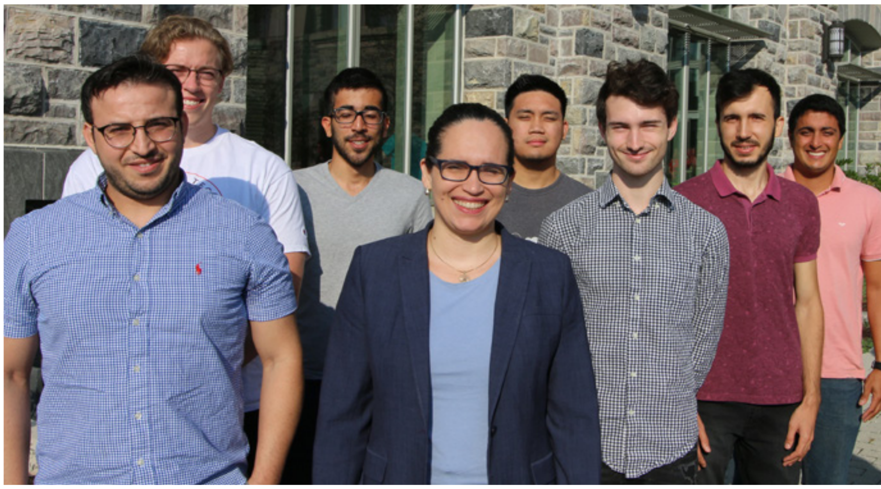


COLLEGE OF ENGINEERING

MECHANICAL ENGINEERING

VIRGINIA TECH™

2020 ANNUAL REPORT

FROM THE COVER

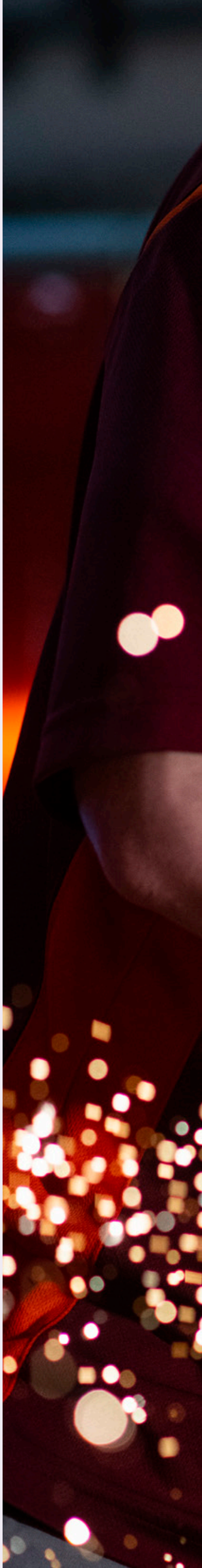
Labs and curriculum have been revamped, creating more hands-on learning opportunities. Story on page 10.

One of several projects for fighting COVID-19 is a 3D-printed mask being made ready for mass production. Story on page 60.

Ling Li is applying the structure of cuttlefish bones to the creation of lightweight cellular ceramics. Story on page 33.

Faculty in nuclear engineering and fire safety engineering are working together to create machine learning aimed at safety for nuclear power plants. More at bit.ly/2QONtjK.

A drone school in Malawi got some help during the COVID-19 pandemic from graduate student Brianna Friedman. More at bit.ly/34YaRnm.



Graduate student Grant Carter works on a grinder for the Grand Touring Team in the Randolph Hall garages before competing in an endurance race. Photo taken in early 2020.

RYAN YOUNG FOR VIRGINIA TECH

Greetings, colleagues.

The 2019-2020 academic year has been one unlike any I can remember. The challenges of facing COVID-19 and its effects on campuses around the globe have necessitated a great deal of creativity to find new ways to serve our students, our industry partners, our medical service providers, and our community. I have been proud to work with a dedicated and talented team to achieve all of those objectives.

To serve our students, we have rapidly pushed academics online to allow students to continue or finish their education. Our faculty already had a series of take-home labs, and those unique tools have enabled the expansion of those methods and experiences to other classes.

Serving our industry partners and sponsors has meant working within the confines of state-mandated closures, but new opportunities became available. While some labs went offline temporarily, new projects have still been initiated, including those funded by new NSF CAREER Awards and Young Investigator Awards. Our faculty have continued to innovate, and we have enjoyed media recognition of some exciting breakthroughs.

Working with the medical community to provide resources throughout these past few months has been a particular point of pride. Many of our labs have retooled and repurposed to fill the shortage of personal protective equipment (PPE). It has been inspiring to see our teams of students and faculty come together for the common good. You will read more about that effort in the section dedicated to our fight against the coronavirus.

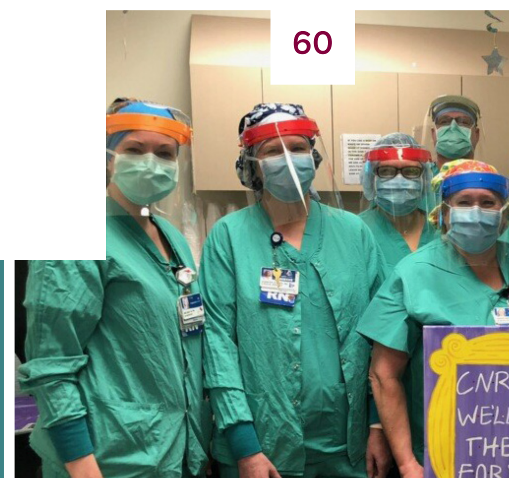
Of course, the obstacles have not been small. I am proud to say that our department has found creative ways to flourish in the most challenging times and continue its path to greater excellence. I invite you to read about them in this report.

Among the features are our new undergraduate curriculum and laboratories, creating unprecedented hands-on opportunities for our students, a set of remarkable research achievements, and a host of impressive awards and recognitions of our team. We are most thankful to our supporters, alumni, and friends who kept contributing to our department throughout these unprecedented times.

Azim Eskandarian, D. Sc.
Department Head and
Nicholas and Rebecca Des Champs Chair
Virginia Tech Mechanical Engineering

COLLEGE OF ENGINEERING
MECHANICAL ENGINEERING
VIRGINIA TECH™

10



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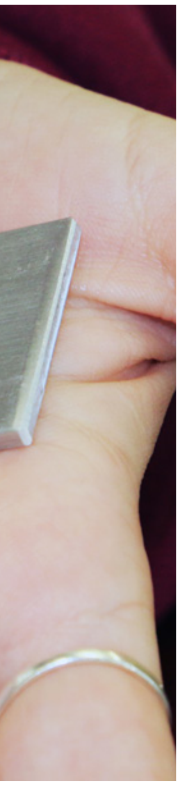
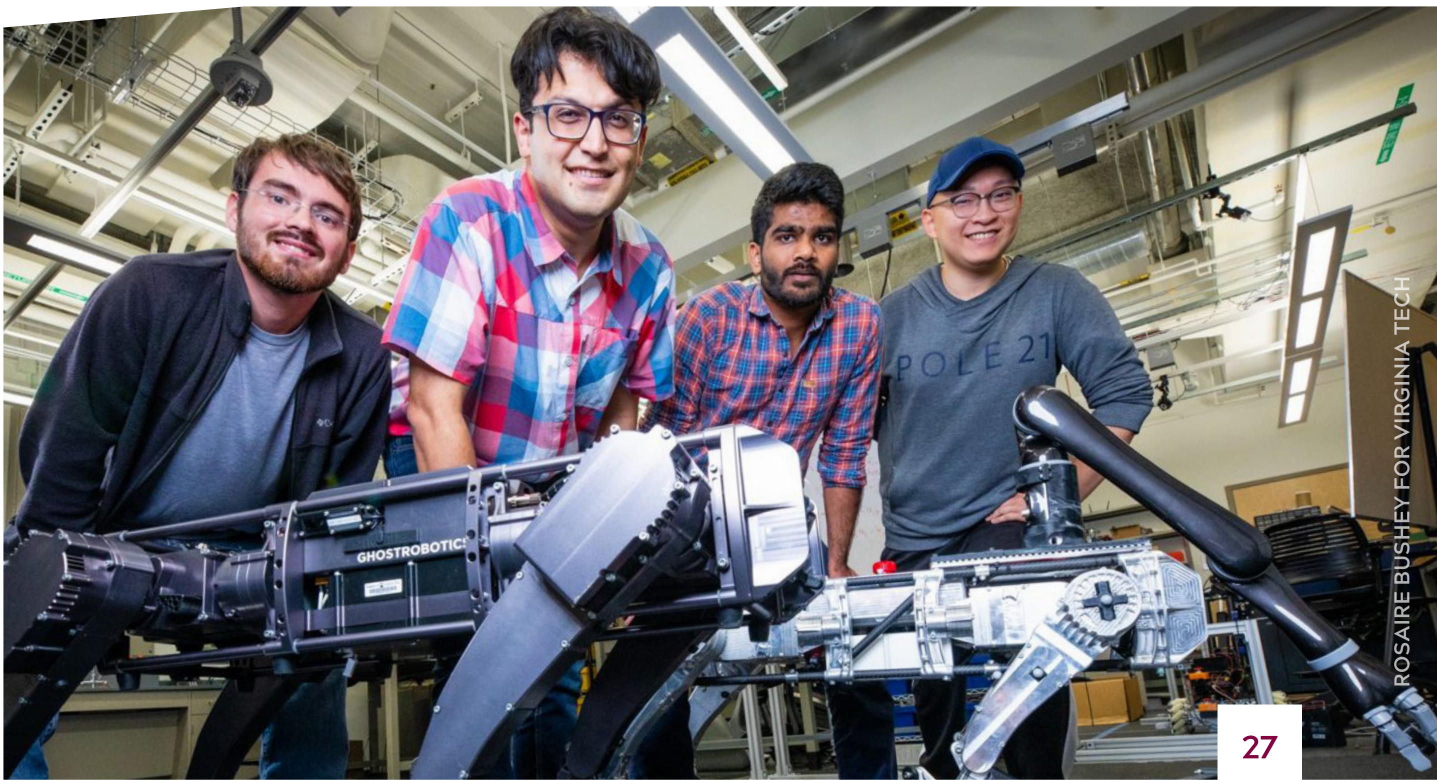
RYAN YOUNG FOR VIRGINIA TECH

21





ROSAIRE BUSHEY FOR VIRGINIA TECH

27

34

DASHBOARD

68 FULL-TIME FACULTY

54 AFFILIATE/ADJUNCT FACULTY

14 CHAIRED/FELLOW FACULTY

#5 IN THE U.S., *MECHANICAL ENGINEERING DEGREES AWARDED*
ASEE

TOP **20%** *GLOBALLY*
- QS WORLD 2020
RANKED 51-100 OUT OF 500 INSTITUTIONS WORLDWIDE

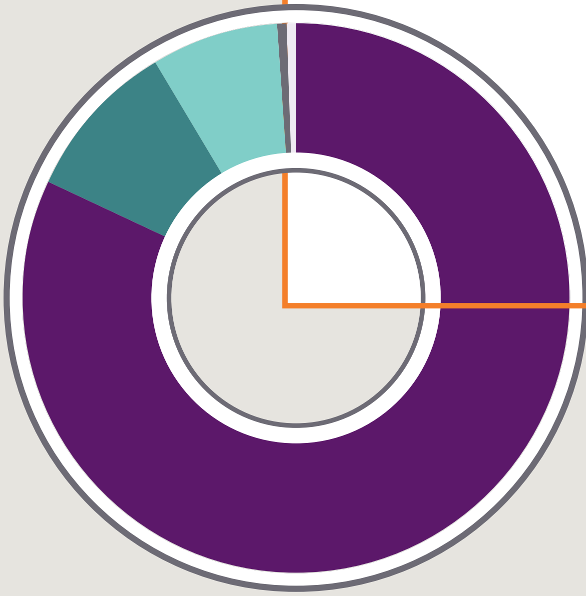
#17 UNDERGRAD PROGRAM IN THE U.S.
#9 *AMONG PUBLIC INSTITUTIONS*
U.S. NEWS AND WORLD REPORT

#17 UNDERGRAD PROGRAM IN THE U.S.
#10 *AMONG PUBLIC INSTITUTIONS*
U.S. NEWS AND WORLD REPORT

10	RESEARCH CENTERS
32	RESEARCH LABS
7	INSTRUCTIONAL LABS

2019-2020 DEGREES CONFERRED

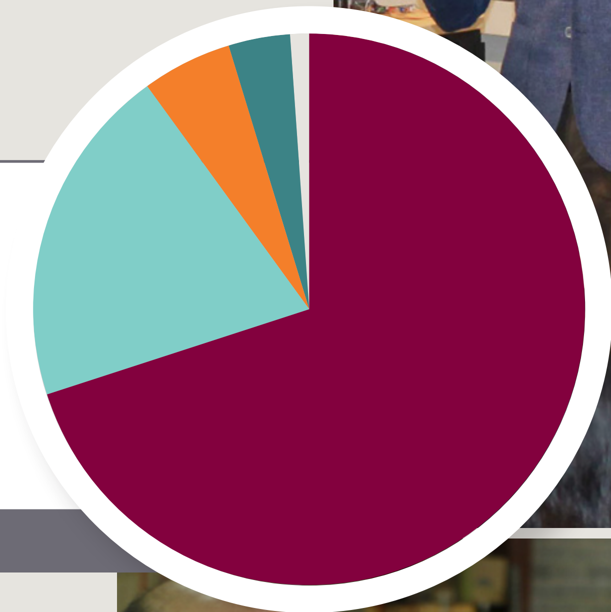
- **BS ME - 407** // *82%*
- **MS ME - 44** // *9%*
- **PhD ME - 37** // *7%*
- **MS NE - 4** // *1%*
- **PhD NE - 3** // *1%*

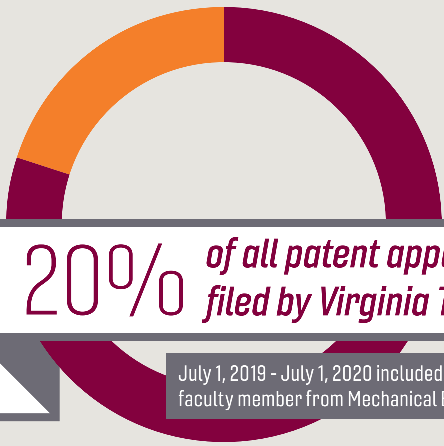


RESEARCH EXPENDITURES

- **Federal** *$11,874,000* // *70%*
- **Commercial** *$3,392,000* // *20%*
- **Virginia Tech Foundation** *$905,000* // *5%*
- **Other** *$656,000* // *4%*
- **State** *$92,000* // *1%*

Total *$16,919,000*





20% *of all patent applications filed by Virginia Tech*

July 1, 2019 - July 1, 2020 included at least one faculty member from Mechanical Engineering

42

LABS & CENTERS

EXPANDING HANDS-ON LEARNING

New curriculum, new labs

The department has increased integration of lab courses into classroom teaching in the interest of better serving our students.

Several three-hour classroom courses have now become four-hour courses, adding an additional lab credit in the same semester.

Facilities have also been bolstered. Randolph Hall has a newly renovated lab space accommodating three separate work areas for studying fluids, controls, and material strength. The fluid study equipment was set in motion thanks to a gift from Nicholas and Rebecca Des Champs, with the department providing funding to complete the other spaces.

Some courses are capitalizing on multiple campus facilities to give students a wider perspective on technology. One of these courses is Associate Professor Bahareh Behkam's three-credit lab and lecture course, designed to be especially responsive to rapid advances in micro- and nano-robotics as they occur. During lab sessions, students make use of Virginia Tech's nanoscale fabrication and characterization laboratory in addition to Dr. Behkam's research laboratories. With these rich resources, students are divided into teams of three to four people to design, analyze and construct a micro-robotic system that has been inspired by the latest advances in their field.

Mobile labs and COVID-19

As part of this new initiative, several faculty have developed adaptable take-home labs.

The first of these take-home labs was developed to expand the learning of heat transfer coursework, spearheaded by Professor Thomas Diller for launch in 2017. Diller worked with two students to assemble the components, starting with an assortment of parts from several manufacturers. As the group worked out the optimal combination of technology, they eventually founded a company to commercialize their unique tool set. The final product was compact and costs less than a textbook.

Since then, this approach has been preferred by students. In spring 2020, Diller expanded the use of boxed labs to the entire class of 350 junior mechanical engineering students studying heat transfer. The rollout was opportune not only because of its effectiveness as a learning tool, but also because this was the same semester in which COVID-19 forced colleges around the world to suspend in-person learning. The class continued

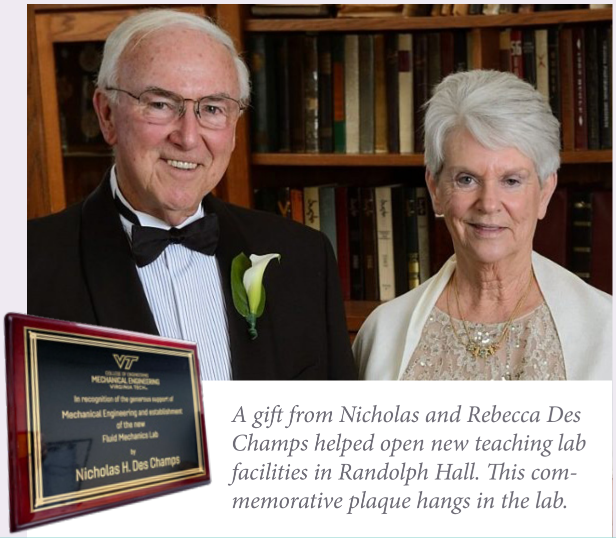
Students use the new fluids lab facilities. Photo was taken in early 2020.

with hands-on experiments for students during the COVID-19 pandemic.

Associate Professor Jan Helge Bohn brought this technique into play for his Engineering Design & Economics class for the Fall 2020 semester, including six students studying overseas and seven domestic students outside the Blacksburg area. The students purchased an Arduino UNO R3 micro-controller, a USB cable to connect to their computer, and a 9-volt battery. The rest of the kit and the controlling software was provided by the department. With this equipment, students could learn electronics and microcontroller fundamentals while working remotely.

With success established, take-home kits soon began expanding. Diller was joined by fellow faculty members Al Wicks and Steve Southward to extend the idea to other classes in mechanical engineering. In addition to heat transfer, the approach will also include mechanical strain sensors, proportional-integral-derivative controllers, inertial measurement, GPS sensors, ultrasound sensors, radar sensors, pressure sensors, and wireless communication.

“This initiative has enabled us to rethink what teaching looks like, and come up with some exciting new options for students,” said Department Head Azim Eskandarian. “We are seeing new levels of innovation and discovery. As part of our larger strategy, we remain focused on our goal of empowering the next generation of inventors and innovators in new ways.”



A gift from Nicholas and Rebecca Des Champs helped open new teaching lab facilities in Randolph Hall. This commemorative plaque hangs in the lab.

DEDICATED TEACHING LABS IN VIRGINIA TECH MECHANICAL ENGINEERING

THERMAL FLUIDS LAB

Required Connected Course:
ME 3414 // FLUID DYNAMICS
Comprehensive first course in fluid dynamics.

CONTROLS LAB

Required Connected Course:
ME3534 // CONTROLS ENGINEERING I
Fundamentals of feedback control theory, time-domain and frequency-domain analysis, automatic control system design synthesis to meet performance and stability requirements, numerical simulation and discrete real-time implementation on microcontrollers.

MECHANICAL DESIGN LAB

Required connected course:
ME3624 // MECHANICAL DESIGN Comprehensive first course in mechanical design.

ROBOTICS AND MECHATRONICS TEACHING LAB

AUDIO ENGINEERING TECHNOLOGY LAB

HEAT TRANSFER MOBILE LAB

EXPERIMENTATION LAB

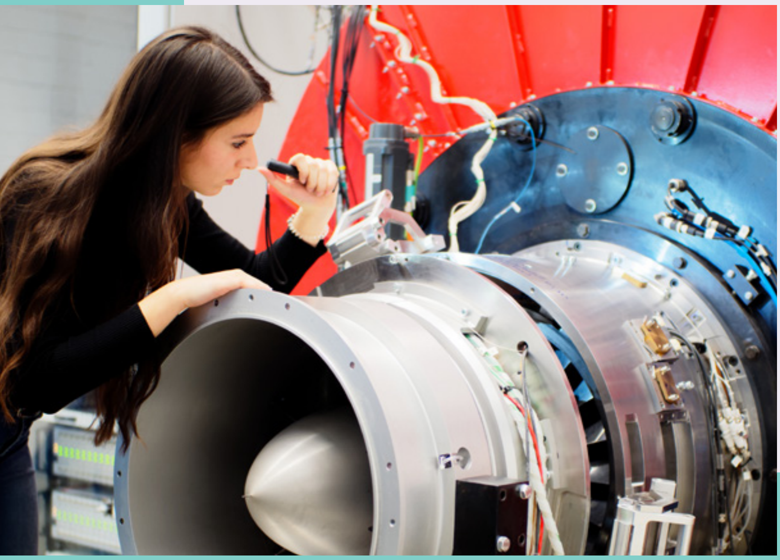
SENIOR CAPSTONE DESIGN

Partnership with German university offers students the opportunity to earn two MS-Thesis degrees at once

Virginia Tech has created a unique two-year, dual-thesis master of science degree program with Technische Universität Darmstadt, one of Germany's leading technical universities. Upon completion, graduates would have extensive international experience in addition to foreign language experience.

The effort is motivated by Virginia Tech's strategic plan and is particularly linked to the advancing of regional, national, and global impact as indicated in the first strategic priority. Continuing to build on Virginia Tech's presence as a global land-grant university, this initiative will create bridges for students to build international experience while simultaneously earning their degree.

Students enrolled in the dual-MSME program simultaneously earn two Thesis Master of Science degrees, one from each institution. The Virginia Tech program yields a thesis Master of Science in Mechanical Engineering (thesis-MSME), while the TUD degree is a Master of Science (M.Sc.) in the field of Mechanical and Process Engineering.



A typical version of the program would require two years, one at Virginia Tech and the other at Technische Universität Darmstadt. In most cases, students would begin at their home campus and move to the second campus in the second year. Depending on the amount of research in which a student was involved, this could extend beyond the two-year estimate.

Students must be independently admitted to both the Virginia Tech Master of Science in Mechanical Engineering degree program and to the TU- Darmstadt Master of Science degree program, following the policies and requirements of each school. Consideration for the dual degree program occurs once the student is admitted into both these programs. Virginia Tech students enrolled in the Accelerated Undergraduate/Graduate Degree (UG/G) program in Mechanical Engineering would not be eligible.

Though this degree program is symmetric, it is not an exchange program. A student is simultaneously enrolled in both degree programs after paying tuition and fees to the university of residence. A combined plan of study must be completed by enrollees.

IMAGES COURTESY TECHNISCHE UNIVERSITÄT DARMSTADT

NUCLEAR ENGINEERING MINORS RECEIVE SCHOLARSHIPS FROM THE DEPARTMENT OF ENERGY

Three Virginia Tech students have received scholarships from the Office of Nuclear Energy in the Department of Energy (DOE-NE) to advance their studies in the field of nuclear engineering.

While Virginia Tech does not yet have an undergraduate degree in nuclear engineering, the first cohort of nuclear engineering minors were conferred in the spring 2020 commencement ceremonies. As the program continues to grow, there is great promise in the academic strength of the students engaged in the program.

Of particular note is a scholarship given by the DOE to a small group of students nationwide. The Office of Nuclear Energy's Integrated University Program includes 86 universities from around the US, of which 42 have students who have received awards. Universities must apply for a grant for their students to be eligible, and Virginia Tech's grant has been active since 2009.

The program offers undergraduate scholarships and graduate fellowships to students interested in futures in nuclear energy. Each undergraduate scholarship provides $7,500 to help cover education costs for the upcoming year. Three Virginia Tech students applied, and all three were awarded. Each was a junior majoring in mechanical engineering.


Adam Berlinerman

Adam Berlinerman, a junior from Richmond, Virginia, was one of this year's recipients. He expressed excitement about the potential of the field of nuclear engineering. "What interests me about nuclear engineering is the intellectual challenges it presents," he said. "The education I am receiving now and will receive will be the foundation for me to pursue my goals of working on the research and development side of new reactors."


Ayden Cohn

Also receiving a scholarship was Ayden Cohn, a junior from Norfolk, Virginia. "Nuclear engineering interests me because it could be a key energy source in the future as we shift away from fossil fuels," he said. "If managed safely, it will be one of the most, if not the most, efficient sources of energy. I hope to apply my education in the future to help make nuclear energy more widely used."


Shayan Sanjideh

The third recipient, Great Falls, Virginia, resident Shayan Sanjideh, also commented on the vital industry to which his education could allow him to contribute. "Nuclear engineering interests me because it is something whose potential isn't fully realized yet," he said. "I want to help contribute as much I can to this relatively new field of science."

Mark Pierson, an associate professor of practice and coordinator of the undergraduate nuclear program, expressed excitement about the momentum that the minor has achieved. "I am very happy with the support that our program is receiving from the Department of Energy. That three of our students in the nuclear engineering minor received a DOE-NE scholarship is a testament to the quality of the students in our program. This is significant since this is a national competition."

More about the Virginia Tech nuclear engineering program is available on the program website, nuclear.ncr.vt.edu.

The nuclear engineering program is administered through the Department of Mechanical Engineering.

SENIOR**DESIGN**

The Mechanical Engineering Program at Virginia Tech graduates more than 400 students each year. A hallmark of this undergraduate experience is the two-semester long Capstone Senior Design course. To accommodate the number of students enrolled, this project-based course is comprised of 50 unique teams, most with between five and eight students, except for larger competition teams.

The cycle for projects is broken into halves. The first semester (Fall) is dedicated to learning basic product design, including the following areas: documenting customer needs, generating design specifications, concept generation and down selection, identifying engineering standards, assessing risk and creating mitigation plans, understanding engineering ethics, and writing verification plans. The second semester (Spring) is dedicated to building and testing the product design. This building phase leads up to the mid-spring product launch; at this time, it is expected that devices will be fully functional. From that point, the remainder of the spring is spent on refinement, evaluation, redesign, and verification. At the end of April, sponsors and the general public are invited to the Senior Design Expo, a trade-show-like event where each team displays and explains their projects to visitors, judges, and fellow students.

Of the 50 teams, projects types are divided between four categories: humanitarian, faculty-sponsored, competition, and industry-sponsored.

HUMANITARIAN

Just as Virginia Tech is dedicated to its motto of *Ut Prosim*, “That I may serve,” engineering projects are also assembled for this purpose. Humanitarian efforts include an effort to design a manual water pump for a village in Malawi, Africa.

FACULTY-SPONSORED

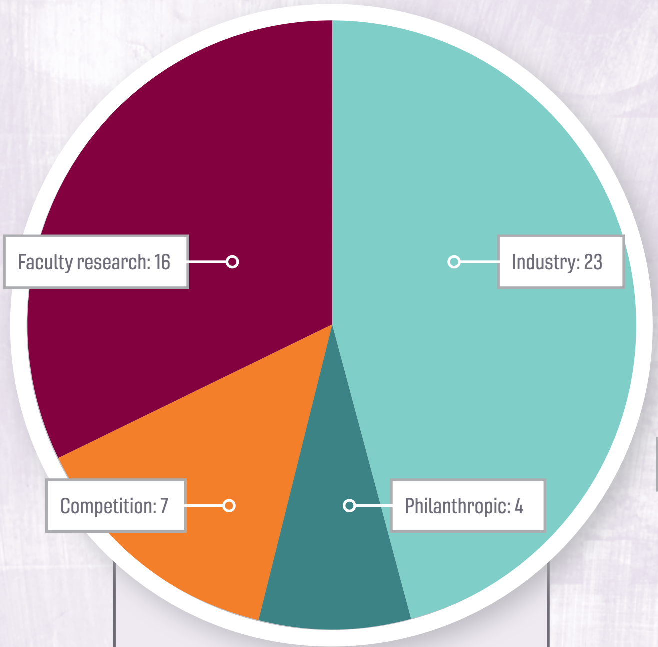
With more than 40 research centers and labs in the department, many projects are already in motion. Some of these require a team of specialists coming together on a specific component, and some require extensive testing. When faculty sponsor a project, students make a valuable contribution to ongoing research at the university.

COMPETITION

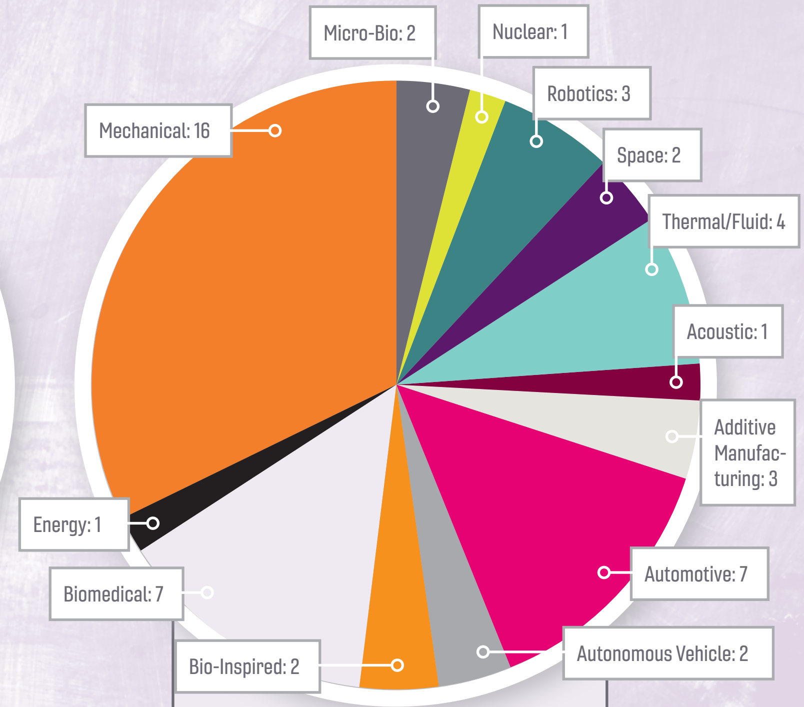
Student teams come together to design, build, and compete with a number of vehicle types. The most common car teams include Formula SAE, Baja SAE, and EcoCar. Most of these teams are ongoing and build on the experiences of past years, continuously improving on design and competing against other schools.

INDUSTRY-SPONSORED

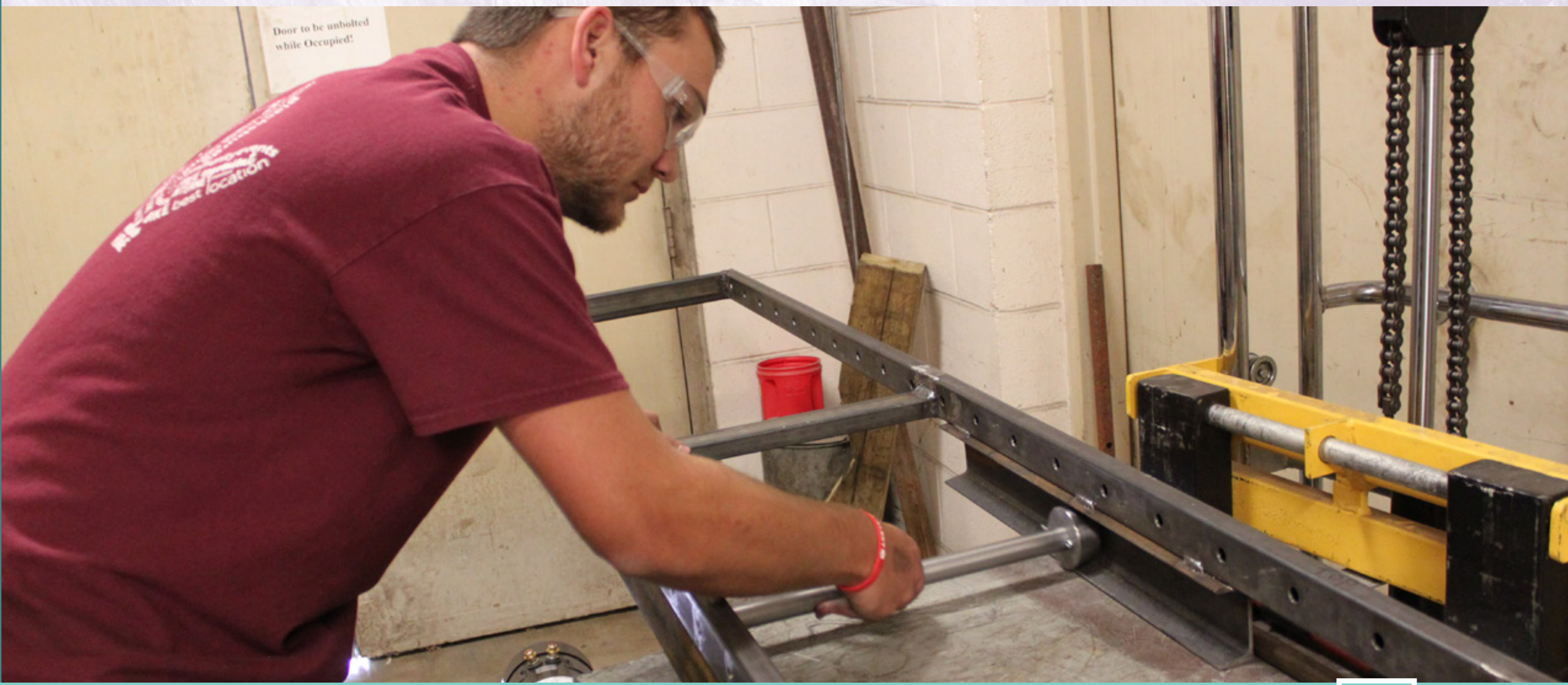
Industry-sponsored projects help both the student and the companies who provide sponsorship. Students gain problem-solving skills from the experiential learning taking place in a real-world, industry context. Industry sponsors benefit from a dedicated team of students who design and implement solutions to projects; they also get a first-hand look at the new engineers coming to work for them–or their competitors.



SENIOR PROJECTS BY TYPE, 2019-2020



SENIOR PROJECTS BY FIELD 2019-2020



SENIOR**DESIGN**

Students spend the fall semester walking through the product development process including collecting customer needs, concept generating, prototyping, analysis and detail design.

By winter break, teams have settled on one concept to move forward with and have completed half of the detailed design for that concept. During the spring semester, students finalize the details of the design then build and test their product.

PLAN

- Team charter
- Project charter
- Customer needs
- Engineering characteristics
- Target specifications

CONCEPTUALIZE

- Concept generation
- Early prototyping
- Risk assessment
- Down selection

Example deliverables schedule

SEPTEMBER

- Customer needs
- Engineering characteristics
- Target specifications
- Concept review

OCTOBER

- Risk assessment
- Design review - present project overview and design concept

NOVEMBER

- Preliminary design review

DECEMBER

- Design review - 50% detailed design complete

FEBRUARY

- Critical design review

MARCH

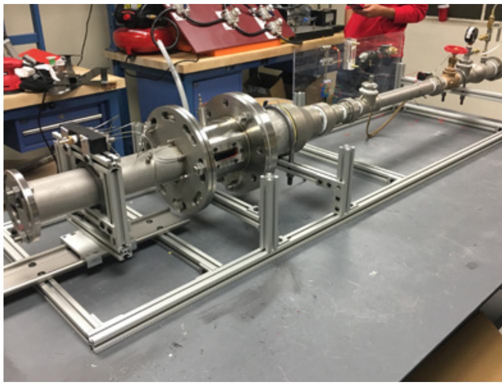
- Product launch presentation

APRIL

- Product test and evaluation
- Design expo and poster session

MAY

- Final design presentation and report
- Final product realization demo



DESIGN

- 3D CAD model
- Simulation
- Analysis
- Tolerance stack-up
- 2D drawings

BUILD

- Get supplier quotes for lead time and price
- Purchase components
- Complete assembly

TEST

- Test/validate for each target specification
- Analyze results

133,000 hours

What sets this program apart from others is that during this two-semester design course the students will design, build and test a product. They don't get to stop at a CAD model, an analysis, or a poster. Every student is required to work a minimum of 10 hours per week on their senior design project. Accounting for the work of each student over both semesters, total hours equal more than 133,000 each academic year.

Senior Design Sponsors

Action Coupling
Aerospace Corp
Altec
Altria/Phillip Morris
Ariston Olive Oil
ASML
Azoth3D
Boeing
Burlington Medical
BWXT
Canon
Collins Aerospace
Dominion Power
Dupont
Flowserve
Fontaine Modifications
Framatome
General Dynamics - Electric Boat
General Motors
Green kW Energy, Inc.
Harris Corp
Hubbell Lighting
Institute for Advanced Learning and Research
Kollmorgen
Lockheed Martin
Meyer Sound
Moog
NASA
NAVAIR
Newport News Shipbuilding
Northrop Grumman
PEO Soldier
Phoenix Innovations
Quality of Life Plus (QL+)
Rolls Royce
Textron
United Coal
Universal Fibers
UPS
United Technologies Aerospace
Volvo Construction

THE POWER OF

TEAMWORK

COMPETITION TEAMS

Student teams give mechanical engineering undergraduates the opportunity to work with engineering faculty to put wheels on their ideas, backed by industry sponsors. Teams often compete against other schools to prove the strength of their ideas.

AUTODRIVE

Virginia Tech, alongside seven other schools, was selected to be a part of the GM and SAE International sponsored AutoDrive Challenge. The objective of this competition is to plan, design, and build a fully autonomous ground vehicle. The team engineers a Chevy Bolt Electric, converted into an autonomous vehicle. The vehicle will then be put to the test in a rigorous urban driving course.

BAJA

Baja SAE® consists of competitions that simulate real-world engineering design projects and their related challenges. Engineering students are tasked to design and build an off-road vehicle that will survive the severe punishment of rough terrain.

Student Michael Bock pulled data from the Baja car during the Spring 2019 Baja Season after a test run by Andrew Touzinsky. "We had developed the linear potentiometers earlier that year to measure shock displacement," said Bock. "That day, we had finished up some electrical stuff and bookkeeping in the code before we left to see if the potentiometers worked on the track."

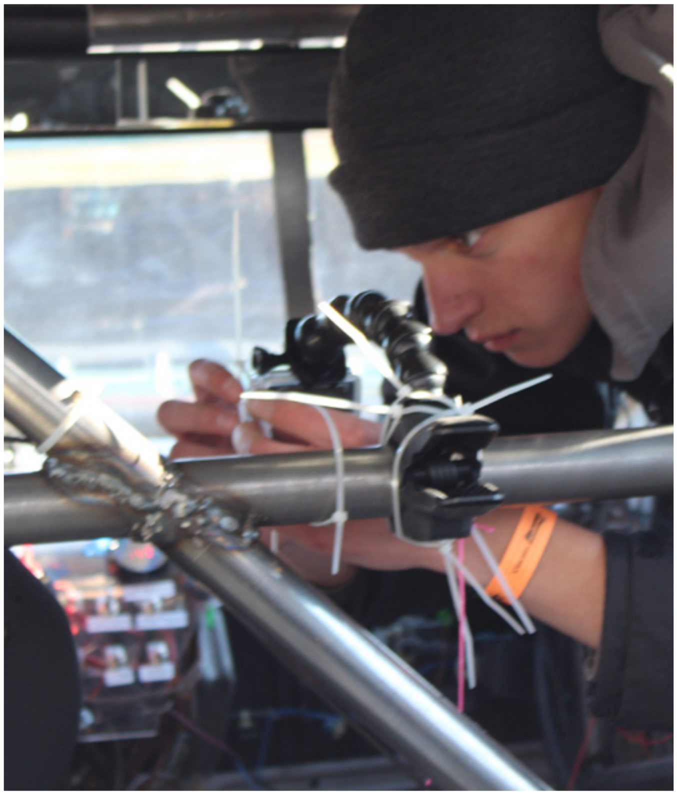
BOLT

The BOLT Team is comprised of mechanical engineering, electrical engineering, and computer engineering students who take an existing motorcycle frame and suspension and design and build a completely electric powertrain inside. The existing gas tank and engine is removed and replaced with lithium polymer batteries, and a power-dense motor controller, and a powerful electric motor. The team's newest prototype, BOLT IV, is based on a Yamaha YZF-R1M chassis. The team competes in multiple national competitions earning top places in their category and overall.

THE POWER OF TEAMWORK

FORMULA SAE

The Formula SAE competition is for SAE student members who conceive, design, fabricate, and compete with small formula-style racing cars. The restrictions on the car frame and engine are limited so that the knowledge, creativity, and imagination of the students are challenged. The cars are built with a team effort over a period of about one year and are taken to the annual competition for judging and comparison with approximately 130 other vehicles from colleges and universities throughout the world. The end result is a meaningful engineering project for young engineers, as well as the opportunity to work in a dedicated team effort.



GRAND TOURING

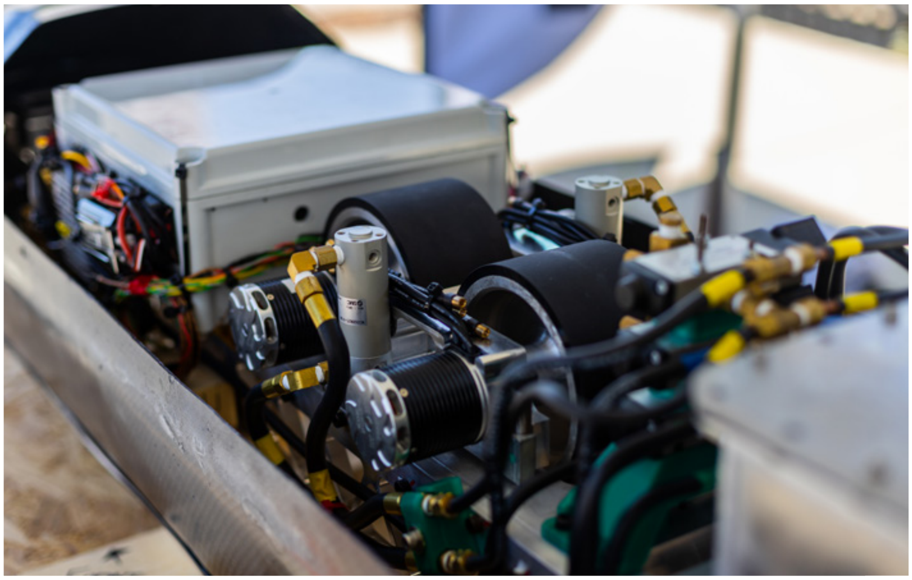
The Virginia Tech Grand Touring Team is a competition senior design team through the Mechanical Engineering Department of Virginia Tech with the goal of modifying a late model production vehicle to compete in an endurance race hosted by the ChampCar Endurance Series at Virginia International Raceway.

The 2020-2021 School Year will be the first year of racing the team's 1999 Honda Civic. The team hopes to place in the top 30 with this vehicle, advancing six spots from last year. The ChampCar World Series offers endurance races that range from 7-38 hours, VTGT will be competing in the 12 hour race at Virginia International Raceway on March 6th, 2021.

THE POWER OF TEAMWORK

HYBRID ELECTRIC VEHICLE TEAM

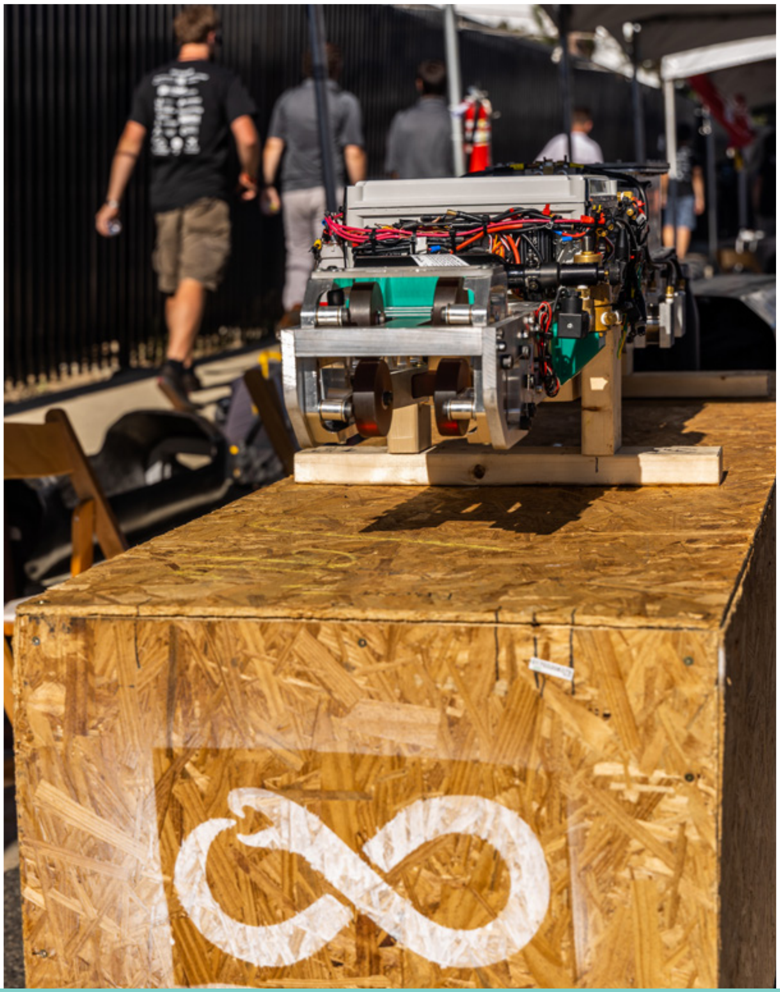
Hybrid Electric Vehicle Team (HEVT) is an EcoCAR Mobility Challenge team based in the Ware Lab. Students are currently in the vehicle build, component integration and initial testing phases of the project. The students who work on the project are highly motivated Sophomore - Senior engineering students across all disciplines from Mechanical, Electrical to Computer and Computer Science.



HYPERLOOP

Virginia Tech's Hyperloop team builds on the vision of Elon Musk, whose vision of an innovative high-speed rail could transform freight transport and domestic travel. To make this vision a reality, Hyperloop at Virginia Tech has represented the university on an international stage in the annual pod competition hosted by SpaceX.

The Virginia Tech finishes in the top 20 out of 2000 applicants every year. Starting in 2020, the team's mission is going beyond winning the competition to focus on research projects directly impacting the industry by partnering with companies to develop technology at the forefront of Hyperloop transportation.



Innovations in science and engineering lead to 3D-printed latex rubber breakthrough

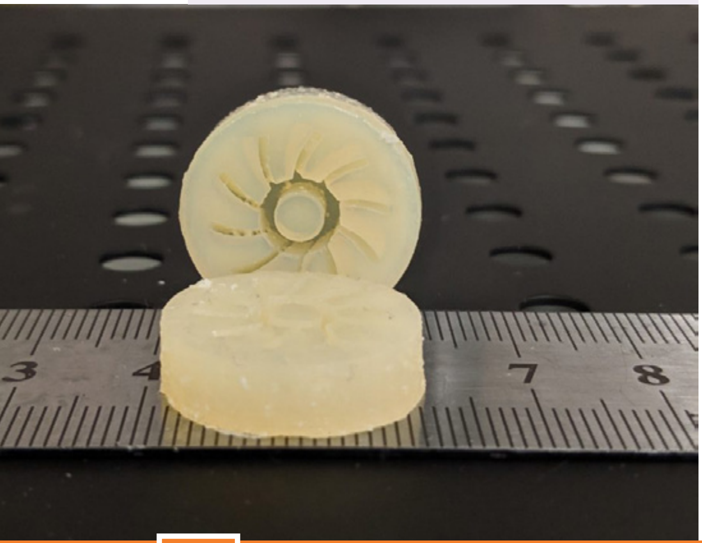
written by Andrew Tie *for Virginia Tech*

Virginia Tech researchers have discovered a novel process to 3D-print latex rubber, unlocking the ability to print a variety of elastic materials with complex geometric shapes.

Latex, commonly known as the material in gloves or paint, refers to a group of polymers – long, repeating chains of molecules – coiled inside nanoparticles dispersed in water. 3D-printed latex and other similarly rubbery materials called elastomers could be used for a variety of applications, including soft robotics, medical devices, or shock absorbers.

3D-printed latex has been documented only a handful of times in scientific literature. None of the previous examples come close to the mechanical properties of the latex printed by an interdisciplinary team affiliated with the Macromolecules Innovation Institute (MII), the College of Science, and the College of Engineering.

An interdisciplinary group of chemistry and mechanical engineering researchers developed a novel process to 3D print latex rubber. Latex rubber parts, such as this impeller printed at 100 micron resolution, allow nondestructive reuse of complex molds because the parts exhibit a unique combination of flexibility and toughness.



Through novel innovations in both the chemistry and mechanical engineering disciplines, the team overcame some long-standing limitations of 3D-printing, also known as additive manufacturing. The researchers chemically modified liquid latexes to make them printable and built a custom 3D-printer with an embedded computer vision system to print accurate, high-resolution features of this high-performance material.

"This project represents the quintessential example of interdisciplinary research," said Timothy Long, a professor of chemistry and a co-principal investigator on this project along with Christopher Williams, the L.S. Randolph Professor of mechanical engineering and interim director of MII. "Neither of our labs would be able to accomplish this without the other."

This project is a joint collaboration between Virginia Tech and Michelin North America via a National Science Foundation award aligned with the Grant Opportunities for Academic Liaison with Industry program, which supports teamed research between academia and industry. Details of their initial results are detailed in a journal article published in ACS Applied Materials & Interfaces.

Novel materials development in science

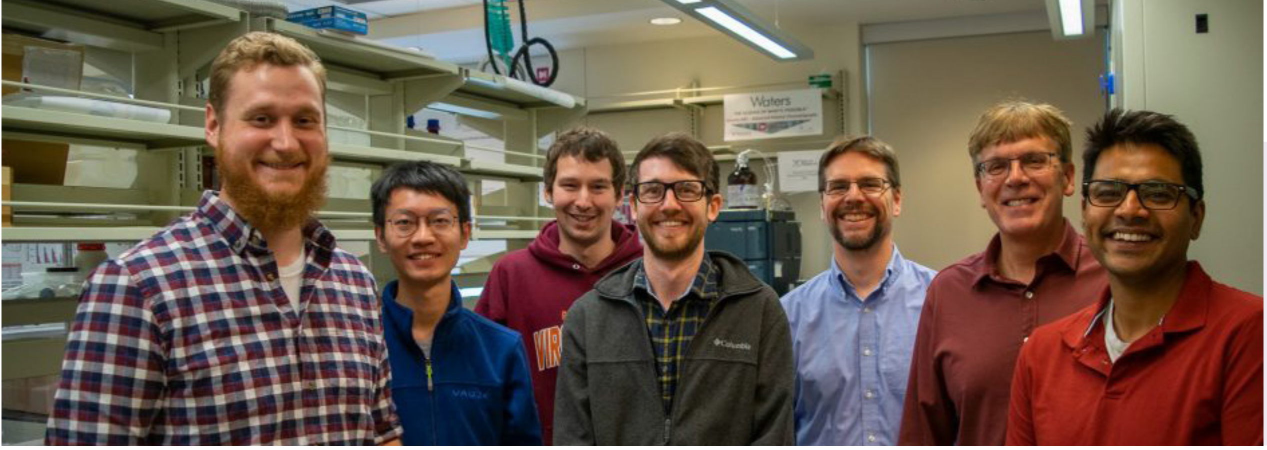
After unsuccessful attempts to synthesize a material that would provide the ideal molecular weight and mechanical properties, Phil Scott, a fifth-year macromolecular science and engineering student in the Long Research Group, turned to commercial liquid latexes.

The researchers ultimately wanted this material in a solid 3D-printed form, but Scott first needed to augment the chemical composition to allow it to print.

Scott ran into a fundamental challenge: liquid latex is extremely fragile and difficult for chemists to alter.

"Latexes are in a state of zen," said Viswanath Meenakshisundaram, a fifth-year mechanical engineering Ph.D. student in the Design, Research, and Education for Additive Manufacturing Systems Lab who collaborated with Scott. "If you add anything to it, it'll completely lose its stability and crash out."

Then, the chemists came up with a new idea: What if Scott built a scaffold, similar to those used in building



Chemists and mechanical engineers from the research groups of Timothy Long and Christopher Williams collaborated on this project.

construction, around the latex particles to hold them in place? This way, the latex could maintain its great structure, and Scott could add photoinitiators and other compounds to the latex to enable 3D-printing with ultraviolet (UV) light.

"When designing the scaffold, the biggest thing you have to worry about is stability of everything," Scott said. "It took a lot of reading, even stuff as basic as learning why colloids are stable and how colloidal stability works, but it was a really fun challenge."

Novel processing development in engineering

While Scott tinkered with the liquid latex, Meenakshisundaram had to figure out how to correctly print the resin. The researchers chose to use a process called vat photopolymerization, in which the printer uses UV light to cure, or harden, a viscous resin into a specific shape.

Needing a printer capable of printing high-resolution features across a large area, Meenakshisundaram built a new printer. He and Williams, his advisor, came up with the idea to scan the UV light across a large area, and in 2017, they filed a patent for the printer.

Even with the custom printer, the fluid latex particles caused scattering outside of the projected UV light on the latex resin surface, which resulted in printing inaccurate parts, so Meenakshisundaram devised a second novel idea. He embedded a camera onto the printer to capture an image of each vat of latex resin. With his custom algorithm, the machine is able to "see" the UV light's interaction on the resin surface and then automatically adjust the printing parameters to correct for the resin scattering to cure just the intended shape.

"The large-area scanning printer was a concept I had, and Viswanath made it into reality in short order," Williams said. "Then Viswanath came up with the idea of embedding a camera, observing how the light interacts with the material, and updating the printing parameters based on his code. That's what we want from our Ph.D. students: We provide a vision, and they accomplish that and grow beyond as an independent researcher."

Meenakshisundaram and Scott discovered their final 3D-printed latex parts exhibited strong mechanical properties in a matrix known as a semi-interpenetrating polymer network, which hadn't been documented for elastomeric latexes in the prior literature.

"An interpenetrating polymer network is like catching fish in a net," Meenakshisundaram said. "The scaffold gives it a shape. Once you put that in the oven, the water will evaporate, and the tightly coiled polymer chains can relax, spread or flow, and interpenetrate into the net."

Molecules-to-manufacturing approach

The novel advances in both materials development and processing highlight the interdisciplinary environment fostered between the two groups.

Long and Williams both credited their counterpart's expertise for making the collective breakthrough possible.

"My philosophy is these types of innovations are only achievable when you partner with people who are very different from you," Long said.

The two professors said 3-D printed latex provides the conceptual framework for printing a range of unprecedented materials from rigid plastics to soft rubbers, which have been unprintable until now.

"When I was a graduate student working on this technology, we were excited to get unique performance from the shapes we could create, but the underlying assumption was we had to make do with very poor materials," Williams said. "What's been so exciting about this discovery with Tim's group is being able to push the boundary of what we assumed was the limit of a printed material's performance."

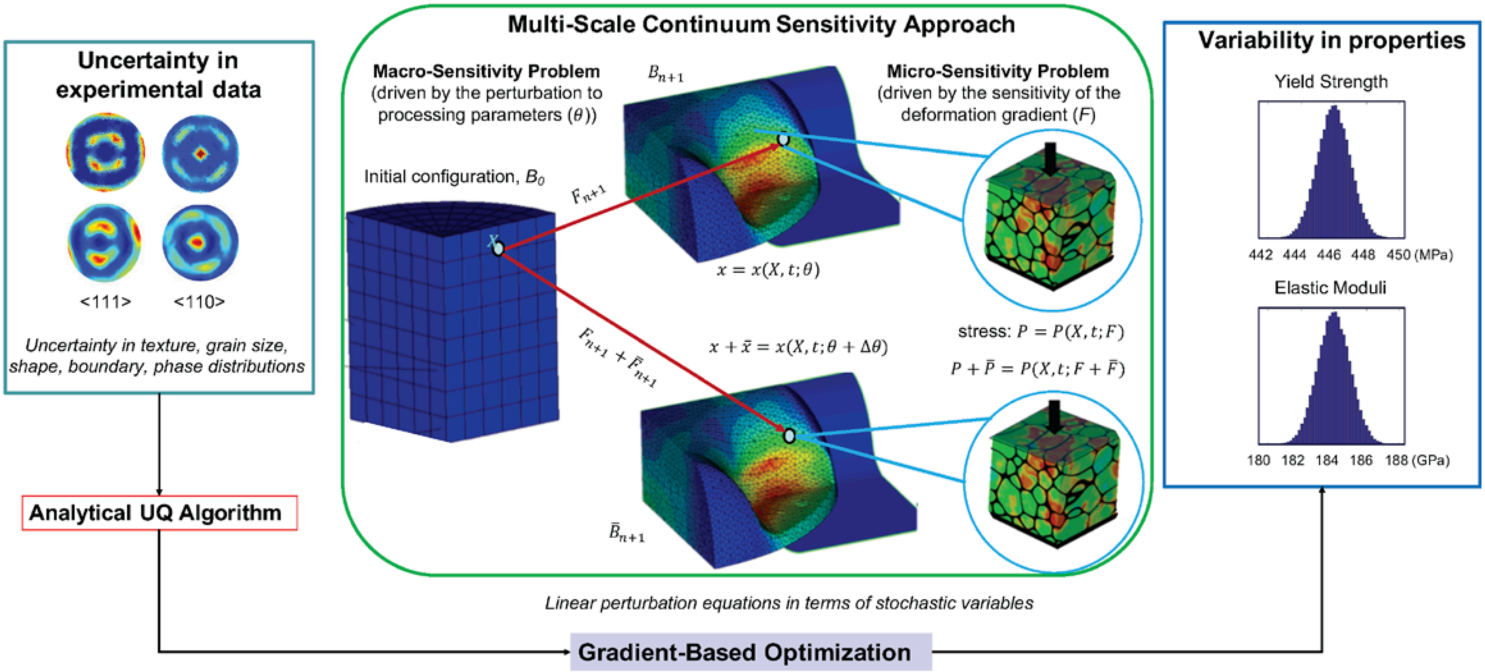
MODELING UNCERTAINTY

Pinar Acar
Assistant Professor

Dr. Acar's research team has been working on multi-scale modeling and design of materials under the effects of uncertainties. The ultimate goal is to tailor microstructural parameters, including orientational (i.e., crystallographic texture, sub-grain texturing) and morphological (i.e., grain size, grain boundaries, and grain shapes) aspects, to improve structural-scale material properties. The multi-scale problem is challenging as it involves billions of microstructural degrees of freedom. Besides computational complexity, this numerical framework also poses several problems on the basis of understanding the relationships between processing and microstructure, and between microstructure and properties.

Additionally, Dr. Acar's team has been working on the quantification of the uncertainties that arise due to the fluctuations in stress and thermal gradients during thermo-mechanical processing. These impact the microstructural features and, thus, the expected material performance by propagating in multiple length-scales. Accordingly, Dr. Acar's team has been developing theoretical and computational tools to address the multi-scale uncertainty quantification and design for different materials that are subtractively or additively manufactured.

Such quantification has been recognized as a critical research direction by NASA 2040 Vision, despite the limited progress in this field. The efforts of Dr. Acar's team in this area are prominent and well-recognized by the community. As an indication, Dr. Acar has been recently invited to write a state-of-the-art review article, "Recent progress of uncertainty quantification in small-scale materials science."



PROGRAMMING LEGGED ROBOTS

Dr. Akbari Hamed and his research team in Hybrid Dynamic Systems and Robot Locomotion Laboratory (HDSRL) are working to develop intelligent and distributed control algorithms for collaborative legged robots to co-operatively work with each other and people to achieve a variety of tasks in complex environments.

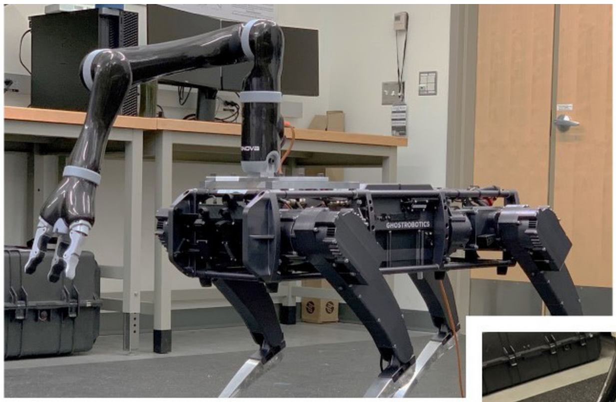
This problem is motivated by collective phenomena in biology. Social ants collaboratively work with each other to transport large payloads that can be hundreds or even thousands of times the weight of an individual ant. More than half of the Earth's landmass is unreachable to wheeled vehicles - this motivates the deployment of ubiquitous legged robots to enable the accessibility of these environments and thus bring robots into the real world.

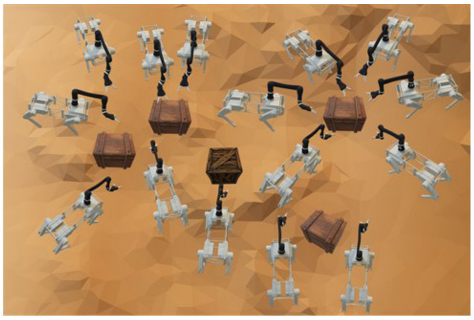
Although important theoretical and technological advances have allowed the development of distributed controllers for complex robot systems, existing approaches are tailored to the modeling and control of multiagent systems composed of collaborative robotic arms, multifingered robot hands, aerial vehicles, and ground vehicles, but not collaborative legged agents. Legged robots are inherently unstable, as opposed to most of the systems where these algorithms have been deployed.

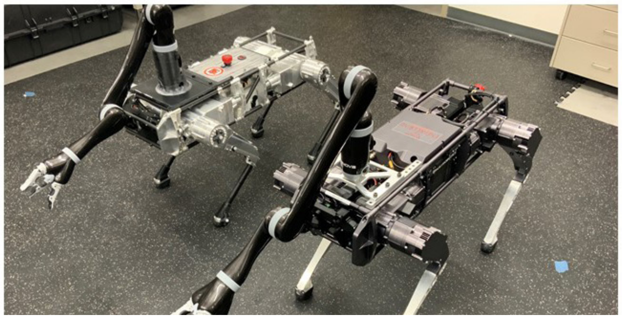
The team has developed a formal foundation to synthesize distributed controllers for teams of legged robots, based on convex optimization and advanced nonlinear control theory. The team is collaborating with Caltech and the project is supported by the National Science Foundation (NSF). Dr. Akbari Hamed has also delivered a TEDx talk on the deployment of the next generation of collaborative legged robots that will save our future cities.

Kaveh Akbari Hamed

Assistant Professor



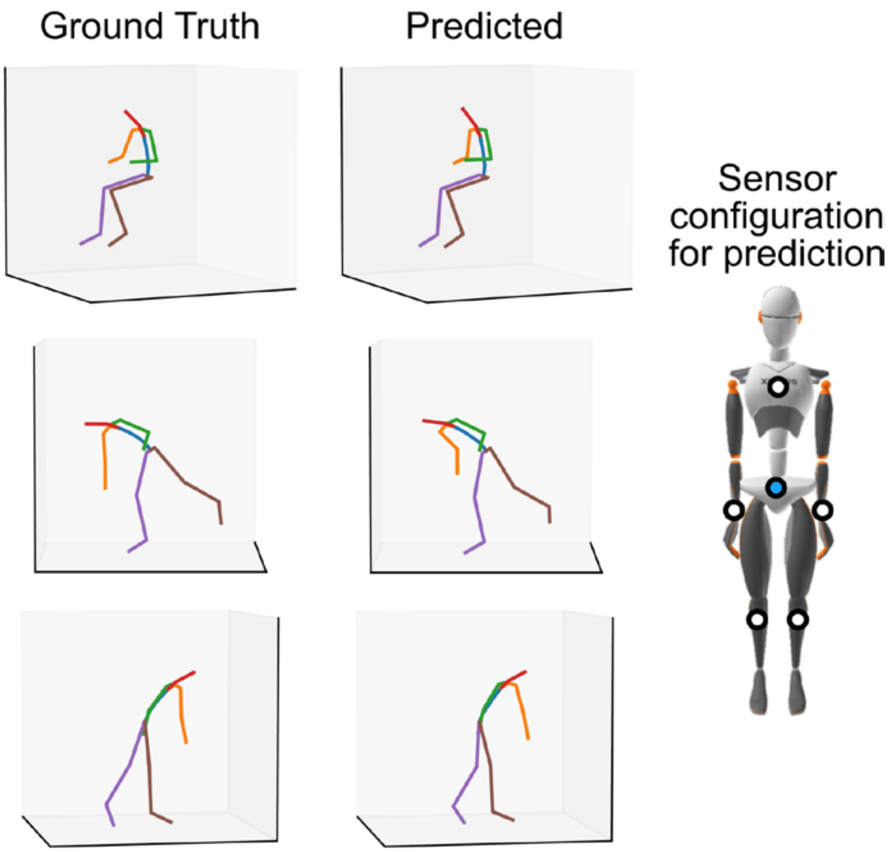




FULL-BODY KINEMATICS

Alan Asbeck
Assistant Professor

Dr. Asbeck and his lab have created and released a new dataset of natural motion, including kinematics of workers in a store and individuals doing unscripted activities of daily motion. This is the largest dataset of real human motion to date, and is the only one that captures how people move in everyday life. Using this dataset, Dr. Asbeck and graduate student Jack Geissinger have used machine learning algorithms to predict the full-body kinematics using only five or six inertial measurement units: one on the pelvis and/or chest, and one on each of the wrists and ankles. Even with this minimal sensor suite, the algorithms have surprisingly accurate results. Dr. Asbeck and his team are now using similar algorithms for monitoring progress during stroke rehabilitation.



The left panel shows several postures predicted by our algorithms ("Predicted") as compared to the true posture ("Ground Truth"). The right panel shows the locations of the sensors (white and blue circles) used to perform the motion inference.

PETER MEANS FOR VIRGINIA TECH

Student Liam Chapin fashions face shields as a part of Virginia Tech's COVID-19 response. More about this effort on page 60.

SAFE STORAGE OF SPENT NUCLEAR FUEL

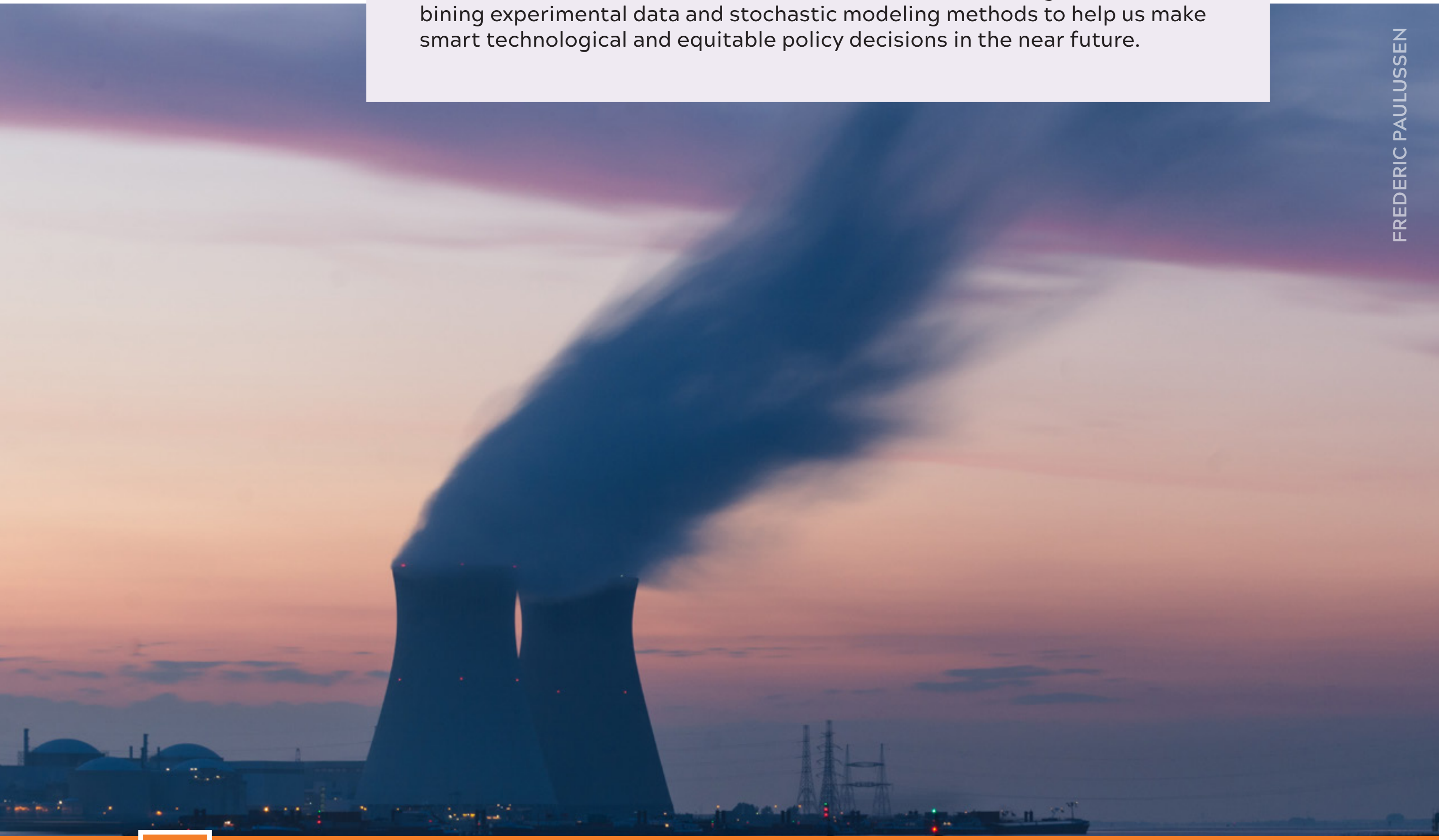
Juliana Duarte

Assistant Professor

Dr. Duarte is the lead principal investigator in a research grant funded by Virginia Tech Intelligent Infrastructure Human-Center Communities (IIHCC) Destination Area. The goal of this project is to study the challenges associated with the long-term use of dry cask systems used to store spent nuclear fuel. Dr. Rebecca Cai from the Materials Science and Engineering Department and Dr. Sonja Schmid from the Department of Science, Technology, and Science are also part of the team.

Nuclear power is considered a zero-emission energy source that is crucial to meet the global demand to reduce greenhouse gas emissions. One of the factors slowing down the utilization of nuclear energy is the uncertainties associated with the long-term storage of Spent Nuclear Fuel (SNF).

One of the main technical safety concerns of dry storage systems (DSC) is the stress corrosion caused by a harsh environment (high temperature, radiation, the proximity of seawater, etc.). Nuclear plants, and therefore DSCs, are often located close to the marine environment, which increases the concentration of salts in the atmosphere leading to aggressive chemistry that could result in this specific corrosion mechanism. We will investigate the chloride-induced stress corrosion cracking (CISCC) under conditions consistently encountered in storage sites using accelerated laboratory experiments to simulate marine environments. We will also investigate the effects of welding techniques, temperature, relative humidity, and dust deposition on CISCC in accelerated controlled experiments. Our future goals are combining experimental data and stochastic modeling methods to help us make smart technological and equitable policy decisions in the near future.



FREDERIC PAULUSSEN

THE AFRICAN DRONE AND DATA ACADEMY

Dr. Kevin Kochersberger has received initial funding of $948,000 from UNICEF to establish the African Drone and Data Academy (ADDA) in Lilongwe, Malawi; a one-of-a-kind drone technology program offering in-person and online accredited unmanned aircraft training for pan-African students. The ADDA graduated its first 10-week, in-person cohort of 25 students on March 18, 2020, covering topics in drone flight operations, airspace rules and regulations, and data/GIS analysis tools and techniques. Along with Dr. Kochersberger, three Virginia Tech students from the Unmanned Systems Lab traveled to Malawi to assist in flight training. Nine African nations were represented in the first class, including one student originally from the Democratic Republic of Congo who is now a refugee at the nearby UNHCR Dzaleka Camp.

Unique to this program is accreditation by the Association of Unmanned Vehicle Systems International (AUVSI), providing students with the Trusted Operator Program (TOP) Level 2 Certificate upon successful completion of a practical flight test. The curriculum also satisfies the requirements of the Malawi Remote Pilot License (RPL) for those wishing to work as drone pilots in Malawi.

“Drones for Good” is the programmatic theme encompassing UNICEF’s interest in unmanned aircraft, beginning with the opening of a test corridor in Malawi in 2017. Applications in public health such as vaccine delivery and disaster response and management are promoted by the ADDA, which also provides incubator space for promising new company start-ups.

A four-week online course is currently being offered, and three more cohorts will be taught this year with a plan to bring students to the ADDA in 2021 to complete their in-person flight training. Complementing the flight training are laboratory activities in aerodynamics, propulsion, radio communications, imaging and payloads, and electrical test and fabrication techniques.

UNICEF completed a Long Term Arrangement (LTA) with Virginia Tech on July 1 worth $4.1M to continue operation of the ADDA and its programs through June, 2023.

Kevin Kochersberger
Associate Professor

ONE LAB, MANY ROBOTS

Erik Komendera
Assistant Professor

Members of Field and Space Experimental Robotics (FASER) Lab have made progress in several areas as the lab prepares for advanced hardware trials on the Assemblers project, a collaboration with NASA Langley Research Center which seeks to develop methods for robots to autonomously assemble structures on the surface of the Moon.

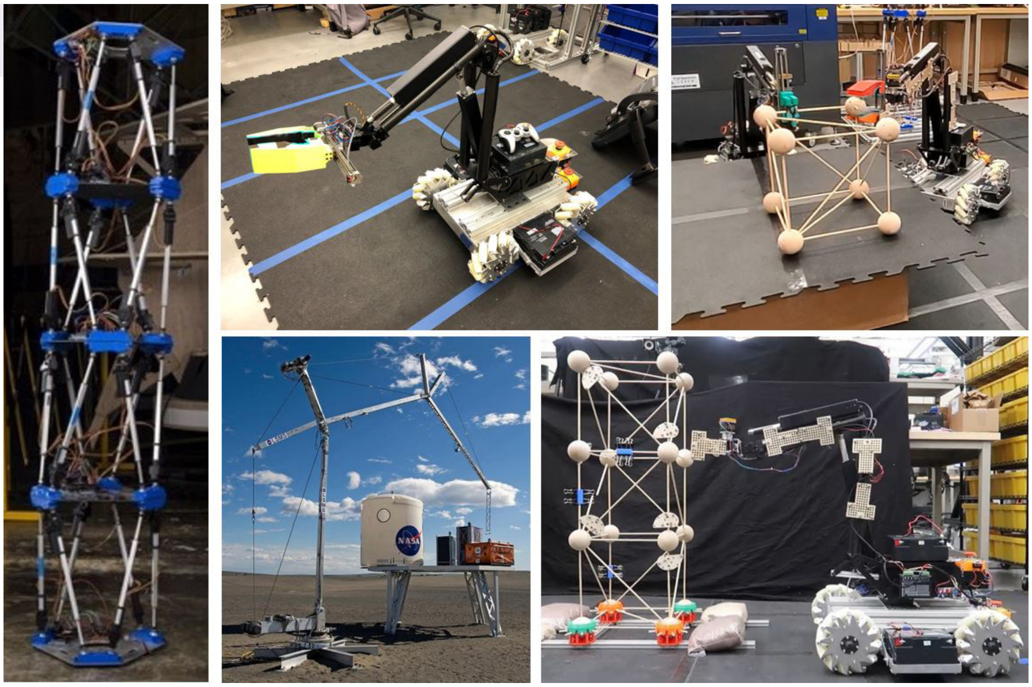
Graduate student Joshua Moser has begun developing and studying the applications of mixed integer programming and reinforcement learning for stochastic multi-robot parallel task allocation with the potential for restarts and failure recovery.

Graduate student Matthew Anderson has developed a method by which robots can use sensory input (upper right image) to assess the status and health of a structure being assembled which uses an ensemble of supervised learning methods to estimate types and locations of structural faults with high accuracy.

Undergraduate student William Chapin has developed and refined a methodology for rapidly determining optimal poses over a variety of metrics for the lab's truss-like Assembler robots (composed of serialized Stewart platforms), which has applications to other reconfigurable structures, and has also developed a simulation framework for sequence planning, motion planning, and kinematics and dynamics analysis.

Together, FASER Lab has worked on completing and upgrading several robots to perform trials for the Assemblers project and related projects, including the Assembler robot (left), the Mobile Autonomous Robotic Collaborator (MARC) mobile robots and their modular end-effector interfaces (clockwise upper left to lower right), and the 4.25 meter tall, 7.5 meter long Lightweight Surface Manipulation System (LSMS), in anticipation of performing collaborative robotic assembly trials during the 2020-2021 academic year.

FASER Lab robots

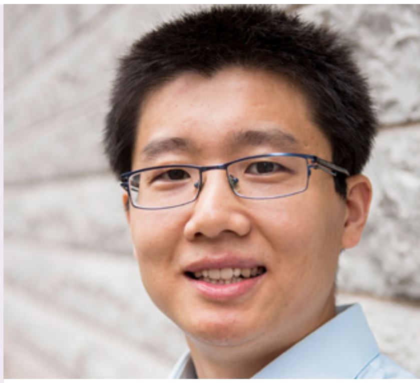


BIO-INSPIRED, LIGHTWEIGHT, STIFF, AND TOUGH STRUCTURES

Cuttlefish, like octopuses and squid, are cephalopods that have been trolling the oceans for about 500 million years, long before the first shark or fish ever evolved. Completely different from the soft swim bladders of fishes, cuttlefishes use a highly porous but stiff bioceramic cuttlebone for buoyancy regulation. It is fascinating how this porous internal skeleton, with more than 90% porosity, can withstand strong water pressure as high as 60 atm for some cuttlefish species.

Assistant Professor Ling Li and his team have employed synchrotron-based micro-computed tomography, *in-situ* mechanical tests, digital image correlation, and finite element analysis to elucidate the mechanics of cuttlebone. Their findings, recently published in PNAS, report that the chambered microstructure of the cuttlebone, which consists of vertical walls and horizontal septa, allows for lightweight, high stiffness, and damage tolerance simultaneously – the result of an optimal waviness gradient evolved by the vertical walls over time. Additionally, the wavy and corrugated walls regulate the damage to well-defined locations and enhance the energy absorption capability of cuttlebone impressively to values comparable to engineering metal foams.

The design principles found in cuttlebone can inspire the design of novel lightweight cellular ceramics, which may have a range of potential applications in packing, transportation, and infrastructure. The authors include ME graduate students Ting Yang, Hongshun Chen, Zhifei Deng, and Liuni Chen, undergraduate student Wenkun Liu, and post-doc Zian Jia. This work is supported by Air Force Office of Scientific Research through the Young Investigator Award.



Ling Li
Assistant Professor

PETER MEANS FOR VIRGINIA TECH

Ling Li inspects a cuttlefish bone.

Harvesting water, even from the lightest fog

written by Alex Parrish

What do you get when you cross a novel approach to water harvesting with a light fog? The answer: a lot more water than you expected.

The development of the fog harp, a Virginia Tech interdisciplinary pairing of engineering with biomimetic design, was first reported in 2018. The hope behind the fog harp's development was simple: in areas of the world where water is scarce but fog is present, pulling usable water from fog could become a sustainable option. While fog nets are already in use, the superior efficiency of the fog harp could dramatically increase the number of regions worldwide where fog harvesting is viable. The difference comes in the fog harp's uncanny ability to derive water from less dense fog than its predecessors.

The partnered approach has been a combination of new design with existing science. The science initiated with Assistant Professor Jonathan Boreyko from the Department of Mechanical Engineering within the College of Engineering. His group hypothesized the harp approach and characterized the performance of the harp prototypes. Design development has been led by Associate Professor Brook Kennedy from the Department of Industrial Design in the College of Architecture and Urban Studies. Kennedy's product development and materials knowledge brought the project to the point where it could be prototyped and tested in real-world environments. Early funding came from the Institute for Creativity, Arts, and Technology.

"Billions of people face water scarcity worldwide," Kennedy said. "We feel that the fog harp is a great example of a relatively simple, low-tech invention that leverages insight from nature to help communities meet their most basic needs."

The "harp" design uses parallel wires to collect ambient water from fog, whereas current technology in use around the globe relies primarily on a screen mesh. The lab-proven theory for the new device was that parallel wires are more efficient at gathering water, avoiding clogs and enhancing drainage into the collector. The researchers' small-scale early tests showed that in high-fog conditions, their harps outpaced mesh by a factor of two to one.

Boreyko and Kennedy

PETER MEANS FOR VIRGINIA TECH

Testing then literally moved to the field. In the open fields of Virginia Tech's Kentland Farm, then-undergraduate Brandon Hart built roofed structures to prevent rainfall from impacting findings. Under these coverings, fog harps were placed side-by-side with three different mesh harvesters: one with wire diameters equivalent to the harp, one with a wire size more optimal to harvesting, and one using Raschel mesh – a mesh made of flat-panel ribbons in v-shaped arrays between horizontal supports. This v-shaped mesh is currently the most popular among fog harvesting sites around the world.

Whereas heavy fog conditions were used in the lab, the actual fog conditions surrounding Virginia Tech are generally much lighter. As field tests began, Boreyko and Kennedy were skeptical that the available fog would provide the feedback they needed to do adequate testing. They were pleasantly surprised.

As fog began rolling over the hills of the New River Valley, the fog harps always showed results. In thin fog, the collection pipes of the mesh collectors were completely devoid of drips. Even as fog density increased, the harps continued outperforming their companions. Depending on the density of the fog, this ranged from twice as much output to almost 20 times.

Bringing together lab studies and field data, researchers determined that collection potential is the result of multiple factors. Greatest among these is the size of collectable water droplets between mesh and harp. To be harvested in both cases, water must be caught on the mesh or harp as air passes through, traveling downward into collection points by gravity. Fog harps use only vertical wires, creating an unimpeded path for mobile drops. Mesh collectors, by contrast, have both horizontal and vertical construction, and water droplets must be significantly larger to cross the horizontal pieces. In field tests, mesh collectors routinely require droplets reaching a size roughly 100 times larger than those on harps before descending. Water that never drops will simply evaporate and cannot be collected.

"We already knew that in heavy fog, we can get at least two times as much water," said Boreyko. "But realizing in our field tests that we can get up to 20 times more water on average in a moderate fog gives us hope we can dramatically enhance the breadth of regions where fog harvesting is a viable tool for getting decentralized, fresh water."

Full publication of the field tests have been accepted by Advanced Sustainable Systems, written by lead author Weiwei Shi.

PETER MEANS FOR VIRGINIA TECH

Close-up of fog harvesting.

FOLLOWING THE PHASES OF AVIATION FUEL

John Palmore, Jr.

Assistant Professor

The Palmore Research Group uses numerical analysis and high-performance computing to investigate engineering problems involving multiphase (droplet-in-gas or particle-in-gas) flows. The research has focused on investigating how multiphase flow physics affects the performance of aviation engines. Related to this mission, the group has been investigating the effect of fuel droplet dynamics inside of the engine. Although the fuel is injected into the engine as a liquid fuel, combustion occurs in the gas phase. Between these processes complex multiphase events occur including liquid break-up into small droplets and vaporization of the liquid fuel. While gas-phase combustion has a rich body of literature, the effect of these multiphase flow phenomena is less quantified. The Palmore Research Group has made progress on this front.

Our research has centered around improving the standard model of liquid fuel break-up and vaporization. Although real combustion occurs in a turbulent flow environment, the standard modeling approach considers droplets moving in a uniform flow. This year the group demonstrated that flow non-uniformities such as those present in real flows have a complex, non-linear impact on the process of droplet vaporization. Another issue with the standard is the neglect of the fluid motion inside of the droplet on processes like break-up. The group demonstrated how this internal circulation can significantly delay or increase the time of break-up for fuel droplets.

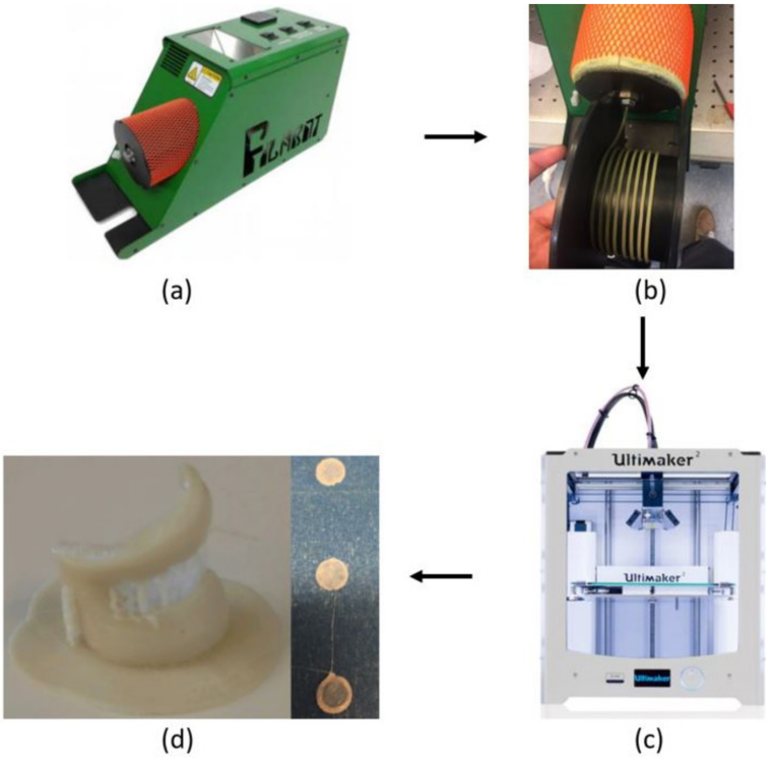
SEAN ALABASTER

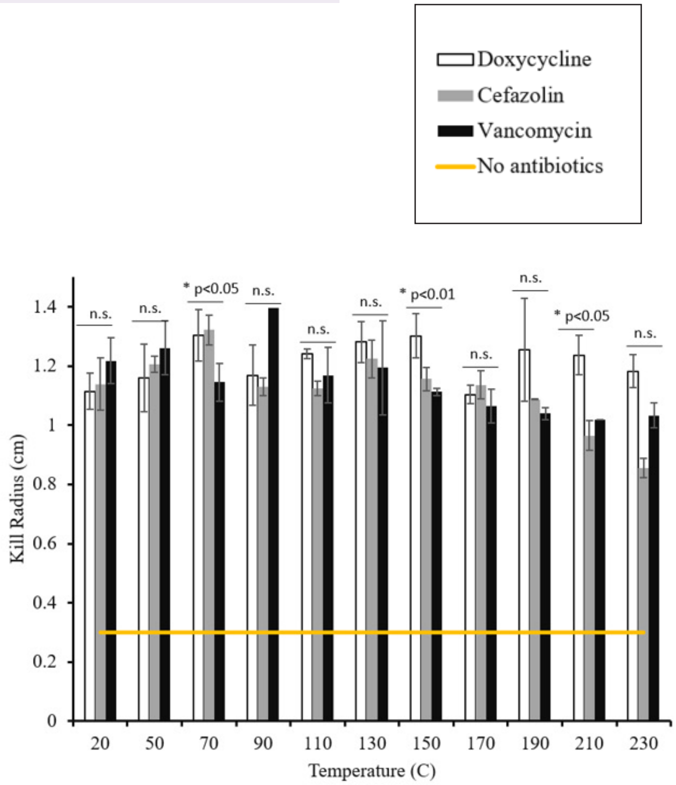
EFFECT OF TEMPERATURE AND ULTRAVIOLET LIGHT ON THE BACTERIAL KILL EFFECTIVENESS OF ANTIBIOTIC-INFUSED 3D PRINTED IMPLANTS

The cost associated with the treatment of Prosthetic Joint Infections (PJI) is over a billion dollars, in the United States alone. The current gold standard for treatment of infection after total knee arthroplasty is a 2-stage process whereby the implant is removed and a temporary spacer made of PMMA (bone cement) with antibiotics is inserted. The patient receives a 6-8 week course of intravenous antibiotics, and then returns to surgery for a re-implantation of a new joint replacement. Unfortunately, PMMA as a drug delivery material has limitations in terms of mechanical and drug-eluting properties. Furthermore, the polymerization reaction for PMMA is highly exothermic, thereby limiting the variety of antibiotics used for the treatment of infections. We have designed a family of 3D printed orthopaedic implants that not only overcome the limitations of PMMA, but can also be designed to be load bearing and customized to individual patient needs. Our implants are `smart' since they incorporate built-in design features such as micro-channels and reservoirs that enable them to act as antibiotic delivery vehicles. From the perspective of fundamental science, such implants must necessarily comply with the competing requirements stemming from both mechanics and biological perspectives. In particular, we examined the effect of print manufacturing conditions (high temperature and UV light exposure) on the kill effectiveness of eluted antibiotics in collaboration with Cooper University Health Care. Our results indicate that 3D print manufacturing conditions such as those encountered in FDM and SLA printing do not adversely impact the bacterial kill effectiveness of the printed implants.

Shivakumar Ranganathan

Associate Professor





TIRE PERFORMANCE IN SOIL

Corina Sandu

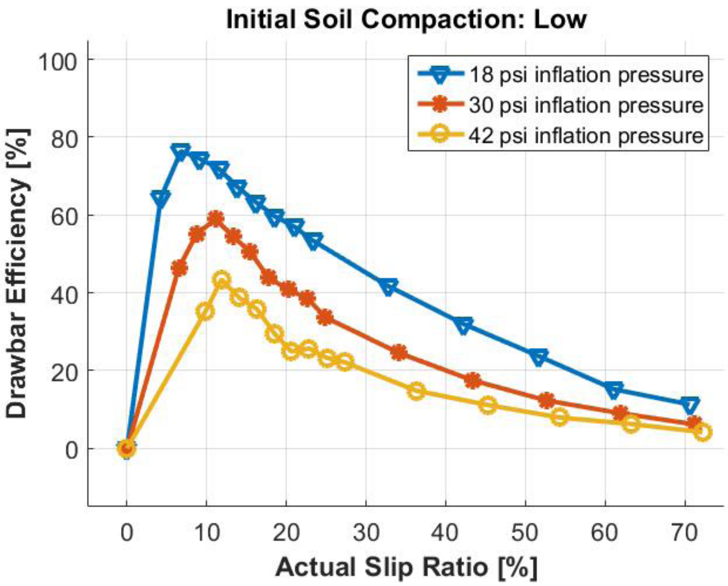
Robert E. Hord Jr. Professor & Associate Department Head for Graduate Studies

Dr. Corina Sandu and her recently graduated PhD student, Dr. Rui He, have been investigating the performance of tires on soil for the past four years. The work was funded by the Engineer Research and Development Center. Their study has enhanced the understanding of tire tractive performance on soil and advanced the development of terramechanics and tire model parameterization methods through experimental tests.

The tests (static tire deflection, static tire-soil, soil properties, and dynamic tire-soil) resulted in data that can be used in off-road traction dynamics and terramechanics modeling. The 225/60R16 97S Uniroyal Standard Reference Test Tire was used. The study included the quantification and/or measurement of soil properties of the test soil, pre-traffic soil condition, the pressure distribution in the tire contact patch, tire off-road tractive performance, and post-traffic soil compaction.

The influence of operational parameters (tire inflation pressure, normal load, slip ratio, initial soil compaction), or the number of passes on the measurement data of tire performance parameters or soil response parameters was analyzed. New methods of the rolling radius estimation for a tire on soft soil and of the 3-D rut reconstruction were developed. A multi-pass effect phenomenon, not discussed in available existing literature, was discovered.

The test data was fed into optimization programs for the parameterization of the original Bekker's pressure-sinkage model, a modified Bekker's model which accounts for the slip sinkage effect, the Magic Formula tire model (adapted to account for the combined influence of tire inflation pressure and initial soil compaction on the tire tractive performance and validated by the test data), and a bulk density estimation model.



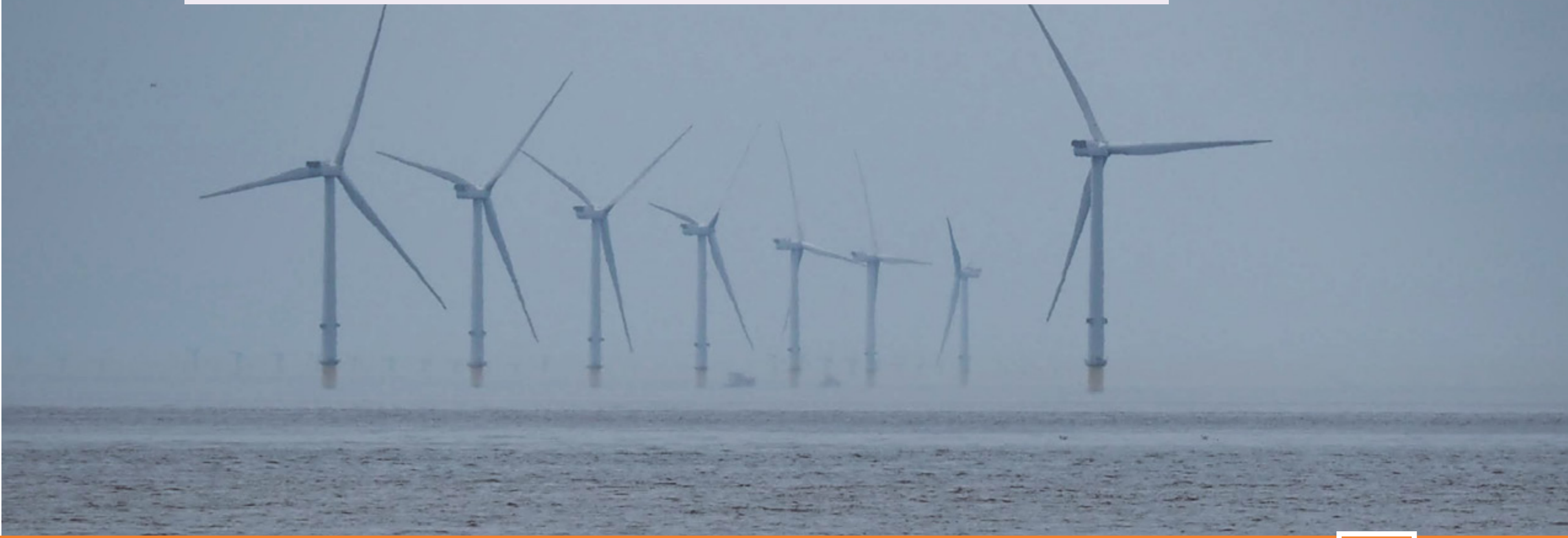
PIONEERING MARINE RENEWABLE ENERGY RESEARCH

More than 50% of U.S. population lives within 50 miles of the Nation's coasts, and cost-effective marine renewable energy technologies can not only supply renewable electricity to consumers but also empower the blue economy in coastal area. Dr. Lei Zuo, Robert E. Hord Jr. Professor of Mechanical Engineering and Director of the NSF I/UCRC Center for Energy Harvesting Materials and Systems (CEHMS), is a pioneer of marine renewable energy and has more than a decade experience with $7 M funding from the DOE, NSF, USAID, EPA, CIT, NYSERDA and the industry. He was recently awarded a Department of Energy (DOE) grant in the amount of $1.8M together with collaborators at Stevens Institute of Technology and Resolute Marine Energy, Inc, for 100KW floating oscillating surge wave energy converter (OSWEC) design. This is a second project after a previous $2M grant from DOE Water Power Technologies Office (WPTO) after WPTO was established in 2016, in which Dr. Zuo and his colleagues designed and developed 1-10KW highly-efficient power takeoff (PTO) systems and tested in wave tank and on the NREL dynamometer. In the past year, he was also awarded two NSF projects to develop ocean wave powered resilient food-energy-water (FEW) nexus systems and bio-inspired self-powered fish telemetry, one DOE STTR project to develop sustainable marine aquaculture system, one project from the National Offshore Wind R&D Consortium to develop a technology to stabilizing the offshore wind platform by ocean wave energy harvesting, one project from the Sandia National Lab to develop active-controllable mechanical motion rectifier, and one project from the European Union's MaRINET2 program to test wave-current hybrid energy converters in France. Recently he was also jointly appointed as a Chief Research Scientist at Pacific Northwestern National Lab.

In the past year, he guided student teams who won several national competitions, including American Made Challenges Waves to Water Prize, Ocean Observing Prize, Marine Energy Collegiate Competition launched by the DOE, and P3 National Students Design Competition launched by the EPA. He was the Invited Panel Moderator for Marine Energy Forum at the 2019 Global Sustainable Technology and Innovation Conference (2019 in Brussel, Belgium), an Invited Keynote Speaker at the 4th Asian Wave and Tidal Energy Conference (2018 in Taipei, Taiwan).

Lei Zuo

Robert E. Hord, Jr. Professor & John R. Jones III Faculty Fellow



JACK HUNTER

FACULTY

Mechanical Engineering is a broad field, representing one of the original areas of study at Virginia Tech since its opening in 1872. Today, the department puts its focus in five areas. Faculty have one primary and at least one secondary area of study within these areas. This interdisciplinary approach creates many unique intersections.

Thrust areas:

> Bio, Micro and Nano Systems
> Design, Materials and Manufacturing
> Energy Engineering and Science
> Nuclear Engineering and Science
> Robotics, Autonomous and Dynamical Systems

Pinar Acar
Assistant Professor
DMM

Mehdi Ahmadian
J. Bernard Jones Professor
DMM

Kaveh Akbari Hamed
Assistant Professor
RADS

Alan Asbeck
Assistant Professor
RADS

Oumar Barry
Assistant Professor
RADS

Michael Bartlett
Assistant Professor
DMM

Bahareh Behkam
Associate Professor
BMNS

Pinhas Ben-Tzvi
Professor
RADS

BMNS Bio, Micro and Nano Systems

DMM Design, Materials and Manufacturing

EES Energy Engineering and Science

NES Nuclear Engineering and Science

RADS Robotics, Autonomous and Dynamical Systems

Jan Helge Bøhn

Associate Professor

DMM

Jonathan Boreyko

Associate Professor

BMNS

Ricardo Burdisso

Professor & Associate Dept. Head for Strategic Initiatives

RADS

Jiangtao Cheng

Associate Professor

EES

Lance Collins

Innovation Campus Vice President and Executive Director, Professor

EES

Clinton Dancey

Associate Professor & Associate Dept. Head for Undergraduate Programs

EES

Thomas Diller

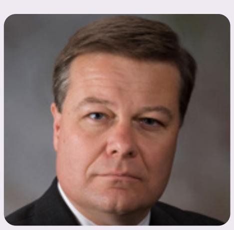
Professor

EES

Juliana Duarte

Assistant Professor, Nuclear Engineering Program

NES



Michael Ellis

Associate Professor

EES

Azim Eskandarian

Department Head & Nicholas and Rebecca Des Champs Chair

RADS

John Ferris

Associate Professor

RADS

Chris Fuller

Samuel Langley Distinguished Professor of Engineering

RADS

Alireza Haghighat

Professor,
Director of Nuclear Engineering Program

NES

Warren Hardy

Associate Professor

BMNS

Celine Hin

Associate Professor,
Nuclear Engineering Program

NES

Scott Huxtable

Associate Professor

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Sohan Kale

Assistant Professor

BMNS

Mary E. Kasarda

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RADS

Kevin Kochersberger

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Erik Komendera

Assistant Professor

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Andrew Kurdila

W. Martin Johnson Professor

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Brian Lattimer

Professor

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Professor
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Jack Lesko
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Professor

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Corina Sandu
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Shima Shahab
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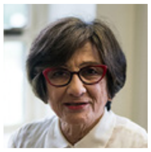
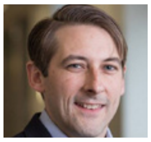
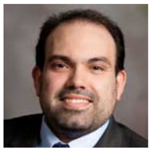
	Stefan Duma	Harry C. Wyatt Professor and Executive Director Institute for Critical Technology and Applied Science, Virginia Tech
	Diana Farkas	Professor Department of Materials Science and Engineering, Virginia Tech
	Clay Gabler	Professor and Biomedical Engineering Graduate Chair Department of Biomedical Engineering and Mechanics, Virginia Tech
	Jake Grohs	Associate Professor Department of Engineering Education, Virginia Tech
	Serkan Gugercin	Class of 1950 Professor Department of Mathematics, Virginia Tech
	Patrick Huber	Professor Department of Physics, Virginia Tech
	Andrea L'Afflitto	Assistant Professor Department of Industrial and Systems Engineering, Virginia Tech
	Jonathan Link	Professor Department of Physics, Virginia Tech
	Todd Lowe	Associate Professor Kevin T. Crofton Department of Aerospace & Ocean Engineering, Virginia Tech
	Camillo Mariani	Associate Professor Department of Physics, Virginia Tech

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	Patrick Roberts	Associate Professor School of Public and International Affairs, Virginia Tech
	John Robertson	Professor Department of Biomedical Engineering and Mechanics, Virginia Tech
	Shane Ross	Professor and EM Graduate Chair Kevin T. Crofton Department of Aerospace & Ocean Engineering, Virginia Tech
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Melissa Williams
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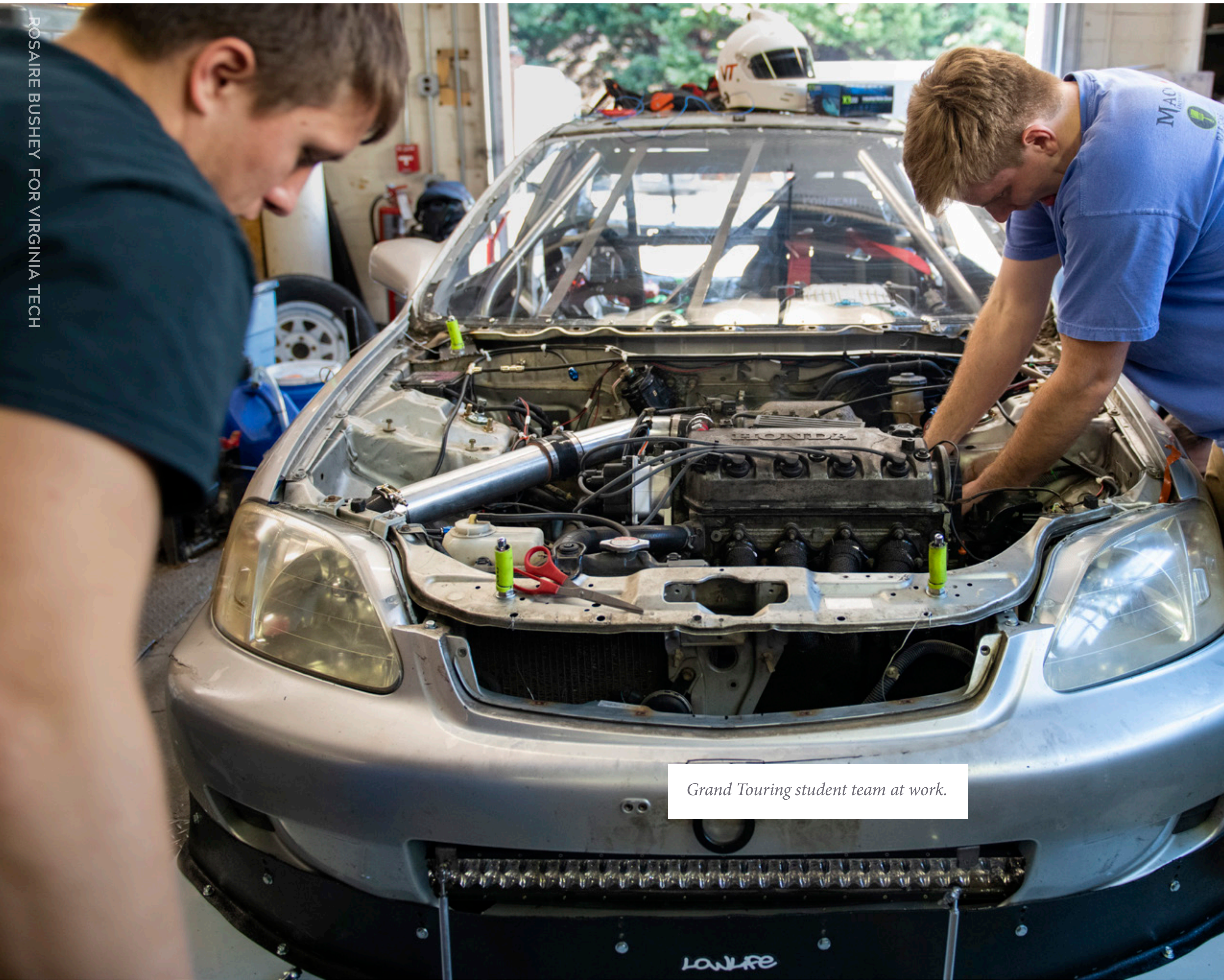

ROSAIRE BUSHEY FOR VIRGINIA TECH

Grand Touring student team at work.

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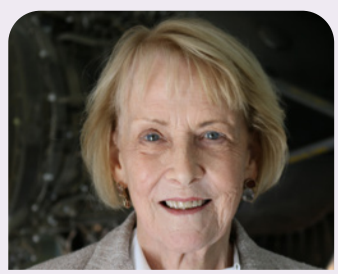

Mary "Prim" Jones

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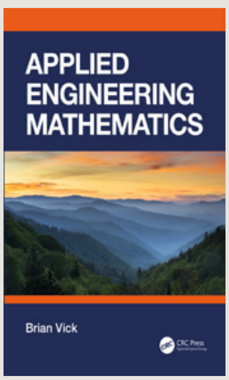
Keith Van Houten

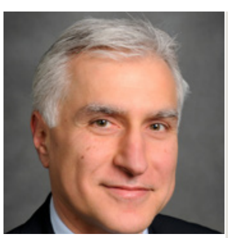
Manager, Active Safety &
Automated Driving Performance
Simulation Group,
General Motors' Center for
Autonomous Vehicle Development

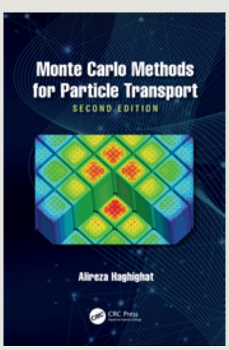
SUPERLATIVES & AWARDS

We celebrate with fellow team members who have been recognized for significant accomplishments this year.



Associate Professor **Brian Vick** published *Applied Engineering Mathematics* through CRC Press. According to the CRC website, "Undergraduate engineering students need good mathematics skills. This textbook supports this need by placing a strong emphasis on visualization and the methods and tools needed across the whole of engineering."





Professor **Alireza Haghighat** published the second edition of *Monte Carlo Methods for Particle Transport* through CRC Press. According to the CRC website, the new edition is "fully up-dated with the latest developments in the eigenvalue Monte Carlo calculations and automatic variance reduction techniques and containing an entirely new chapter on fission matrix and alternative hybrid techniques."

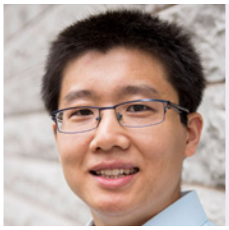
The Institute for Critical Technology awarded Junior Faculty Awards to Assistant Professors **Ling Li** and **Shima Shahab**. These grants fund partnerships between a junior faculty member and a more senior colleague to pursue new approaches to pressing research problems.

Virginia Tech College of Engineering Dean's Awards

Alan Asbeck	Faculty Fellow
Jonathan Boreyko	Faculty Fellow
Mark Paul	Certificate of Teaching Excellence
Zheng Li	Outstanding New Assistant Professor
Mark Pierson	Excellence in Teaching
Corina Sandu	Excellence in Service

Professor **Brian Lattimer** received the Sjölin Award for lifetime contributions to the science of fire engineering in December 2019.

Professor **Rolf Mueller** was elected a Fellow of the Acoustical Society of America in December 2019.

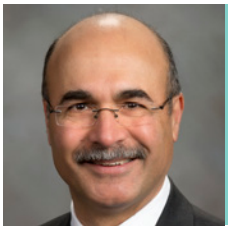


Assistant Professor **Ling Li** received the 3M Non-Tenured Faculty award.

Associate Professor **Jiangtao Cheng** gave the keynote talk in 2020 ASME Fluids Engineering Division's Summer Meeting.

Alumni Distinguished Professor and Christopher K. Kraft Professor **Wing Ng** was honored by the State Council of Higher Education for Virginia with a 2020 Outstanding Faculty Award.

Associate Professor of Practice **Robin Ott** and ME undergraduate student Andrew Bolkhovitinov were awarded a patent for a folding wheelchair lift device operable by a wheelchair user without the user exiting their wheelchair.



Medhi Ahmadian was named J. Bernard Jones Professor.

Corina Sandu was named Robert E. Hord, Jr. Professor.

Chris Williams was named L.S. Randolph Professor.

Lei Zou was named Robert E. Hord, Jr. Professor.

Department Awards: Students

Thomas Gilmore	David R. Shorb Memorial Honor Award
Charlie Lertlumprasert	Mechanical Engineering Outstanding Scholar
Jeffrey Nolte	David R. Shorb Memorial Honor Award
Lindsay Pierle	Carroll F. Hartlove Service Award

Staff Awards

Sarah Deisher	Jenny Frank Award, College Association of Staff in Engineering
Johnny Underwood	Technical Award, College Association of Staff in Engineering

CAREER AWARDS

Oumar Barry, an assistant professor of mechanical engineering in the College of Engineering, is using a National Science Foundation Faculty Early Career Development (CAREER) award to support fundamental research for a self-powered autonomous robot to prevent electric power line defects.

“The U.S. power grid is more than 50 years old and there’s more than 150,000 miles of it – a lot of it in fairly remote areas,” said Barry. “The overhead power lines are exposed to harsh environments and wind-induced vibrations that limit their lifespan.”

Barry’s project proposes a multifunctional self-powered autonomous robot (SPAR) for intelligent vibration control and monitoring of power lines. But before a robot can be built, there are forces that need to be fully understood.

“We need a fundamental understanding of nonlinear dynamic interactions between wind forces, vibrating cables, and a mobile robot, and this hasn’t been explored yet,” Barry said. “The research goal is to create the tools that will enable construction of a SPAR.”

Normally, power lines are fitted with passive vibration absorbers. These are often ineffective because of their narrow frequency bandwidth, and they contribute to fatigue damage in cable strands, which can eventually result in line failure.

“Inspections of lines are usually done by people on foot patrols or via helicopter-assisted inspection,” Barry said. “Both techniques are expensive and dangerous for maintenance personnel. Current inspection robots are starting to be seen but they are bulky, heavy, have a short run time, are energy inefficient, and expensive.”

Barry believes that the research necessary to build a SPAR will provide fundamental breakthroughs at the interface of energy harvesting, fluid-structure interactions, and vibration control. The project will be broken into four tasks:

Construction of a multiphysics model to study wind-cable-robot interactions.

Creation of an effective and adaptive electromagnetic energy harvester to power the SPAR.

Development of a wind-induced vibrations control framework to optimize vibration suppression.

Establishment of a testbed to experimentally investigate the performance of the SPAR.

The term of the award is five years and will be funded at a total of $500,000.

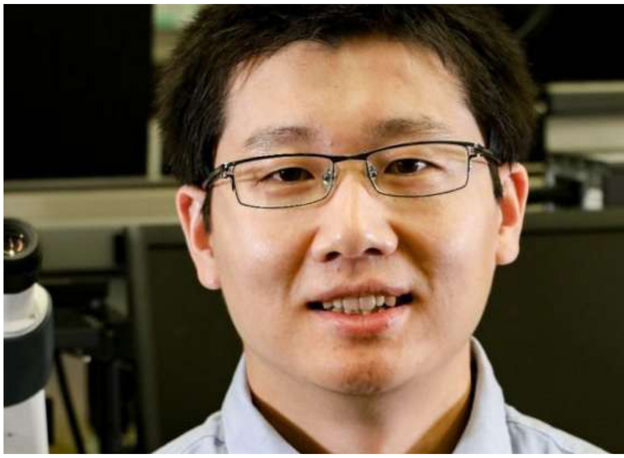
Ling Li, an assistant professor of mechanical engineering in the College of Engineering, has received a National Science Foundation Faculty Early Career Development CAREER award to support research to study the structural designs and formation mechanisms of biomineralized architected materials.

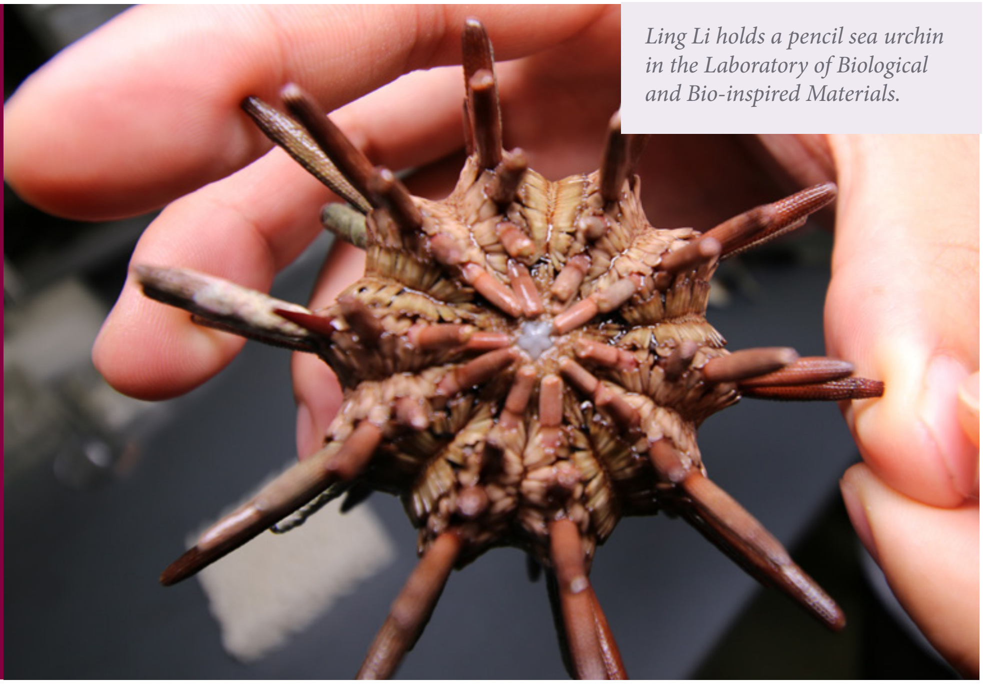
The $520,000 five-year award will support Li's research of the design and formation of biomineralized starfish skeletons.

"The internal microscopic structures of many biomineral-based structures found in organisms have extremely intricate 3D organizations," Li said. "They show remarkable mechanical strength, durability, and efficiency, despite the fact that they are made of intrinsically brittle minerals and are often highly porous."

Li's research group focuses on the understanding the mechanical and multifunctional design of a variety of biological materials, such as low-density biological porous structures and tough biocomposites. His research also aims to develop new materials by utilizing the design strategies learned from biological material systems. For example, his group recently developed a chiton mollusk-inspired armor that provides simultaneous mechanical protection and flexibility.

"Currently, we have limited knowledge in explaining how biominerals' complex 3D microstructures are controlled and how they are related to their mechanical properties. By using the biomineralized skeleton in a starfish as a model system, we aim to quantitatively characterize its 3D network-like microstructure, the underlying formation mechanisms as well as its mechanical significance," he said.





Ling Li holds a pencil sea urchin in the Laboratory of Biological and Bio-inspired Materials.

Starfish skeletons contain hundreds of millimeter-sized mineralized elements known as ossicles, which are embedded within the soft body of the starfish. This skeletal design allows the starfish to be flexible in motion and stiff when required.

"Ossicles are characterized by their lattice-like porous microstructure, which is based on a single-crystalline calcite, which makes them lightweight, strong, and damage tolerant," Li said. "The new knowledge gained from this study will provide us better understanding of the 3D structural evolution processes for echinoderms, or possibly even other invertebrate and vertebrate biomineralized tissues."

Li said the work will provide lessons on the design and fabrication of synthetic low-density materials.

In addition to the CAREER Award, Li received the 2018 Air Force Office of Research Young Faculty Award, the 2019 MIT Technology Review TR35 China Award, and the 2019 College of Engineering Dean's Award for Outstanding New Assistant Professor.

FIGHTING

COVID-19

TOGETHER

RAPIDLY PRODUCED FACE SHIELDS

COURTESY ALEXANDER LEONESSA

Within the first month of the COVID-19 outbreak, a team led by mechanical engineering professor Alex Leonessa and undergraduate student Liam Chapin organized the mass production of face shields after rapidly prototyping and running 15 designs by staff from Carilion Clinic and LewisGale Hospital. In this photo, a group of Carilion health care workers wear the face shields produced by the team.

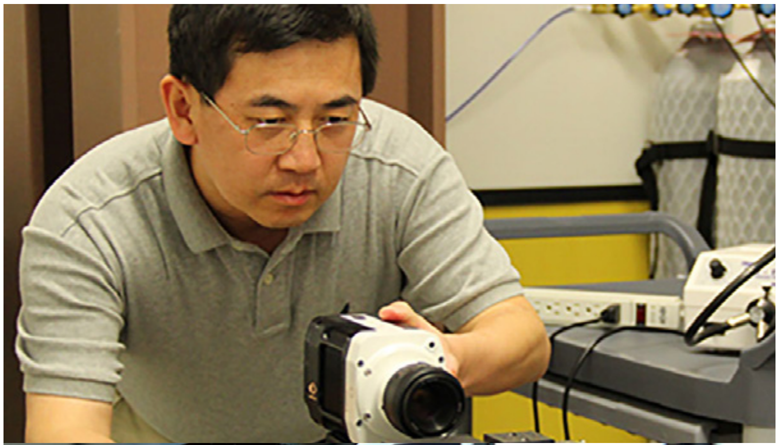
Read more about the project:
https://bit.ly/3hVGAcn

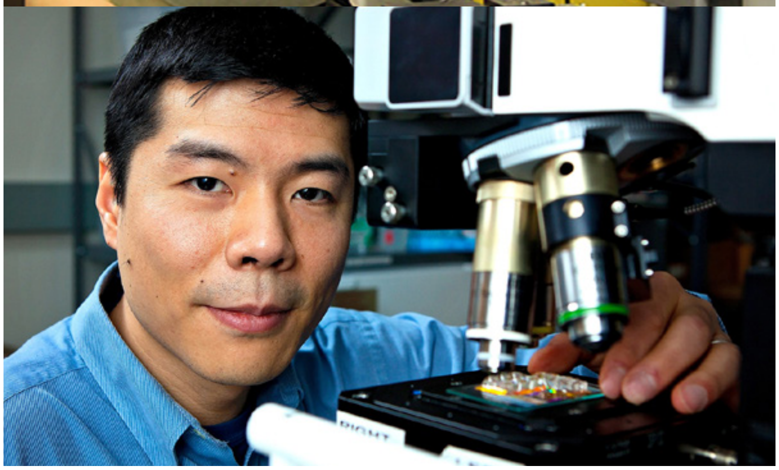
FINDING COVID-19 FASTER

Mechanical engineering associate professor Jiangtao Cheng and electrical and computer engineering assistant professor Wei Zhou have developed an ultrasensitive biosensing method that could dramatically shorten the amount of time required to verify the presence of the COVID-19 virus in a sample.

The method uses a combination of engineered surfaces and lasers to quickly identify the contents of a sample. This method takes place in a fraction of the time of current common methods.

Read more about the project:
https://bit.ly/31P4UHo





COURTESY AREF VANDADI

LEE FRIESLAND FOR VIRGINIA TECH

VENTILATORS FROM BIPAPS

To meet the need for ventilators, several labs combined their capabilities to create the possibility of converting machines normally made to help those with sleep apnea into ventilators. The labs of Christopher Williams, Joseph Meadows, and Alfred Wicks worked with the Virginia Tech Carilion School of Medicine to create unique pieces that made it possible to repurpose bilevel positive airway pressure (BiPAP) machines into ventilators in the event of a shortage.

At left, students Ashwin Kumar and Austin Guevara work together to work on the component that monitors air flow.

Read more about the project: https://bit.ly/34WDnFO

COURTESY ROD LA FOY

AN EFFECTIVE, REUSABLE MASK

Mechanical engineering Ph.D. student Rod La Foy wears a novel respirator and holds up a circular set of 3D-printed molds used to shape new respirator shells. Led by Chris Williams, head of the Design, Research, and Education for Additive Manufacturing Systems Laboratory, a team of Virginia Tech mechanical engineering graduate students has created a reusable respirator using rapid tooling and 3D printing resources from on-campus maker spaces and research labs.

In efficacy tests run by Blacksburg company NanoSafe, the design has performed as well as or better than an N95. As the team adjusts the final design, they're making sure that their tools and fabrication methods can be scaled up for rapid production.

Read more about the project: https://bit.ly/31PCz3t

THE VALUE OF DIVERSITY

To solve the world's most pressing problems, it is critical to engage multiple points of view. Engineering is a field where this is particularly critical, as the principles that drive engineering are often complex. Innovations in technology are often the product of a multidisciplinary group working together.

The Department of Mechanical Engineering recognizes the struggles that several people groups have historically experienced when trying to enter this field, particularly women and people of color. To better equip our community to face the challenges of the future, we are working to better hear the voices of those from underrepresented groups who are already part of our department.

To place this new focus in the forefront, we have taken a fresh approach to the department's diversity committee. The membership has been expanded to include students, and we are also making a concerted effort to hear from all corners of our group. The team has been renamed the Inclusivity, Diversity and Equity for All (IDEA) Committee. We are also actively seeking input from faculty, staff, and students to assist us in guiding this initiative.

While we recognize the challenges behind us, we remain diligent to making changes where they are needed. We anticipate a brighter future that we all build together.

DEPARTMENT OF MECHANICAL ENGINEERING **IDEA COMMITTEE**

Corina Sandu
Faculty; Chair

Oumar Barry
Faculty

Jiangtao Cheng
Faculty

Clint Dancey
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Faculty

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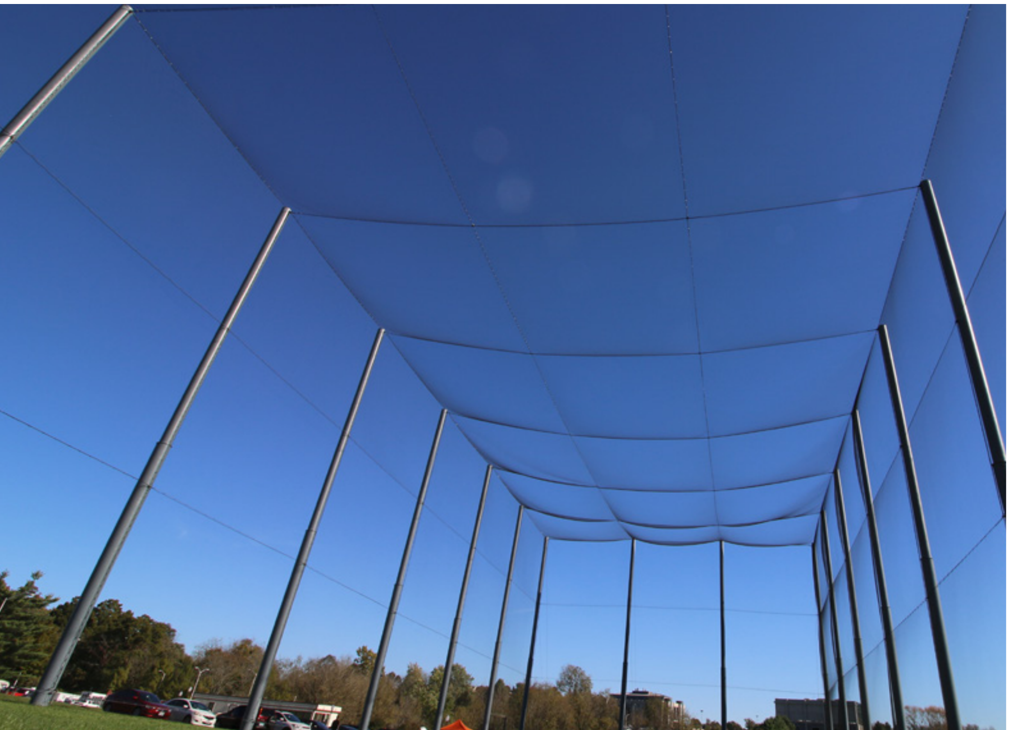

PETER MEANS FOR VIRGINIA TECH