Human Needs, Novel Solutions.

2019 ANNUAL REPORT

Rensselaer Department of Mechanical,
Aerospace, and Nuclear Engineering

Rensselaer

Human Needs,
Novel Solutions.

2019
ANNUAL REPORT

INSIDE

FACTS & FIGURES
DEPARTMENT OF MECHANICAL, AEROSPACE, AND NUCLEAR ENGINEERING

STUDENTS

1,491
UNDERGRADUATES

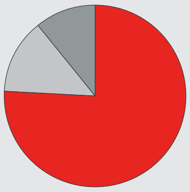
210
GRADUATES

100%
OF CURRENT FULL-TIME DOCTORAL STUDENTS RECEIVED FINANCIAL ASSISTANCE

DEGREES OFFERED

Aeronautical Engineering (B.S., M.Eng., M.S., Ph.D.)
Engineering Physics (M.S., Ph.D.)
Mechanical Engineering (B.S., M.Eng., M.S., Ph.D.)
Nuclear Engineering (B.S., M.Eng., MS)
Nuclear Engineering & Science (Ph.D.)

DEGREES AWARDED (AY) 2019



286 BACHELORS
38 MASTERS
22 PH.D.s

RESEARCH EXPENDITURES
(IN MILLIONS)

14.9
TOTAL DEPARTMENT EXPENDITURES

3.1
AERONAUTICAL/AEROSPACE ENGINEERING

6.5
MECHANICAL ENGINEERING

5.4
NUCLEAR ENGINEERING

RESEARCH

7
AFFILIATED RESEARCH CENTERS

- Center for Automation Technologies and Systems
  cats.rpi.edu
- Center for Flow Physics and Control
  www.scer.rpi.edu/cefpac
- Center for Modeling, Simulation and Imaging in Medicine
  www.scer.rpi.edu/cemsim
- Center for Engineering-based Patient Modeling
  cepm.rpi.edu
- Scientific Computation Research Center
  scorec.rpi.edu
- Gaerttner Linear Accelerator Center
  http://hahn.ne.rpi.edu
- Center for Mobility with Vertical Lift
  http://move.rpi.edu

RESEARCH AREAS

AEROSPACE SCIENCE AND ENGINEERING

- Fluid Dynamics/ Aerodynamics
- Advanced Structures/ Materials
- Optimization
- Space
- Combustion/Propulsion

NUCLEAR SCIENCE AND ENGINEERING

- Nuclear Power Systems
- Applied Radiation Technologies
- Radiation Protection, Medical and Industrial Uses of Radiation
- Nuclear Materials

MECHANICAL SCIENCE AND ENGINEERING

- Mechanics and Materials
- Thermal and Fluids Engineering
- Design and Manufacturing
- Dynamics and Controls

CROSS-CUTTING RESEARCH AREAS

- Energy Science and Engineering
- Materials, Materials Processing and Controls
- Human Health and Safety

MESSAGE FROM **THE DEPARTMENT HEAD**

> "The intellectual breadth of our department, embracing the disciplines of Mechanical, Aerospace and Nuclear Engineering, provides us unique opportunities to improve the human condition through research and education."

Dear Friends,

Greetings from the Department of Mechanical, Aerospace and Nuclear Engineering (MANE) at Rensselaer Polytechnic Institute. It is my pleasure to present to you the 2019 MANE Annual Report.

In this report, we celebrate members of our exceptional community of scholars. This year, we welcomed Fudong Han as the inaugural Priti and Mukesh Chatter '82 Career Development Chair in MANE. Emily Liu was promoted to the rank of Full Professor, Tom Haley to the rank of Professor of Practice and Josh Hurst and Chia Leong to the rank of Senior Lecturer. Professor Catalin Picu was honored with a **Doctor Honoris Causa** from the Polytechnic University of Bucharest. Professor Michael Amitay was elected **Fellow** of the American Institute of Aeronautics and Astronautics. Professor Nikhil Koratkar received the **Distinguished Alumni Award** from the Indian Institute of Technology (IIT) – Bombay. Professor Wei Ji received the **Graduate Faculty Teaching Award** from the Northeastern Association of Graduate Schools. Professor Kristen Mills won the twin accolades of the **CAREER award** from the National Science Foundation and the **New Investigator Award** from the Department of Defense. Professor Sandipan Mishra won the 2019 **Outstanding Young Investigator Award** from the American Society of Mechanical Engineers' Dynamic Systems and Control Division and the **James M Tien '86 Early Career Award for Faculty** from Rensselaer. Professor Henry Scarton won the **Jerome Fishbach '38 Faculty Travel Award**. MANE student Ariel Walters received the prestigious **SMART scholarship** from the Department of Defense. Four students won the Vertical Lift Society **Foundation Scholarships**, and the Rensselaer team won third place in the society's **student design competition** in the graduate category.

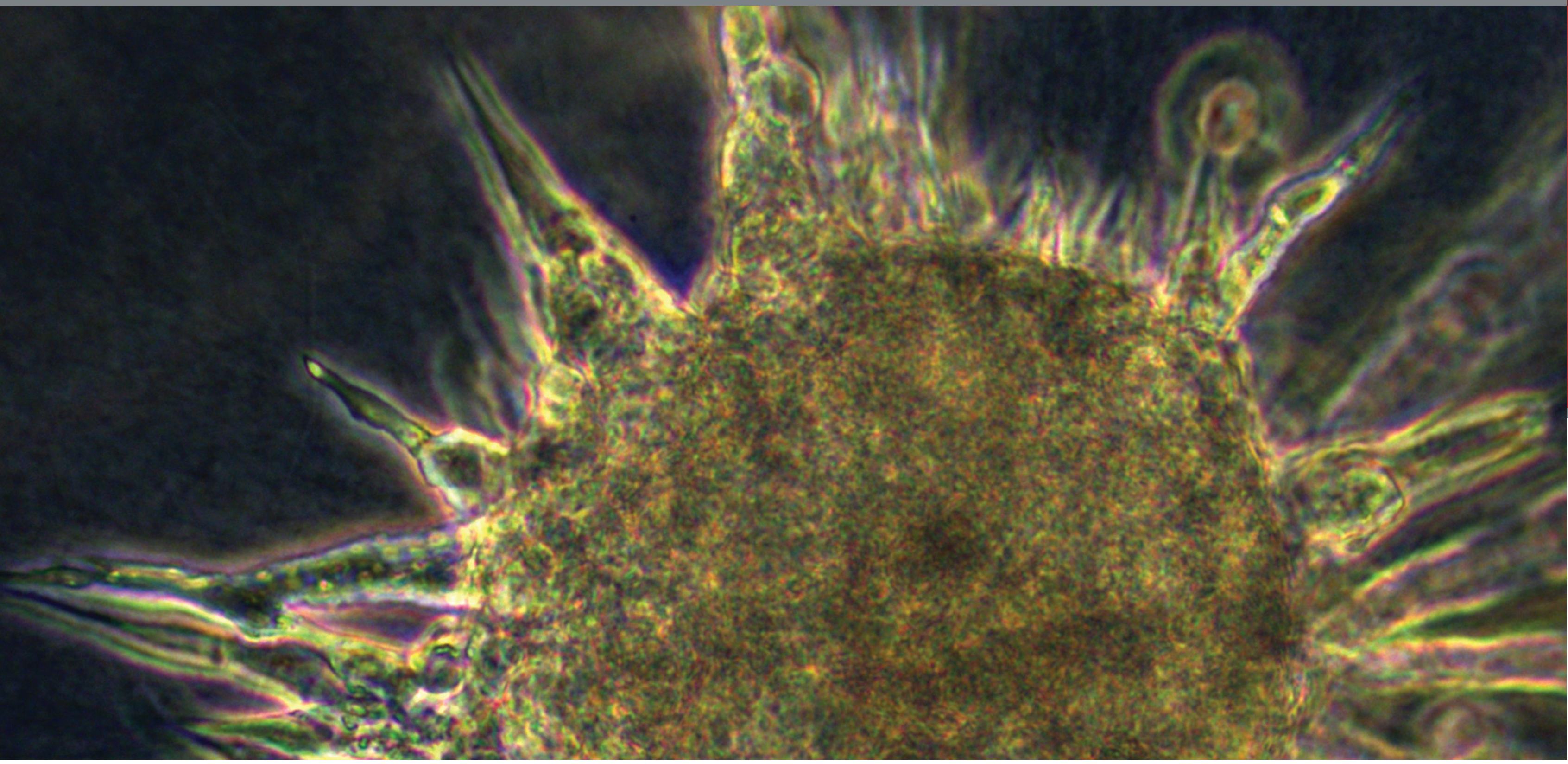
As we reflect on our achievements as a community of engineers, we realize that we are bound together by a common sense of purpose – to enrich human lives. We work together to find solutions to the most pressing needs of food, housing, clean water, clean air, health, and energy. With advancing civilization, we ascend Maslow's hierarchy of needs, addressing safety, security, and emotional needs and finally, the needs of self-actualization that enables us to live long, fulfilling high-quality lives. Humanism, the focus on humans and the flourishing of humans, is the theme of this year's annual report.

Humanism, as a concept, is very powerful in how society thinks and chooses to act. As a tenet of ethics and political philosophy, humanism can be traced back to the ancient Greeks - Aristotle, among others. As concerns regarding globalization, growing inequality and the emergence of disruptive technologies such as artificial intelligence have cast a shadow on modern society, re-focusing our mission on humanism reaffirms our commitment to our innate humanity and serves as a framework to work collaboratively across ethnic, gender, intellectual, and geographic boundaries. Humanism is thus an economic and social imperative. It is no coincidence that in August this year, the Business Roundtable, the association of the chief executive officers of some of the most powerful corporations in the US, announced the release of a new Statement of Purpose that affirmed commitment of corporations to their stakeholders, underscoring the role that the companies will need to play in improving society, signaling the advent of "conscious capitalism". Universities will need to lead the way in educating the next generation with a singular focus of serving humanity.

In MANE, we have already adopted humanism as our guiding mantra. The intellectual breadth of our department, embracing the disciplines of Mechanical, Aerospace and Nuclear Engineering, provides us unique opportunities to improve the human condition through research and education. In this report, we present a few vignettes, which we hope you enjoy reading.

Suvranu De

J Erik Jonsson '22 Distinguished Professor of Engineering and Head



Plexiform tumor in collagen from the Mills Lab.

Stiff Challenge … Stiffer Resolve

Two major awards help Kristen Mills continue her research into tissue stiffness and tumor cells

Kristen Mills

In the fight against a suite of nightmare diseases, Kristen Mills keeps narrowing her research focus from small to smaller. Now her efforts have brought her two very big awards.

The National Science Foundation recently presented Mills with its Faculty Early Career Development (CAREER) award, while the U.S. Department of Defense gave her a New Investigator Award through the Neurofibromatosis Research Program (NFRP) within its Congressionally Directed Medical Research Programs (CDMRP). Both awards stem from the core of Mills' research: the interaction between cells and the mechanics—specifically, the stiffness—of the tissue that surrounds them.

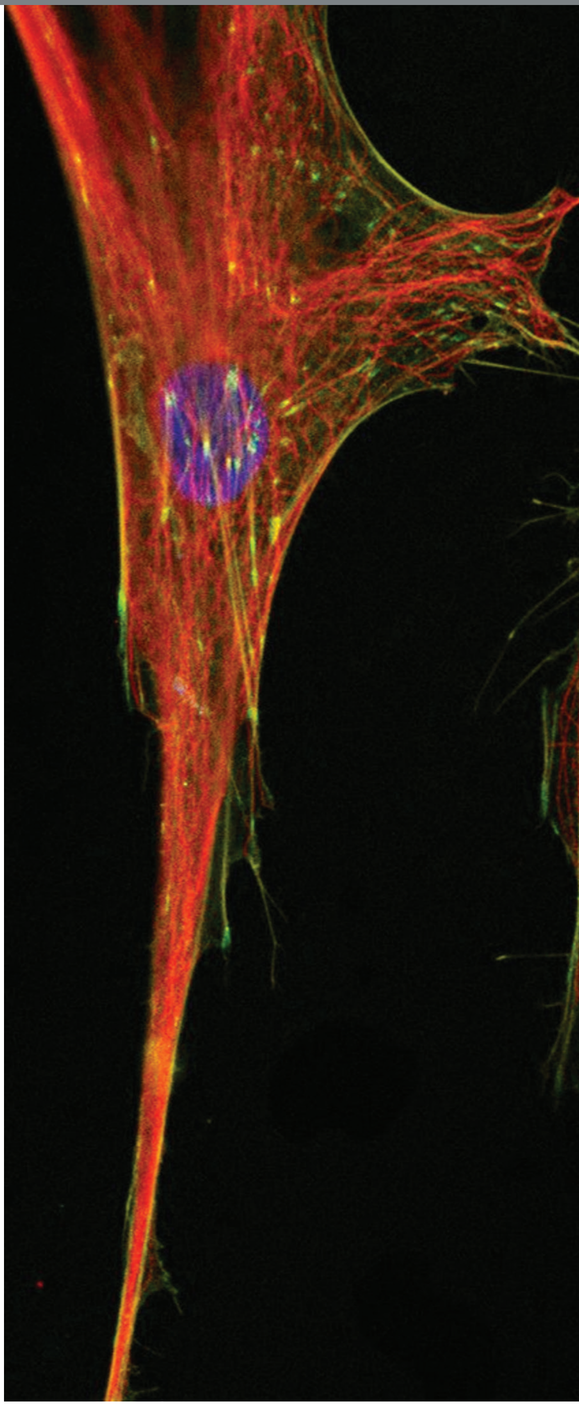
"Every tissue in our body has a characteristic stiffness—e.g., bones are stiff and breast tissue is soft—that is intimately related to its health and the function that it performs," Mills explained in a 2016 interview. "A hallmark of some diseases, including cancerous solid tumor growth, is an abnormal stiffening of the tissue. I have found that stiffness of the environment influences the shape to which tumors grow."

But how? That question has dogged Mills of late—and spurred her to focus on ever-smaller subjects.

"To answer several questions about how tumor cells grow in the mechanical environments they do, I found myself

> "A hallmark of some diseases, including cancerous solid tumor growth, is an abnormal stiffening of the tissue. I have found that stiffness of the environment influences the shape to which tumors grow."

Fibroblast cytoskeleton immunostain from the Mills Lab.



always thinking about the mechanism at smaller and smaller length scales," she said. "My original work in this area was based on model tumors, which were initiated with hundreds of tumor cells, embedded in hydrogels. Since then, my group (the Mills Lab at RPI) has studied how hydrogel-embedded single cells develop into these model tumors. Now we want to know what is happening at the sub-cellular scale as a tumor cell divides against a stiff matrix."

The resulting confinement-induced compression forms the subject of her CAREER award research. As cells divide, they compress against the tissue that surrounds them. Normal cells know how much compression is healthy, and when the compression exceeds normal limits—as it does in stiffer, pathological tissue, like a breast lump—they begin to die. Cancer cells, however, don't get the memo: in fact, they flourish in abnormally stiffened tissue. Mills will use her CAREER award to uncover the dynamics involved, with the goal of illuminating new paths to cancer treatment.

She'll also bring her lessons learned to students at many levels, leveraging such Rensselaer outreach programs as Engineering Ambassadors (in which undergraduates present their chosen fields of study to middle and high school students). Three interactive modules for young teens, residential research summer programs for high schoolers, mentorship of undergraduate researchers, and a graduate-level curriculum will all highlight the importance of biomechanics and disease.

There may even be a dance in the works.

"When I talk about my research, I use my hands and body a lot, and I have been told it looks like I am dancing," said Mills, who in fact is a dancer by avocation. "Again, I looked to the resources on campus, and the EMPAC (Experimental Media and Performing Arts Center) theater and dance curator, Ashley Ferro-Murray, is very interested in bringing the dance and science worlds together at RPI. At least in the initial stages, it is envisioned that a visiting choreographer meets with my lab and incorporates ideas, imagery, and movements from our work into a new dance piece."

Meanwhile, the CDMRP NFRP New Investigator Award supports Mills' research on neurofibromatosis type 1, a genetic disorder characterized in part by tumors (called neurofibromas) in the peripheral nervous system. About 10 percent of patients with plexiform neurofibromas (those located deep inside tissue) develop malignant peripheral nerve sheath tumors (MPNSTs), which are associated with very low life expectancy. Mills will use her award to determine the mechanical stiffness of neurofibromas and MPNSTs, then use those data in 3-D experimental modeling to investigate the underlying mechanobiology.

MAKING Wind Work

Two MANE researchers are removing key obstacles to wind as a mature energy source

Onkar Sahni

Michael (Miki) Amitay

If wind power is ever to reach its full potential, several hurdles must be overcome. Like when bad things happen to turbine blades the size of a U.S. football field.

"In the last two decades, wind turbines have grown in size by a tremendous amount, as manufacturers aim to capture more power more efficiently," explained MANE professor Michael (Miki) Amitay. "Today, blades approaching 100 meters in length are in prototype and testing. That presents quite the structural challenge: the blades need to hold up not only to their own weight, but to the tremendous aerodynamic loads they generate."

"At that scale, it becomes important to account for non-uniformities in the oncoming wind, due to wind shear, turbulence, and gusts, and mitigate their negative effects," MANE associate professor Onkar Sahni added.

> In the last two decades, wind turbines have grown in size by a tremendous amount, as manufacturers aim to capture more power more efficiently..."

The two researchers are well-qualified to describe the situation. Amitay serves as the James L. Decker '45 Endowed Chair in Aerospace Engineering as well as the director of Rensselaer's Center for Flow Physics and Control (CeFPaC). Sahni, a MANE associate professor, focuses his research on (among other areas) fluid mechanics and turbulence simulations. Together they have been developing ideas to measure and address the daunting problems that condemn such blades to a relatively short, suboptimal life.

At the root of the problems are unsteady air flows that interact with turbines in complex, often unpredictable ways. In a pattern known as dynamic stall, for instance, the wind separates over the front edge of the moving blade to form a leading-edge vortex—which detaches early from the blade, causes it to vibrate, dramatically decreases the lift, and increases drag. Less lift and more drag mean less power generated, while the vibrations induce structural fatigue and shorten blade life.

So the solution would seem simple: make the unsteady air flows steady and keep them attached to the blades' surface—in other words, implement active flow control. Nothing in aerodynamics is that easy, of course. Not only is the unsteadiness a root cause in itself, it makes analysis of the problem exceedingly difficult.

Amitay and Sahni have used a careful sequence of experiments and numerical simulations to address these challenges. The focus of their solution is the synthetic jet actuator, a zero-net-mass device that modulates airflow when activated. The researchers aim to amass enough positive evidence to encourage manufacturers to incorporate synthetic jets in blade design.

Rensselaer wind facilities and high-fidelity simulation tools provided a platform for initial testing. After simulations to determine an appropriate placement of the jets, Amitay and Sahni began their experiments in the on-campus wind tunnel. When the results proved promising, they shifted to the institute's 10kw residential-scale turbine, a "low-risk setup that allowed us to test and verify the actuators and control system," Amitay said.

All of that was preparation for the big stage: a full-scale test on a 600kw turbine at the National Renewable Energy Laboratories (NREL). This utility-scale research turbine features removable tips (in which the synthetic jets were to be installed) and "a plethora of sensors to measure the benefit." The synthetic jets used were developed by Actasys, Inc., a startup that originated at Rensselaer.

That benefit was eye-opening. With just 10 percent of one blade actuated with synthetic jets, the turbine scored a 7 percent reduction in structural vibrations. The experiment also verified the efficacy of the closed loop used to actuate the jets.

"At the end of the day, we were able to demonstrate two major findings," Amitay said. "First, synthetic jet actuation has a profound ability to increase the efficiency of wind turbine airfoils while eliminating the effects of unsteady and/or non-uniform winds. Second, these actuators can be implemented on both residential- and utility-scale turbines with a closed-loop actuation scheme."

For a full-scale test of their synthetic jets, Amitay and Sahni turned to the 600kw turbine at the National Renewable Energy Laboratories (NREL).

From here the research can go in several directions: gathering more statistical data on key questions, experimenting with fully actuated blades, continuing the development of the jets themselves, and developing a tool that manufacturers can use to incorporate synthetic jets into blade design.

"Using synthetic jet technology will enable the capture of more energy from the wind while keeping the turbines operational for a longer time," Amitay said. "Moreover, preliminary results suggest that these machines can be deployed in regions that were traditionally considered 'unusable,' such as in areas of very high winds or very low winds."

Out of Thin Air (and Salt Water)

Could humidity and oceans ease the global water shortage? Shankar Narayanan is finding out

Shankar Narayanan

Harvest water vapor from the air. Remove the salt from ocean water. Use the sun to power both efforts. Voilà: you've mitigated the world's water crisis.

The greatest ideas may be the simplest, as William Golding said, and Shankar Narayanan's pursuits have that brilliantly simple quality to them. Making them happen, however, is anything but simple. The associated challenges—and the potential benefit for a world running out of water—have motivated the MANE assistant professor to pursue the dream of water harvesting and solar desalination for the past six years.

To call humidity an untapped water resource would be an understatement: in a Science paper from 2017, Narayanan and his collaborators noted that the total water in the atmosphere (vapor and droplets) amounts to around 13 quadrillion liters. Several solutions for harvesting it have emerged in the past few years, but they have significant shortcomings, especially when it comes to power requirements.

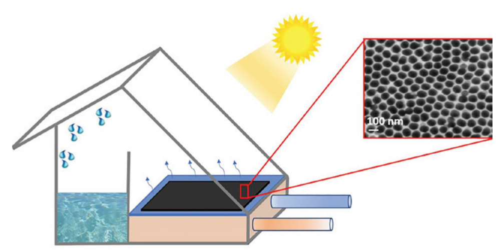
"Energy consumption is invariably involved in the generation of clean water," Narayanan explained. "Currently, regions that experience water shortages also face energy scarcity. Hence, proposing energy-intensive water purification techniques is impractical in many locations."

Narayanan's solution involves the use of nanomaterials like "metal-organic frameworks," or MOFs, which draw on solar energy to produce clean water. The MOF adsorbs water vapor from the air in cooler weather, typically at night, and releases it as water when the temperature goes up. A prototype MOF device, developed by Narayanan and collaborators, produced 2.8 liters of water per kilogram of MOF per day.

The ability to customize these devices in different ways adds to their global value. "The materials can be chosen based on the region and seasonal variations in humidity," he said. One MOF compound, for instance, would be better suited to north Africa, another to the climate of northern India. "The harvester can be implemented as a standalone unit for an individual household or as a wide array for a community. It is possible to make these systems completely self-reliant, which will allow them to function in remote locations far from the grid."

On another front, desalination of the world's ocean water for human consumption, the big challenge is efficiency. Older methods tend to produce insufficient water; a more recent innovation—concentrating solar radiation—has improved production but loses significant energy in the process, which limits its ability to produce even more water.

In the effort to remove these limits, Narayanan has again turned to a class of nanomaterials. "These materials have unique optical properties that allow them to absorb solar energy without losing it back to the environment by radiation," he said. "We hope that this will create higher temperatures for the water desalination process, which will promote the rate of production."



Metal-organic frameworks (MOFs) draw on solar energy to produce clean water. The MOF adsorbs water vapor in cooler weather and releases it as water when the temperature goes up.

While challenges remain—among them the identification of inexpensive raw materials from which to synthesize the nanostructures—Narayanan envisions this technology playing a substantial role in meeting a basic human need.

"My vision is to see a vast array of solar desalination panels installed close to a sea or an ocean, delivering potable water for consumption with minimal or zero dependence on the grid for electricity," he said. "The use of pipelines can deliver water to inland regions as well. And small-scale, mobile systems can be developed for rapid deployment in natural disasters."

Moreover, he thinks it can happen soon. "We are close to demonstrating this concept in the laboratory and expect a working system in the near future."

A Dose of Precision

George Xu advances the difficult—perhaps life-saving—science of calculating radiation doses

Given the risks associated with radiation, no dose calculation can ever be too precise.

Indeed, pinpointing the right dosage for CT scans can preserve patients' long-term health while yielding accurate images. Yet the sheer number of variables involved, from body size to the scanner's manufacturer, can make such precision elusive.

That's why George Xu and his collaborators have created VirtualDose: web-based software that uses a broad array of advanced "virtual patients" to make radiation dosing more accurate—and safer—than ever.

"Before this project, hospitals used data derived from an older generation of patient anatomical models that were not accurate," said Xu, a nuclear engineer by profession and MANE's Edward E. Hood Endowed Chair Professor of Engineering. "With VirtualDose, users in the hospitals can precisely estimate the amount of radiation that various patients—of various ages and body sizes—receive in CT scans. This helps radiologists to optimize CT scanning procedures by ensuring the procedure is accurate and safe."

Users log onto the VirtualDose website and encounter a simple dashboard, with input panes and dropdown menus for such parameters as body shape, scan type, scanner name and manufacturer, and technical details like beam collimation. A graphical model of the virtual patient appears with sliders to pinpoint the area to be scanned.

Supporting the interface are several innovations that Xu and his team developed previously. VirtualDose includes 25 "phantoms," or virtual patients, that model a range of body types from newborn to adult, from normal weight through obese, even women at three stages of pregnancy. The dose calculations, meanwhile, are made so accurate through another Xu innovation: he and his team were among the first to propose and demonstrate the idea of real-time Monte Carlo radiation dose simulations.

Prof. George Xu stands next to a poster that introduces ARCHER technology during the Annual Conference of the American Association of Medical Physicists in San Antonio, Texas, in July 2019.

The software's user growth has been impressive. Since its launch in 2015, Xu said, VirtualDose has been used in thousands of hospitals worldwide.

Neither is its value restricted to CT scans. A related version of the software, VirtualDose IR, provides the same service for interventional radiology, a growing field in which surgeons use real-time radiological images to see what they're doing during minimally invasive surgery.

"In recent years, IR procedures have expanded beyond the traditional cardiovascular applications to many other specialty areas," the VirtualDose website explains. "Long exposure times can subject patients to acute injuries to the skin and other tissues, and the large accumulated doses pose a long-term radiation risk that can be monitored and managed.… VirtualDose provides an important tool to understanding and managing IR dose."

At the same time, Xu has turned his attention to another key parameter of radiation dosimetry: calculation speed.

ARCHER, Xu's rapid dose computation program, is also based on Monte Carlo simulations. According to a description of ARCHER, the product leverages massively parallel computing via hardware originally developed for gaming and other high-performance applications. The results so far are promising: "In a recent clinical testing, ARCHER was found to reduce dose computing time for cancer patient radiation treatment from hours to seconds."

For both VirtualDose and ARCHER, Xu and his team received support from the Small Business Technology Transfer (STTR) program, which awards federal funds to stimulate technological innovation.

A Clean Break from the Thermostat Wars

Personalized heating and cooling—with a drop in greenhouse gases—may be coming to a space near you

If you have ever shared a space—an office, a house, an apartment—you know one incontrovertible fact: no matter what the temperature, somebody will be unhappy with it.

And that's the least of the problems with today's typical HVAC system.

"The use of traditional, compressor-based technologies has a detrimental effect on greenhouse gas emissions, partly due to refrigerant leaks," said Theodorian Borca-Tasciuc, MANE professor and an expert in solid-state thermoelectric energy conversion and heat transfer. "However, costs for more efficient alternatives are too high, so many building owners are stuck with the old technologies."

Borca-Tasciuc, along with a team of entrepreneurs, may have the solution. The Modular Indoor Micro-Climate system (MIMiC for short) consists of a compact unit to provide both heating and cooling via compressor-less technologies. The system uses no refrigerants, eliminating greenhouse gas emissions.

The design approach, according to the website of MIMiC Systems Inc.—the company founded to advance the technology—is "based on providing thermal comfort 'when and where needed' instead of conditioning an entire space."

At the core of MIMiC is a technology Borca-Tasciuc has investigated for many years: a solid-state heat pump.

"Thermoelectric heat pumps consist of an array of junctions between dissimilar thermoelectric materials," Borca-Tasciuc explained. "These solid-state heat pumps need materials with high electrical conductivity, high Seebeck coefficient (a ratio of thermoelectric voltage to temperature difference), and low thermal conductivity."

According to NYSERDA, HVAC equipment is responsible for at least 32 percent of greenhouse gas emissions in New York State.

Finding materials with all three properties is a stiff challenge, since they typically correlate with one another. To overcome the challenge, Borca-Tasciuc—in partnership with Ganpati Ramanath, John Tod Horton Professor of Materials Science and Engineering at Rensselaer—turned to the nanoscale. "Almost continually since 2002," Borca-Tasciuc recalled, "we researched nanostructured thermoelectric materials, where the nanostructure effect could enhance energy conversion performance."

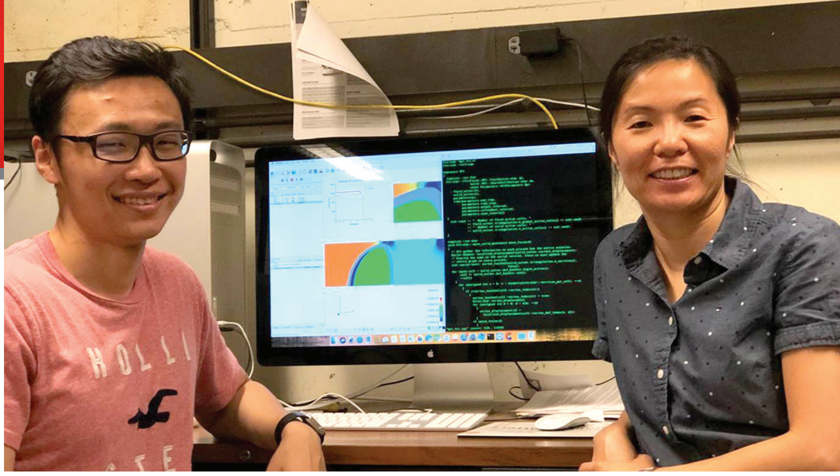
In addition to this research, MIMiC Systems Inc. continually considers system-level innovations, synergistic with solid-state technology's unique capabilities and specific customer needs. For his part, Borca-Tasciuc has turned to designing solid-state-based heat pump systems and prototyping products like MIMiC.

MIMiC has drawn attention from the New York State Energy Research and Development Authority (NYSERDA), which just funded a project under its NextGen HVAC challenge for residential applications. The stakes for successful solutions in this space are high: according to NYSERDA, HVAC equipment is responsible for at least 32 percent of greenhouse gas emissions in New York State.

MIMiC may deliver other benefits as well—especially personal comfort. "Depending on the specific applications (for example, residential or commercial), a solid-state HVAC unit will provide a significant improvement in the indoor environmental conditions for each end user," Borca-Tasciuc explained. "It will also eliminate the noise typically caused by compressors in traditional HVAC systems. Ultimately the unit may be compact enough to be portable, easily moved from place to place as the user needs."

Theodorian Borca-Tasciuc

Giving People Their Voice Back



Graduate student Feimi Yu (left) and Prof. Lucy Zhang (right) working on the vocal fold simulations.

Lucy Zhang's simulation could make the diagnosis and treatment of voice disorders far more efficient—and painless

Lucy Zhang has a personal reason for investigating vocal folds and glottal airflow: she knows what happens when they don't work.

"For several semesters in a row, I taught four hours straight for two days a week, every week," said the MANE associate professor. "It didn't take me long to lose my voice—and experience the frustration of not being able to speak."

She's not alone. According to the National Institute on Deafness and Other Communication Disorders, which funds Zhang's research, an estimated 17.9 million U.S. adults reported voice problems in a 12-month period. Nearly one in 12 U.S. children had a disorder related to voice, speech, or language in the past 12 months.

Zhang's research aims to transform the often painful diagnosis and treatment of such disorders. The key is a software tool that models the two key aspects of voice production—vocal fold movement and airflow—in a single full-scale simulation.

In developing the tool, Zhang found herself right on the leading edge of the field. "Almost no one was doing full-scale simulation with the full set of vocal folds," she remembered. "Some were using mechanical models; others were simulating just the vocal folds, or just the airflow. We used numerical manipulation in a fully coupled system to capture the cyclical processes that are so complex yet so critical."

When complete, the simulation should enable physicians to quickly pinpoint

> "Most gratifying for Zhang has been the reaction from people with voice disorders and the doctors who treat them. "They're astonished," she said.

the root causes of their patients' vocal disorders—a major step forward from the trial-and-error approach that has long been standard practice in the field.

That standard practice is anything but pleasant. "If you have trouble speaking, you go to the doctor, they listen to you, then they probe the area with an instrument attached to a camera," Zhang explained. "Then, multiple CT scans to make sure they don't miss a particular angle. If everything looks normal, now there are a whole lot of tests—including a probe put inside your throat while you vocalize, which is very painful. After all this, you may undergo one or two years of therapy, or else surgery. Some of these surgeries are often irreversible."

Zhang's simulation translates patient data into a visual representation of what's happening inside the throat, and how different therapies will affect that. "With this tool, you can see the physical model as the lung pressure enters into the throat, what happens to the air jet when the folds vibrate," she said. "We input a particular procedure or therapy and see the results."

The simulation is a central element in a broad-based collaborative effort that uses several approaches to address the physics involved. A team from Penn State oversees a life-size physical model for experiments; researchers at the University of Nebraska—including former Rensselaer faculty member Tim Wei—run a large-scale experimental model; and Massachusetts General Hospital, a leader in treating vocal disorders, provides prospective patient data to validate some of the evaluation techniques.

The applications for Zhang's research do not stop with voice production. One version of her tool simulates the left atrial appendage closure in cardiac surgery. An upcoming project may involve simulation of the stomach in digestion. "As long as you have fluids and solids interacting, we can configure our software to simulate it and measure key variables," she said.

Most gratifying for Zhang has been the reaction from people with voice disorders and the doctors who treat them. "They're astonished," she said. "It's amazing how on board they are with the concept. As one doctor told me, 'At the end of the day, every patient is different. We have to customize our treatment for every single person.' Our simulation will give them the ability to do that."

Solar Blankets, Green Fuel Filters...

Two student provisional patents are among the latest advances with origins in Inventor's Studio

A lifelong fascination with cars—and how to reduce the pollution they cause—inspired Gino Gasbarro's master's degree project: a diesel fuel filter made from biodegradable material in mushrooms.

It might have stayed "just a project" without a nudge from his advisor.

"Dr. [Asish] Ghosh continually mentioned that he knew this could be patented," said Gasbarro, who earned his master's degree in 2019, founded Pure Earth Systems LLC, and now holds a provisional patent for the filter made of mycelium. "It was difficult for me to grasp that my idea was truly patent-worthy in the beginning, but his encouragement gave me the passion to make it a reality."

The project had its roots in Inventor's Studio, which gives undergraduates hands-on experience with the process of innovation and entrepreneurship. Started by the legendary Burt Swersey, Inventor's Studio has expanded to three courses under Ghosh (a MANE professor of practice) and MANE professor Catalin Picu.

Gasbarro's diesel particulate filter, or DPF, overcomes several barriers faced by conventional filters in reducing the soot generated by diesel engines. Most diesels use a ceramic filter, which is expensive, difficult to clean, and fossil-fuel-intensive in the manufacturing process. The mycelium DPF, in contrast, can be made at a small fraction of the cost by growing mycelium in a mold filled with organic agricultural byproducts.

In another Inventor's Studio class, a student team turned its attention to the plight of refugees crossing the Mediterranean. "One of the many issues [they face] is the inability to generate heat or light…during the journey," the team wrote in a description of the project. "With no reliable heat sources available when the sun sets, many refugees struggle with hypothermia during the night. With no reliable light sources, refugees can be stuck in total darkness halfway across the sea."

The team—which included Rensselaer

> "In addition to learning the tools to innovate and design new products in Inventor's Studio, students also learn how to use these tools and processes to address global challenges."
>
> Asish Ghosh
> MANE Professor of Practice

Gino Gasbarro's master's degree project was to develop of a diesel fuel filter made from biodegradable material in mushrooms.

undergraduates Christopher Miller, Jeffrey Brewer, Noah Pan, and Mallory Peskens—came up with a novel solution: the Deployable and Compactable Solar Blanket. Featuring a layer of solar panels, the blanket is designed to be cast onto the water during the day, drawing photovoltaic energy that gets stored in an external battery. Meanwhile a mylar layer enables the blanket to retain the sun's heat, so it can be used to warm refugees during the night.

The solar blanket came out of a four-week "blitz" that forms part of Inventor's Studio. In each blitz, teams of four or five students research and reflect on aspects of a particular human problem, then use those reflections to define engineering requirements for a possible solution. Recent blitz teams have focused their efforts on hurricane recovery efforts in Puerto Rico, refugee camps around the world, and ensuring adequate supplies of food, energy, and water in the year 2050.

Meanwhile, Ghosh and Emily Liu (associate professor of nuclear engineering and engineering physics) have brought Inventor's Studio to pre-college levels as well. For two weeks in the summer, the STEAMM (Science, Technology, Engineering, Math and Medicine) Inventor's Studio immerses high schoolers in campus life and career exploration. During the afternoons, the students devote themselves to developing engineering solutions to societal issues such as clean energy and access to healthcare.

The results have been impressive. This past summer student teams developed a green roof to offset the effects of climate change, a cooling system for athletes, and lightweight leg supports that eliminate the need for a cane.

"In addition to learning the tools to innovate and design new products in Inventor's Studio, students also learn how to use these tools and processes to address global challenges," Ghosh said. "One could say that they learn how to design for resilience or sustainability."

For two weeks in the summer, the STEAMM (Science, Technology, Engineering, Math and Medicine) Inventor's Studio immerses high schoolers in campus life and career exploration.

In each Inventor's Studio "blitz," students use their research and reflections on a particular human problem to define engineering requirements for a possible solution.

Beyond the Ruins

Students install solar power while respecting local culture in a remote Mayan village

If you'd ever taken a shower in Ek' Balam, a tiny indigenous village near Mayan ruins in Yucatan, you could thank Rensselaer students for keeping the hot water hot.

Since 2011, students from the Rensselaer chapter of Engineers for a Sustainable World (ESW)—a global network of volunteers creating solutions for communities in need—have visited Ek' Balam to design and install one photovoltaic and several solar water heater systems. The work has brought needed electric power to the remote village, even as the students take care to work within local culture in everything they do.

We asked the program's technical manager, Randy McDougall, and several students and alumni to share insights about the project, the village, and lessons learned. They include Rafael Boscan '18, chapter president Mark Calicchia Jr. '20, Jennifer de Souza '16, and former president Brianna Harte '19.

Solar water heater for eco-home, installed in May 2019 in Ek' Balam, Yucatan, Mexico.

Children of Ek'Balam.

An old-school palapa, now used as a home, with sides made of hundreds of poles (1-2 inches in diameter) woven together side by side.

Since 2011, students from the Rensselaer chapter of Engineers for a Sustainable World have visited Ek' Balam, in Mexico's Yucatan state, to design and install one photovoltaic and several solar water heater systems.

Q&A

Q. What is Ek' Balam like?

McDougall: : The vast majority of houses are old-school palapas, with sides made of hundreds of poles (1-2 inches in diameter) woven together side by side. There are many block-work outhouses and lots of happy, healthy kids.

Boscan: Ek' Balam is very unusual as it still has active Mayan speakers. The early and secondary schools teach some classes in Mayan.

Calicchia: Chickens, pigs, and other livestock were roaming the village the entire time we were there. The men go off during the day, mostly to work in the fields. The women stay home and watch after the children, weave hammocks, cook, and do other household chores.

Harte: The hammocks are one of the main sources of income for most families. Some make additional money by running little shops that sell snacks and drinks.

de Souza: The village is very gracious. Families in the village take turns hosting us for lunch.

Q. What role does the eco-house play?

Harte: The idea behind the eco-house was to provide a place for volunteers to stay while using as few of the village's resources as possible.

McDougall: The eco-house is where we installed, and continue to iteratively improve, our solar water heater system. The PV system there (which we installed on earlier trips) provides power to light the building and charge electronics.

Boscan: The eco-house also gives us somewhere to test prototypes of ideas we may develop during the trip. The main focus, however, is to have a place for the stakeholders to see the projects we're working on.

Harte: The kids in the village see what we build at the house and get involved, knowing who we are and what we're making.

de Souza: The villagers like to see that the designs we come up with (1) work and (2) are something they can maintain. The visitor hut is a place where they can check on the proof of concept and how it's going.

Q. Has the technology transferred to the village homes as well?

Calicchia: Yes. Our chapter has built numerous systems (mainly solar water heaters) for families to keep at their homes. In addition, we are currently working with some Ek' Balam villagers who are building a community center for the entire village.

de Souza: Before the solar hot water heater villagers would have to heat the water themselves if they wanted a warm bath. Now they can take a shower in peace without worrying about the water getting cold too quickly.

Q. It sounds as though the villagers have welcomed your work. That's not always true when nonprofit groups travel to "do good" in developing countries.

Boscan: Every year we manage to gain more interest from different households. If we didn't take our time, we'd risk offending the villagers or making undesirable changes to their culture, which is not the end goal. We want to mutually exchange aspects from both cultures.

de Souza: While I believe it's important to bring technology to everyone, it's equally as important to make sure that the technology is useful given a village's or person's situation, standard of living, and culture.

Q. What does the future hold?

McDougall: The short-term goal is to expand the PV system and completely power the house, to include ceiling fans and refrigeration. Beyond that would be to create enough energy to equitably provide power for local use.

de Souza: I think if the solar panels can be net positive with power, the villagers can sell the excess electricity back to the grid and generate more money for the village.

Q. What have you taken from the experience?

Calicchia: The impact on me personally has been monumental. I would recommend an experience like this to all engineering students: it goes well beyond taking classes for four years and then working for a company. It's been humbling and it's been rewarding, knowing that my work is impacting other people's lives.

Harte: It's an experience I will carry throughout my career and life. The ability to work on projects and be challenged outside the classroom, in a setting like ESW, is something I think every student—and honestly anyone aspiring to be more—should have.

Going Electric

A company led by a Rensselaer alumnus recently emerged from stealth and is already creating shockwaves in the automotive industry.

R.J. Scaringe '05

Rivian, automotive maker of an all-electric truck and SUV, was founded in 2009 by R.J. Scaringe '05. The company made a huge splash last November at the Los Angeles Auto Show, where it unveiled its first two battery-powered autos: the R1S, a seven-seat sport utility vehicle, and a five-seat RT1 pickup. Business Insider called the R1S one of the "24 hottest cars at the LA Auto Show," while Forbes proclaimed, "Meet R.J. Scaringe, Founder of Rivian Automotive — and Tesla's Worst Nightmare."

The vehicles, powered by a battery pack and designed for upscale adventure, are scheduled to come to market at the end of 2020.

With engineering in Plymouth, Michigan, and technology offices in California, Scaringe originally planned to develop an electric sports coupe, much like Tesla's Roadster, but within a couple of years, his outlook — and plans — changed, because the auto-loving yet ecologically minded Scaringe wanted to make more of a difference. "It was frustrating knowing the things I loved were simultaneously the things that were making the air dirtier and causing all sorts of issues, everything from geopolitical conflict to the smog to climate change," Scaringe told Forbes.

So Scaringe pivoted, focusing on environmentally friendly electric vehicles (EVs) that could also satisfy his love of the outdoors. "[We weren't] building something that the world truly needed, that was different than other things in the market," Scaringe told Forbes.

According to Scaringe, Rivian is a new kind of brand, selling a new kind of vehicle. In the early days of the company, he says, a statement plastered on the wall served as their guidepost: "We're building this car because it does not exist."

Unlike many automakers who are feverishly trying to adapt their cars created for internal-combustion engines into EVs, Rivian took a "clean-sheet approach," designing the vehicles from the ground up. "The challenge and the beauty of a clean sheet is you can do things the right way, without worrying about the legacy of the past, but still leverage and learn from what's been done before," Scaringe says.

"We can learn a lot from Rivian, how quickly they turn around ideas," said Ford Motor Company's chairman, William C. Ford Jr., in an interview with The New York Times in April. "There's a great benefit from working with a clean-sheet approach" to electric vehicles.

Perhaps that's why Ford is investing $500 million in Rivian. According to Forbes, "the announcement is another sign that automakers are betting heavily on EVs as their path toward the future."

Rivian's EVs, which Scaringe has dubbed "electric adventure vehicles," are aimed at customers who love the outdoors and are committed to preserving the environment. "Adventure is life," proclaims Scaringe. "Your destination could be fishing, it could be golfing, it could be taking the family out for lunch."

Rivian's EVs can be driven 400+ miles on a single charge, and can go from 0 to 60 mph in just three seconds, while 100 mph takes less than seven seconds. With 14 inches of ground clearance, they can handle a wading depth of three feet, enabling them to ford streams and rivers because of their sealed battery pack and drive units.

According to Rivian, the electric drive delivers remarkable power and torque through four independent motors — with 200 horsepower available for each wheel. The pickup truck, which the company says will start at about $69,000, will have an 11,000-pound tow rating and a cargo capacity of 1,760 pounds.

Both vehicles are built on a skateboard platform — a flat frame that contains the batteries, suspension, motors, and braking. They boast a unique lockable gear tunnel that sits under the cab and bed (think paddleboard storage) and flexible crossbar system to mount gear on the vehicle's roof or bed.

Level 3 autonomy-capable hardware will be available on every Rivian vehicle. The multiple redundant sensor suite features lidar, radar, cameras, and ultrasonic sensors, "because four safety nets are better than one," Scaringe says.

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