SPRING 2018

SUMMIT

SMART STRUCTURES

How CEMS-led Research on Smart and Lightweight Polymers are Reducing Cost and Waste for the Automotive and Aerospace Industries

The University of Vermont
COLLEGE OF ENGINEERING & MATHEMATICAL SCIENCES

THE DEAN'S VIEW

DEAN LUIS GARCIA
Photo: Sally McCay

Dear Alumni and Friends of CEMS,

In June of 2013, when I made a five-year commitment to serve as Dean of the College of Engineering and Mathematical Sciences, I was excited by the prospect of joining this community and being part of the college's evolution. Now, nearly five years later, my enthusiasm for the future of CEMS is even greater. I am humbled by how much we have been able to accomplish during the last five years and the completion of my appointment provides a natural transition for new leadership in the college. It is with this backdrop that at the end of October I informed President Sullivan and Provost Rosowsky of my intention to step down at the conclusion of my term.

CEMS has charted a course for greatness, fueled by transformational accomplishments such as improved infrastructure (Votey renovations and the construction of Discovery and Innovation Halls); the best ABET visit in the history of UVM; the restructuring of the School of Engineering into three vibrant new departments; the addition of new certificate, undergraduate and graduate programs; the successful transition to Incentive Based Budgeting (IBB) with multi-million dollar surpluses and a reserve of almost 10% of our annual budget; reaching the CEMS comprehensive campaign goal almost two years ahead of the end of the campaign; and a marked expansion and strengthening of our faculty and staff.

We have also grown our undergraduate and graduate student bodies while increasing the quality and diversity of our students. My hope is that CEMS will build on our strong foundation as it continues to strive for progress and success in the next five years and beyond.

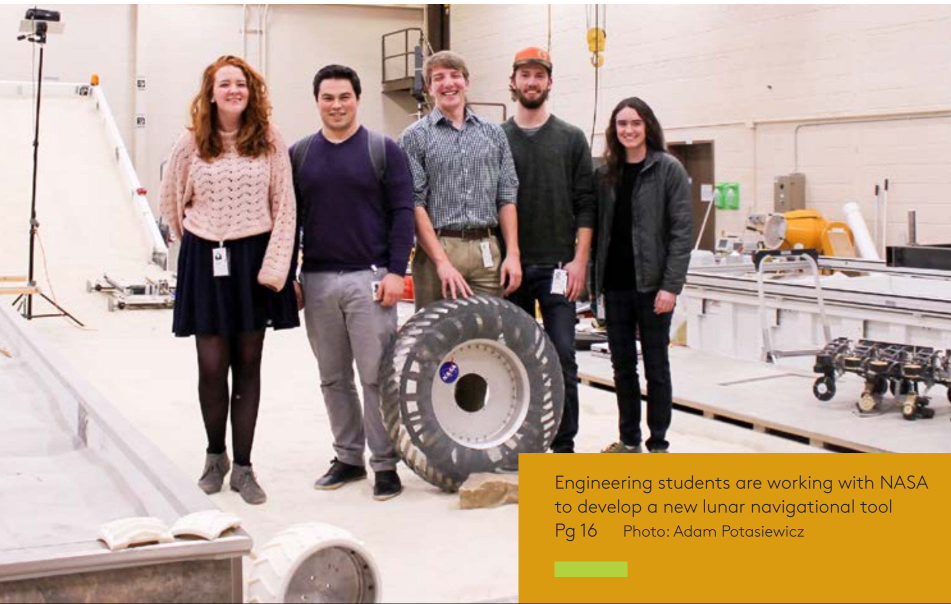
A national search is underway for a new Dean who is expected to start July 1st. The new Dean will be introduced in the fall issue of SUMMIT.

I gratefully acknowledge that CEMS' success during my tenure as Dean is largely a result of the combined efforts of our faculty, staff, students, alumni and friends of the college. I look forward to a fantastic future for CEMS as the college realizes its' full potential.

All the best,

Luis Garcia

Luis Garcia, Ph.D.
DEAN AND BARRETT FOUNDATION PROFESSOR
COLLEGE OF ENGINEERING AND MATHEMATICAL SCIENCES



Engineering students are working with NASA to develop a new lunar navigational tool
Pg 16 Photo: Adam Potasiewicz

CEMS-led research on smart and lightweight polymers
Pg 14 Photo: David Seaver

TABLE OF CONTENTS

Smart Structures: How CEMS-led Research on Smart and Lightweight Polymers are Reducing Cost and Waste for the Automotive and Aerospace Industries and Beyond 14

CEMS News and Updates 2

Reliable Renewables: A Team of CEMS UVM Researchers Want to Balance Supply and Demand in the Nation's Electrical Grid, One Packet of Energy at a Time 10

Solving for the Digital Age 12
A Cyber Approach to ACL Rehab:
Toth and Skalka BME Grant Breaks New Ground

Wheels in Motion: Engineering Students Work with NASA to Develop a New Lunar Navigational Tool 16

Biomedical Engineering Students Dive into Research 18

Student Engineers Her Future with Help of UVM's Fab Lab 22

A New Angle on Gerrymanders: UVM Mathematicians Invent Tool to Judge When Voting Maps Have Been Unfairly Drawn 24

EDITOR
Jenn Karson

GRAPHIC DESIGN
Ion Design

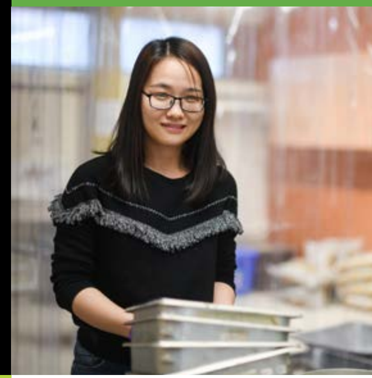
PHOTOGRAPHY/IMAGES
Maddie Anderson, Joshua E. Brown, Maggie Eppstein, Eric Hudiberg, Brian Jenkins, Sally McCay, Adam Potasiewicz, David Seaver, Ian Thomas Jansen-Lonnquist

CONTRIBUTING WRITERS
Michelle Bookless, Joshua E. Brown, Luis Garcia, Jenn Karson, Ed Neuert, Erin Post, Sarah Tuft Dunn, Jeffrey Wakefield, University Communications

PROOFREADER
Rita Daley

SUMMIT is published twice a year by the Dean's Office at the College of Engineering and Mathematical Sciences

Maddie Anderson and LeAnn Gove at the 2017 Grace Hopper Celebration of Women in Computing in Orlando, Florida
Pg 2



Yujie Li preparing samples in Votey's new Geomaterials Laboratory. Read about our new facilities in the new STEM Complex
Pg 14
Photo: David Seaver

WWW.UVM.EDU/CEMS

SEND LETTERS AND ALUMNI NEWS TO:
Summit@uvm.edu

NEWS

GREEN AND GOLD **Record number of athletes continue UVM's remarkable Olympic run**

Rounding out UVM's representation on Team U.S.A. were the Patterson siblings, both UVM CEMS alumni. Cross-country skiers Scott '14 and Caitlin '12 both recently scored national titles at the 2018 L.L. Bean U.S. Cross Country National Championships, and both were Nordic skiers in Vermont. At the 2018 Winter Olympic Games in PyeongChang Scott was the first American with an 11th-place finish in the men's 50K Nordic race, the best American finish in the event in Olympic history. Caitlin skied in two Nordic events at the beginning and end of the games. She was the second American in the 15K skiathlon, 34th overall. In the final event of the Games, Patterson skied to a 26th place finish in the 30K race.

SIBLINGS AND CEMS ALUMNI
Scott Patterson '14 and Caitlin Patterson '12
Photo: Patterson Family

STUDENTS FIND INSPIRATION AND ENCOURAGEMENT AT GRACE HOPPER CELEBRATION

UVM sent a contingent of 29 to the 2017 conference. Twenty-one students were supported with BRAID funding: two students with FAST Enterprises funding, one post-doc funded by Professor Josh Bongard, and one student was sent by Amazon where she interned and they arranged her travel. In addition BRAID funded one faculty member, CEMS funded one faculty member and two staff.
Photo: Maggie Eppstein

For the third year in a row University of Vermont students traveled to the Grace Hopper Celebration of Women in Computing—the world's largest gathering of women technologists—where they found job and internship opportunities, made new connections with their classmates, and had the opportunity to meet inspiring female leaders in the field. BRAID funding was instrumental in funding student travel.

LEARN MORE ABOUT BRAID

HTTPS://ANITAB.ORG/BRAID-BUILDING-RECRUITING-AND-INCLUSION-FOR-DIVERSITY/

CONGRATULATIONS TO THE 2017 CEMS UVM AWARD RECIPIENTS

Outstanding Junior Faculty Performance	**Jim Bagrow**
Faculty Award for Excellence in Research	**Frederic Sansoz**
Outstanding Faculty Performance	**Mandar Dewoolkar**
Faculty Award for Excellence in Teaching	**Priyantha Wijesinghe**
Outstanding Faculty Advisor Award	**Ryan McGinnis**
Faculty Award for Excellence in Service	**Will Louisos**
Staff Award	**Pattie McNatt**

Mandar Dewoolkar received the 2017 CEMS Outstanding Faculty Performance Award.
Photo: Sally McCay

FORWARD THINKING

Computer science student Nikki Allen spends her Friday afternoons teaching the next generation to code.

BY SARAH TUFF DUNN

As a high schooler in the Bronx, Nikki Allen '19 enjoyed the popular blog site Tumblr, but wanted to make better-looking templates and add customization.

< / >

TEACHING CODE
Student Nikki Allen teaches young girls to code on Friday afternoons.
Photo: Brian Jenkins

"I'd pull from other sites and put them in Tumblr, and I realized I was learning HTML, CSS and JavaScript," recalls Allen, now a junior at UVM. "I was learning how to code—and learning how flexible computer science could be."

Now, Allen is sharing that sense of discovery with girls as young as 4 as she devotes a few hours each Friday. Yes, 4-year-old Julie and her older sister Kyla, 6, are already learning to do much more than "drag and drop" thanks to their computer science lessons with Allen, for which they travel from Charlotte to the UVM campus.

The connection came about when Nikki accompanied a group of UVM computer science students and faculty to The Grace Hopper Celebration in October 2017, the world's largest gathering of women technologists. Allen learned from Maggie Eppstein, Chair of Computer Science at UVM, that the two girls were looking for a tutor. "I just jumped at the opportunity," says Allen. "I was going to tutor them at home, but we thought it would be more interesting in a college setting. They were definitely nervous at first, but I was so excited, and they opened up quickly. Now, they are so sure of themselves, and ready to start coding when they get back in their dad's car!"

Having attended Collegiate Institute for Math and Science, Allen was naturally inclined toward an interest in STEM, and has had several internships to prepare her for her career after college. She's worked with Girls Who Code (GWC) on its goal to reach 1 million by 2020, and has also been a GWC teacher's assistant. Her favorite stint, however, was serving as a software development and editorial intern for AOL-owned Cambio.com. "I was able to perform tasks and see immediate results," she says.

Allen adds that Eppstein has been an enormous influence on her college career, followed by Joan Rosebush and Jim Eddy, the professor who's helping her prep for a job in cybersecurity. Her advice for incoming freshmen? "Learning how to manage your time wisely is key," says Allen. "Don't be afraid to ask questions in class, because there's a good chance that other people have the same question. Take advantage of office hours—if not to have a better understanding, then just to introduce yourself."

Her next internship is at Bank of America in the summer of 2018, for which she'll return to New York City. She is pursuing a career in cybersecurity and also intends to stay involved in community education and outreach after graduation. "Once you give a girl a computer and show her what she can do, the possibilities are endless."

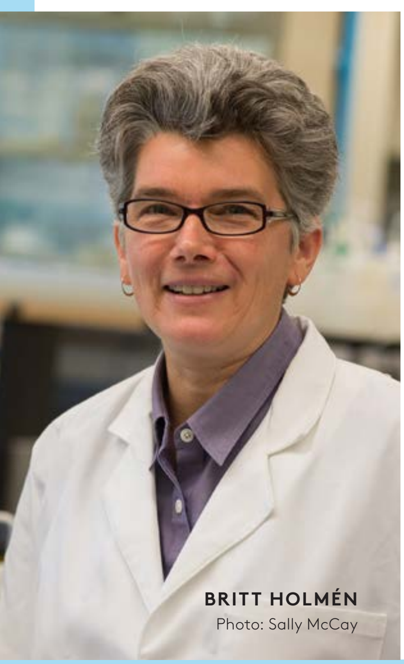
RESEARCH AWARDS

Faculty from across the College are engaged in leading-edge research sponsored by other funding agencies.

LEARN MORE
For more awards visit **UVM.EDU/CEMS**

PRINCIPAL INVESTIGATOR	SPONSOR	PROJECT TITLE	AWARD
Lisa Aultman-Hall	UC Davis/DOE	National Center for Sustainable Transportation 2017	$ 283,368
James Bagrow	CA Technologies	GitHub Public Data as a Vehicle for Understanding Individuals and Teams: Hypotheses, Challenges, and Proposed Research	$ 69,763
Abby Bleything	DOE	Clean Cities Outreach, Education and Performance Tracking FY18	$ 45,000
Jeffrey Buzas	Vermont Oxford Network	Statistical Support for the Vermont Oxford Network Year 7	$ 147,645
Mandar Dewoolkar	VAoT/USDOT RITA	Bridge-stream Network Assessment to Identify Sensitive Structural and Hydraulic Parameters for Planning Flooding Mitigation	$ 75,000
Douglas Fletcher	ATA Engineering/AFOSR	Structural Profile Disruption Effects for High-velocity Air Vehicles	$ 49,992
Darren Hitt	NASA	Critical Gas-surface Interaction Problems for Atmospheric Entry	$ 750,000
Patrick Lee	Human Biomed, Inc./MTEC	Development of Multi-Functional Extracorporeal Life Support (ELCS) System for Lung and Kidney Support: Pneuma-K ECLS System	$ 141,929
Patrick Lee	EXXONMOBIL	Crystal Nucleation/Growth and Viscosity Study of Polymer+Gas Structures	$ 225,000
Patrick Lee	NSF	CAREER: Understanding Process-Structure-Property Relations in Gas/ Supercritical Fluid-Injected Polymer Coextrusion Foam Processes	$ 500,000
Jason Meyers	Lockheed/DARPA	Electron Transpiration Cooling (ETC) for Thermal Management of Hypersonic Platforms	$ 180,850
James Sullivan	VAoT/USDOT RITA	Improvement and Operation of the Vermont Travel Model: year 10(2017-2018)	$ 80,000
Safwan Wshah	VAoT/USDOT RITA	Detection and Mapping of Roadside Assets from Road Images	$ 70,000
Jianke Yang	AFOSR	Nonlinear Optics in Parity-time-symmetric and Quasi-parity-time-symmetric Systems	$ 634,246

UVM's Gund Institute for Environment announces nearly $250,000 in Catalyst Award Seed Grants and event support



BRITT HOLMÉN
Photo: Sally McCay

Five interdisciplinary teams will receive Gund Catalyst Awards between $35,000 and $50,000 to establish new research projects seeking real-world solutions to critical environmental issues.

Congratulations to Britt Holmén (CEMS) and Cecilia Danks (Rubenstein School of Environment and Natural Resources) who are recipients of an inaugural Catalyst Award. Their proposal seeks to improve understanding of "biogas" (ie. methane, CO2) emissions and dynamics. By developing new technologies and systems for real-time biogas monitoring, the team will link regional partners around applications requiring biogas sensing data, including community adoption of renewable natural gas, an increasingly viable renewable energy source. Scholars and industry partners will establish real-time, spatial emissions monitoring at a pilot field project in Vermont, and aim to develop novel, miniature biogas sensors for deployment on farms, trucks, drones and satellites.

"We are excited to support these ambitious projects with our first Gund Catalyst Awards," says **Donna Rizzo, Acting Director of the Gund Institute for Environment.** "These are important efforts that will attract more funding to UVM, address critical issues, and develop solutions for the people of Vermont, the U.S. and worldwide."

CEMS WELCOMES NEW FACULTY AND STAFF

EVA COSOROABA

Lecturer
Electrical and Biomedical Engineering

A graduate of the Politehnica University of Timisoara in Romania, Cosoroaba recently completed her PhD in electrical engineering at the University of Texas at Dallas. Her research interests include electric machine modeling, design and control methods; and consumer and industry-attractive renewable energy solutions. She brings an enthusiasm for fostering critical, independent and creative thinking to CEMS students.

TAYLOR DUPUY

Assistant Professor
Department of Mathematics and Statistics

Dupuy came to the University of Vermont as a Visiting Assistant Professor in fall 2016 and will be promoted to Assistant Professor. Currently teaching Math 272 and Math 52, his area of focus is arithmetic geometry. Recently he has been involved in the verification of Mochizuki's work on the ABC Conjecture, and was invited to speak on this topic in Kyoto. He also has a popular math vlog on YouTube.

JAMES KAY

Lecturer
Electrical and Biomedical Engineering

With more than 30 years of experience in engineering in the aerospace industry, Kay spent the majority of his career at United Technologies, where he oversaw such systems as aircraft fuel gauging, electric braking, air data, actuation, smoke detection and aircraft health usage and maintenance. He received his bachelor's degree in electrical engineering from MIT, and his master's and PhD from UVM. Kay is also an avid amateur astronomer.

JUNIPER LOVATO

Director of Outreach
Complex Systems Center

Lovato comes to UVM from New Mexico, where she was the co-founder and board member of a nonprofit community makerspace and the Director of Complex Systems Education for the Santa Fe Institute. She is a graduate of the College of Santa Fe and received a master of arts in the Western classics from St. John's College. Lovato also served on influential boards including the Santa Fe Railyard Community Corporation, the Mandela International Magnet School and the Los Alamos National Laboratory Foundation.

BREE MATHON

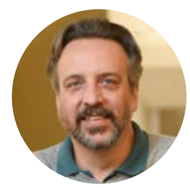
Lecturer
Civil and Environmental Engineering

Before coming to UVM in August 2017, Mathon taught part-time not only here but also at the Community College of Vermont and Johnson State College. She was a professional academic coach at Johnson State College, and studied at Hofstra University, SUNY Stony Brook and UVM, where she received her PhD in 2011. Mathon's dissertation was on assessing uncertainty associated with groundwater and watershed problems using fuzzy mathematics and generalized regression neural networks.

PUCK ROMBACH

Assistant Professor
Mathematics and Statistics

Rombach spent four years as an assistant adjunct professor at UCLA, following the 2013 completion of her PhD at the University of Oxford. During her PhD she researched coloring, centrality and core-periphery structure in graphs; focusing on bridging gaps between the pure and applied sides of graph and network theory. She has also recently worked on algorithm analysis of graphs, as well as coding problems related to graph coloring.



ANDREA VACCARI

Lecturer
Electrical and Biomedical Engineering

Holding a master's in physics from the Università degli Studi in Milan and a PhD in electrical engineering from the University of Virginia, Charlottesville, Vaccari worked for the National Radio Astronomy Observatory from 1998 to 2012, and for the Virginia Image and Video Analysis laboratory from 2010 until joining UVM this spring. His main research interests include image and signal processing with emphasis on remote sensing and biomedical and biological images, model-based data mining for large spatiotemporal datasets, and graph signal processing.

Faculty Photos: Sally McCay and David Seaver

NEW PROGRAMS

BY LUIS A. GARCIA

At the February 2018 Board of Trustees meeting, three exciting new graduate programs in the College of Engineering and Mathematical Sciences were approved. Congratulations to Dean Luis Garcia and the faculty, staff and students in the College.

STEM COMPLEX
DISCOVERY BULIDING
Photo: Sally McCay

ENGINEERING MANAGEMENT (EMGT), MASTER OF SCIENCE

At the dynamic intersection of Engineering and Business Management, the University of Vermont is launching a Master of Science in Engineering Management (EMGT) degree. Built for aspiring professionals who are eager to enter the management phase of their career, we have created a flexible program that will allow a diverse cohort to be trained in the management of engineering, statistical quality control for manufacturing and product delivery, and engineering management information systems. With core courses such as Engineering Project Management and Fundamentals of Accounting and electives in Management, Entrepreneurship, Supply Chain Management, Statistical Analysis, Integrated Product Development and Deterministic Models Operations Research, graduates of the MS in EMGT program will be able to manage complex projects and problems, assess data to make informed and sound decisions, identify and manage risks, lead multidisciplinary teams and communicate effectively with both internal and external stakeholders. Within the program, some students will have the opportunity to work on a project with an Engineering Management faculty member and advisor to gain practical and hands-on experience.

COMPLEX SYSTEMS AND DATA SCIENCE (CSDS), DOCTOR OF PHILOSOPHY

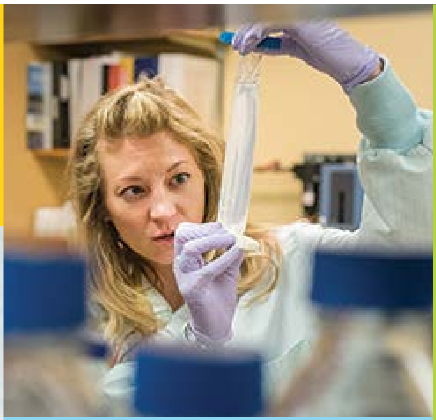
Complex Systems is a growing area of expertise and reputation at The University of Vermont. Since the creation of The Vermont Complex Systems Center in 2006, the University has developed a Certificate of Graduate Study in Complex Systems (2008), a Master of Science in Complex Systems and Data Science (2015) and most recently, a PhD in Complex Systems and Data Science (CSDS), beginning in Fall 2018. The pan-disciplinary PhD in Complex Systems and Data Science will be housed in the College of Engineering and Mathematical Sciences, providing strong computational and theoretical training, but varying with each student's chosen area of focus. Students will work within research groups across campus. With core courses such as Data Science, Principles of Complex Systems and Modeling Complex Systems and electives such as Machine Learning, Complex Networks, Evolutionary Computation, Human Computer Interaction and Data Mining, students will receive core training in empirical, computational and theoretical methods for describing and understanding complex systems and predicting, controlling, managing and creating such systems. Upon graduation, it is expected that graduates from the PhD in Complex Systems and Data Science will be highly sought out for professional roles in data science in a myriad of areas, including but not limited to, government, the military, journalism, professional sports and corporations.

BIOMEDICAL ENGINEERING (BME), MASTER OF SCIENCE

Leveraging strong ties between the University of Vermont's College of Engineering and Mathematical Sciences and the Larner College of Medicine, the new Master of Science in Biomedical Engineering (BME) was created to give students the opportunity to develop advanced skills so that they may apply engineering methods to address problems related to human health. Students enrolled in the MS in BME degree will have the opportunity to pursue a research-oriented, thesis-based, project-based or coursework-based program. Students who want to participate in research may consider some of our interdisciplinary labs to pursue their research interests. In the M-Sense Lab, the team is focused on developing methods for characterizing human biomechanics and physiology that employ cutting-edge technologies such as wearable and mobile devices. The Musculoskeletal Imaging and Orthopaedic Biomechanics (MIOB) Laboratory works to improve human health and performance for those who suffer from musculoskeletal and orthopaedic conditions using both experimental and computational methods. EBRL, or the Engineered Biomaterials Research Laboratory, investigates natural materials and synthetic polymerization techniques to afford a platform of innovative and sustainable products for fields such as materials science, engineering and medicine. Program faculty also work in multi-departmental and multi-disciplinary lab centers, such as the Vermont Lung Center.

RYAN MCGINNIS
Assistant Professor/Director, M-Sense
Department of Electrical and Biomedical Engineering and Department of Mechanical Engineering

PETER SHERIDAN DODDS
JAMES BAGROW
CHRIS DANFORTH
Department of Mathematics and Statistics and Vermont Complex Systems Center



RACHAEL OLDINSKI
Assistant Professor/Director, EBRL
Department of Mechanical Engineering and Department of Electrical and Biomedical Engineering

Photos: Sally McCay

COMPUTING POWER IN NUMBERS

2017 Computer Science Fair features nearly 200 student projects

Improving response to humanitarian crises. Holding politicians accountable for their voting records. Sorting "fake news" from real headlines. Today's world offers no shortage of daunting challenges, at the UVM Computer science fair 354 students presented their solutions to these issues and more in the form of 187 websites, apps, and programs.

The Computer Science (CS) Fair, held every fall semester in the Davis Center, is a chance for Catamounts to show off everything from web design to sophisticated programming to in-depth research projects, and win up to $300 in prizes.

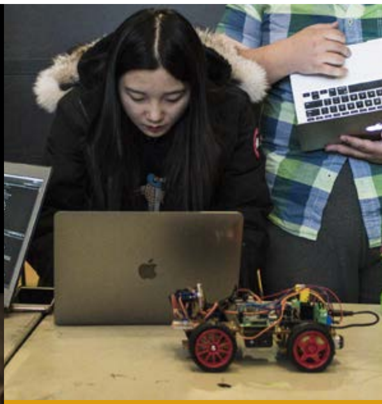
The fair isn't made up of all CS majors or minors; some are students enrolled in their very first computer science course, like business administration sophomores Maddie Stoops and Maia Parker. Over the last semester, the two developed a program that delves into pay inequality in the U.S., an issue both students are curious about. It lets users see how education level, age, race, and profession impact wage. The class, says Parker, has been really valuable. "Coming out with programming knowledge is huge in today's world. It really makes you think in a different way."

Local pros from potential employers, including IBM, MyWebGrocer, and Logic Supply, stroll the ballroom with clipboards, judging the work. Tyler Van Ollefen with Union Mutual says seeing students in action is inspiring. "I like that there's a bunch of people who clearly have a passion for what they're doing."

And for some students, those passions lie in other worlds, like junior Liv Jensen and sophomores Austin Viveiros and Beau Duval, who developed a website that allows visitors to create their own Star Wars character, and see how its attributes rank among peers. Beyond testing their knowledge of planets and weapons, the trio learned how to work like a true team, each finding their niche. "In a group, you have to change the way you think and match up your skills," says Duval.

Other projects included an impressive, smart baby monitor by graduate students Anna Waldron and Viktoria Manukyan, developed in an advanced machine learning course to automatically detect a baby's cry, laughter, and other sounds. And, there was sophomore Phillip Nguyen's CNC router (he describes it as a "3-D printer in reverse,") powered by a small, embedded computer that can be controlled remotely via Internet. The machine, which can cut wood, placed second among intermediate projects. "CNC routers are used in the manufacturing industry," explains Nguyen. "They're usually about three thousand dollars, but this was about two hundred dollars. I wanted it to be as affordable as possible."

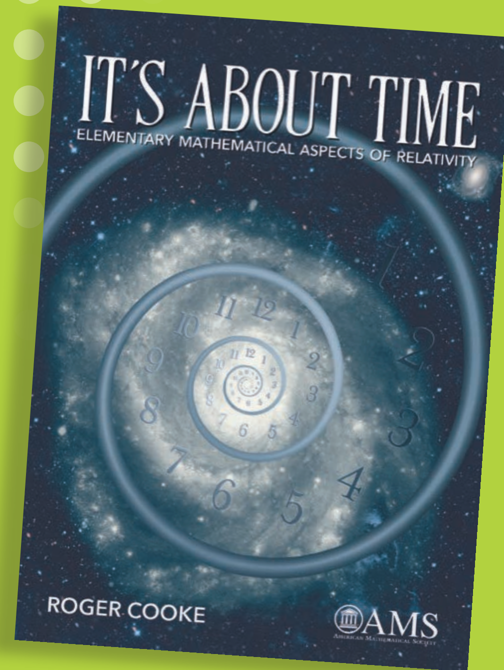
The Computer Science Fair, held each fall semester in the Davis Center, is a chance for Catamounts to show off everything from web design to sophisticated programming to in-depth research projects, and win up to $300 in prizes.
Photo: Ian Thomas Jansen-Lonnquist '09



NEWS

In the introduction to the new catalogue *UVM Publications and Creative Works*, President Tom Sullivan and Faculty Senate President Catherine Paris write, "It is with great pride that we recognize the publication achievements in 2017 of our University faculty and staff, celebrating their path-breaking scholarship and creative output…Our land-grant research University, built solidly upon a foundation in liberal arts and scientific inquiry, endeavors to positively impact our community and our world through the discovery and dissemination of new knowledge."

We congratulate CEMS Professor Emeritus Roger Cooke for his recent publication *It's About Time: Elementary Mathematical Aspects of Relativity.*



IT'S ABOUT TIME:
ELEMENTARY MATHEMATICAL ASPECTS OF RELATIVITY
Roger Cooke
Professor Emeritus, Department of Mathematics and Statistics

UVM STUDY RANKED AMONG 2017'S MOST POPULAR

A UVM research study, which discovered Instagram photos hold clues to aid in the early detection of depression, was one of the 20 most popular pieces of academic research in all of 2017, according to a new ranking.

The annual Altmetric Top 100 ranks which pieces of research have caught the public imagination in the last 12 months. To determine 2017's list, Altmetric tracked over 18.5 million mentions of 2.2 million different pieces of research.

The study by **UVM professor Chris Danforth and Andrew Reece of Harvard University,** "Instagram photos reveal predictive markers of depression," came in at No. 17. Danforth is a professor in UVM's Department of Mathematics & Statistics and co-director of the university's Computational Story Lab.

Published Aug. 8, 2017 in a leading data-science journal, *EPJ Data Science,* the research was covered by media outlets around the world including *The New York Times, USA Today, Quartz,* and nearly 250 others. The study was also mentioned in thousands of tweets, blog posts, and more.

"As in previous years, medical and public health issues have drawn the highest levels of attention," according to Almetric's website.

PREDICTIVE MARKERS
Research from August 2017 shows that Instagram photos posted by depressed individuals had values shifted towards those in the right photograph—darker, grayer and bluer—compared with brighter photos posted by healthy individuals.

Photo: EPJ Data Science

L. Richard Fisher Professor Paul Hines, and Professor and Fulbright Distinguished Chair Jeff Frolik.

< /RELIABLE RENEWABLES >

A TEAM OF UVM RESEARCHERS WANT TO BALANCE SUPPLY AND DEMAND IN THE NATION'S ELECTRICAL GRID, ONE PACKET OF ENERGY AT A TIME

BY JOSHUA E. BROWN

Paul Hines, the L. Richard Fisher Professor at UVM's College of Engineering and Mathematical Sciences, shares an office with Homer Simpson. Well, not technically, but a print of the animated cartoon character at work—cooking hot dogs on the control panel at the Springfield Nuclear Power Plant—hangs on the wall of Hines' office, opposite a whiteboard filled with complicated physics equations.

It's an apt juxtaposition for Hines, as one of three UVM faculty members whose research has formed the basis of Packetized Energy, a new company that is cooking up a hot-dog approach to a control system for renewable energy resources through complex computations, streamlining the way the world charges and stores electricity.

"I'm working on describing how to manage a battery in a power system," says Hines of the whiteboard equations, during an interview on the eve of his departure to speak about this new technology at the Grid Edge World Forum in California. "How do you manage batteries best? When do you put power in, or pull power out?"

All are critical questions, as trains will stop, stoplights will fail, and people will become stranded during the massive power outages triggered by improper management of the electrical grid—the network of power lines that distribute electricity to millions of consumers. "It becomes a near doomsday scenario, and it can happen on a regular basis, because the grid is vulnerable," says Hines.

> **"We're designing a system that can balance the ups and downs of renewable energy in a way that can keep the reliability we've grown accustomed to."**

Growing up in Tacoma, Washington, Hines had a hankering for engineering early on. He tinkered with Legos and was fascinated with how things worked. "Maybe it was rebellion against my parents, who were both English majors—I was going to solve nuclear fusion," he says with a laugh. "I've always been interested in energy." Learning how the world runs on power systems and electricity, he was hooked on discovering "how the grid works, and how to move my career in that direction."

Hines' scholarly pathway has been firmly linked with the grid. He earned a BS in electrical engineering from Seattle Pacific University, and an MS at the University of Washington, where his thesis title was "A Power Systems Capstone Design Project and Associated Simulation Software Designed to Meet the Changing Needs of the Electrical Power Industry and Engineering Accreditation Requirements." That, in turn, gave way to "A Decentralized Approach to Reducing the Social Costs of Cascading Failures," his dissertation for a PhD in Engineering and Public Policy from Carnegie Mellon University.

It wasn't until 2011, however, that Hines took these topics to a new level by brainstorming ideas with Jeff Frolik, a fellow

UVM professor and Fulbright Distinguished Chair in the Department of Electrical and Biomedical Engineering, who had been studying how to manage wireless sensor networks. "We developed a way to take this algorithm and apply it to power," says Hines, adding that the next key development was Assistant Professor Mads Almassalkhi, suggesting that they could extend this theory to other applications—such as water heaters, air conditioners, and batteries.

"So now we're taking these core computational algorithms and applying them to lots of different things that might get plugged into the grid," says Hines, "so that we can run everything without blowing up the grid."

The nationwide power grid—which can only transmit electricity, not store it—is experiencing a period of rapid change, he adds, thanks to the addition of wildly fluctuating wind and solar power sources coming into a system designed for much more stable, predictable nuclear and coal power plants. Put them all together, and you get a grid in crisis. Also seesawing is the price of electricity, which can go from 2 cents per kilowatt hour on a "normal" day to up to an effective price of $100 per kilowatt hour on extremely hot summer days. Synchronizing all the elements flowing into the grid has tremendous value. Instead of managing the supply of electricity at the level of the enormous, sprawling grid, the Packetized device puts supply management right in individual homes and businesses.

That's what guided Hines, Frolik, and Almassalkhi when they co-founded Packetized Energy in 2016, with the basic aim to take their research and use it to build a software platform to connect electricity customers and suppliers in a much more systematic fashion.

"In very simple terms, the technology we are developing, producing, and commercializing aggregates and coordinates a fleet of energy resources that sit in people's homes—in basements and closets—that people do not interact with, but use every day," explains Almassalkhi.

"By doing so, we're able to offer valuable services to utilities and other energy market participants at the very highest level."

On the screen of his MacBook Pro, Hines brings up a dot-filled diagram showing electrical power usage in Poland. Connect the dots as an example of the scholarship he and his colleagues have undertaken, and the resemblance of a circulatory system emerges—an alien system, perhaps, one that pumps a different sort of electronic blood to different, unfamiliar body parts. It's a view of the world that has shaped the dozens upon dozens of peer-reviewed journal articles, book chapters, policy reports,conference papers, and presentations they have authored and co-authored.

Putting these words into action, however, is the mission of Packetized Energy. The groundwork for this was laid even before the company's founding, thanks to the foresight of Almassalkhi, who joined the UVM faculty in August of 2014 and was soon putting together a proposal for the Department of Energy (DOE). "As young faculty, you seek funding, so you come up with crazy ideas," he says, explaining how he reached out to the Advanced Research Project Agency-Energy (ARP-E) with the underlying concept for Packetized Energy. Because the DOE's ARPE requires a commercialization path for approved projects upon completion of a three-year grant, Almassalkhi drafted a basic business plan in his proposal.

ARP-E responded with $1.7 million in funding for UVM's Packetized Energy Management project, to run from mid-2016 through 2019. Instead of waiting for 2019, though, the Packetized Energy team was able to step outside of the standard ARPE template. "It's a highly competitive program, so we realized we were onto something special," he says. "We looked at the market, and the competing technology, and we realized we needed to strike very early."

Their mobilization was swift. They hired chief engineer and UVM graduate Andrew Giroux, and created a website that clearly lays out the premise of Packetized Energy: to design and deploy "human-friendly systems to enable distributed energy sources such as water heaters, electric vehicle chargers, battery storage systems and pool pumps to balance supply and demand in the power grid. As a result, people can better manage their energy costs and the grid can run reliably with renewable energy." The founders also present the advantages of the patent-pending Packetized Energy Management (PEM): local decision-making, privacy, fairness, scalability, and the ability to be adaptive.

The Packetized co-founders, meanwhile, have learned plenty as they meet the obstacles that can arise from introducing an innovative concept to the renewable energy world. "The biggest challenge has been finding partners that are willing to work with a very small company," says Almassalkhi, "with enormous promise but a small track record. How do we find partners that are willing to work with us in the same agile way we work?"

Continued on page 23

< / SOLVING FOR THE DIGITAL AGE >

A CYBER APPROACH TO ACL REHAB: TOTH AND SKALKA BME GRANT BREAKS NEW GROUND

UVM professor and researcher Christian Skalka, demonstrates how RehabTracker out-of-compliance notifications could appear on patients' phones.
Photos: Sally McCay

BY MICHELLE BOOKLESS

In patients who have suffered a traumatic knee injury, a successful return to the skeletal muscle function they had prior to injury is difficult. The injury and surgical repair cause them to be very inactive, causing their muscle to shrink, or atrophy, and weaken. Physical therapy prior to surgery is often not physically feasible, and post-operative strengthening exercises generally don't start for several weeks after the procedure. This muscle atrophy and weakness increases the risk of re-injury and developing knee osteoarthritis in the future.

Over the years, care providers have sought to overcome these hurdles through the use of neuromuscular electrical stimulation (NMES) devices, which contract muscles through the use of electrical stimulation in a manner similar to that generated by normal physical exercise. While the devices have been successfully used in clinical settings to reduce muscle atrophy and improve muscle contraction in post-surgical patients, they are typically not used prior to surgery and are not regularly available to pre- and post-op patients for at-home use. Enter University of Vermont researchers Michael Toth, and Christian Skalka.

In early 2017, the two faculty members—a professor of medicine and associate professor of computer science, respectively—were awarded one of two inaugural UVM Biomedical Engineering (BME) Pilot Research Program grants for their project, "Cyber-physical system innovations to monitor and improve compliance with at-home neuromuscular rehabilitation." Through the project, Toth and Skalka have worked to create a cyber-physical electrical stimulation system that acts as a bridge therapy for patients immediately post-injury and in the time between surgery and the start of physical therapy.

Their idea is simple in concept, a Bluetooth-enabled personal NMES device that collects detailed data about device usage in real-time and sends these data to a mobile phone app. On

CHRISTIAN SKALKA
Photo: Sally McCay

the other end of the data stream, a backend server hosts an automated compliance analysis algorithm that analyzes the data and sends the care provider and the patient either "in" or "out of compliance" messages.

> **"The use of a mobile app pushes the requirement of internet connectivity to the smartphone hosting the app, and therefore reduces the complexity and power requirements of the device, and eases automated data transfer to the care provider," says Skalka.**

If successful, the device will be the first of its kind to provide real-time monitoring of at-home rehabilitation using NMES.

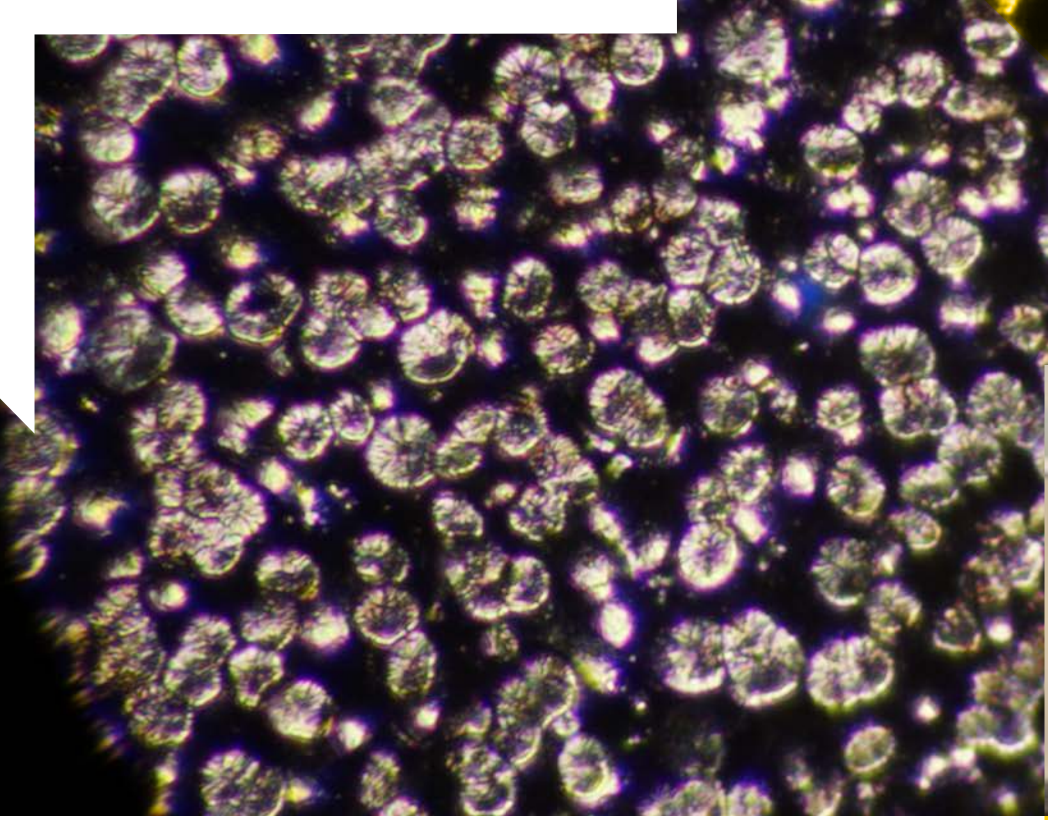
The project grew out of a collaboration between Toth and UVM Professor of Orthopaedics and Rehabilitation Bruce Beynnon, PhD, who are currently conducting a clinical trial testing the utility of NMES in patients with traumatic knee injury under a two-year grant from the National Institute of Arthritis and Musculoskeletal and Skin Disease. While conducting the study, Toth began to consider issues of compliance with prescribed at-home therapies and took the first steps toward developing his and Skalka's new Bluetooth-enabled NMES device prototype. Through a UVM Senior Experience in Engineering (SEED) project directed by Toth in collaboration with Jeff Frolik, Professor and Fulbright-ČVUT Distinguished Chair, Department of Electrical and Biomedical Engineering, the initial building blocks of Skalka and Toth's current project were put in place and a prototype of an instrumented NMES device was successfully created.

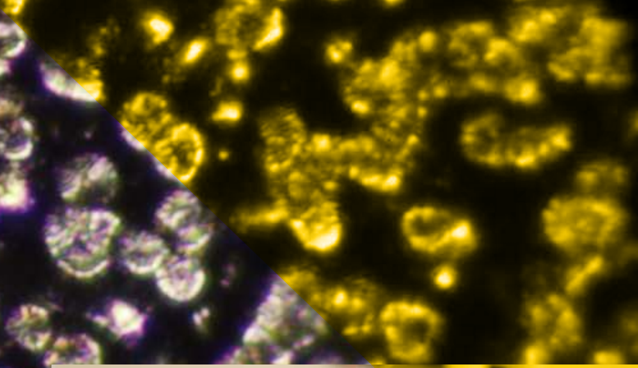
Now, six months into their BME-funded project, Toth and Skalka not only have the hardware piece of their "cyber-physical system" completed, but the iPhone/tablet-compatible mobile app has been completed as well. Supervised by Skalka and using code initially written by students in CS275: Mobile Apps and Embedded Devices, a UVM Computer Science course, BME research graduate assistant Tim Stevens and UVM Global Gateway Program student Chia-Chun Chao, have created a functional app, currently called RehabTracker with a patient interface that provides users with graphical reporting of their recent device usage and notifies them if they are in or out of compliance with their provider-prescribed NMES program. They've also developed the code necessary to analyze the data being sent from the device to the app and a web interface for providers to review device usage and program compliance.

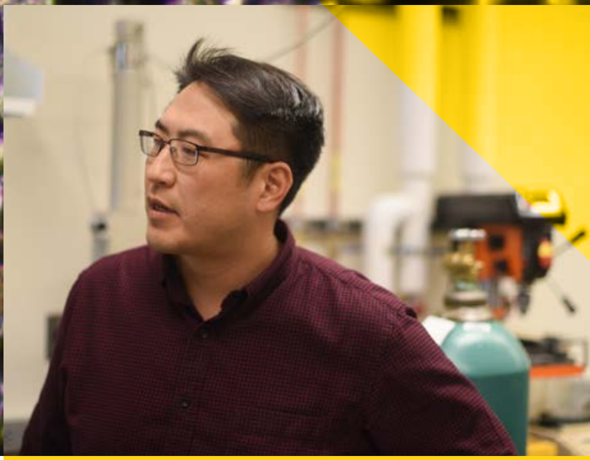
The in or out of compliance messages patients will receive were initially created by Toth and then honed by UVM Professor of Nutrition and Food Sciences Jean Harvey, PhD, RD, who is an expert in digital communications with patients in behavioral weight control and lifestyle modification programs.

The project is expected to enter its next phase with proof-of-principle testing of the system in a cohort of healthy, young patients who have suffered an anterior cruciate ligament (ACL) rupture and are scheduled to receive reconstructive surgery. Toth and Skalka hope the tests will provide evidence that the system successfully tracks patient device usage, transmits and interprets the data in an effective way, and allows innovative clinician-patient communication about compliance with prescribed rehab programs.

If successful, Skalka and Toth will be one step closer to the creation of a new transitional therapy system that could extend the benefits of exercise to those with orthopedic injuries or surgery who otherwise couldn't participate in rehab. They hope that the system will have wider utility in other populations for whom typical exercise is prohibited or difficult, such as patients with cancer undergoing chemotherapy and those with chronic diseases who experience acute disease exacerbation.







POLYMER CRYSTAL DETAIL
Photo: Taylor Ducharme

PROFESSOR PATRICK LEE
Photo: David Seaver

SMART STRUCTURES

BY SARAH TUFF DUNN

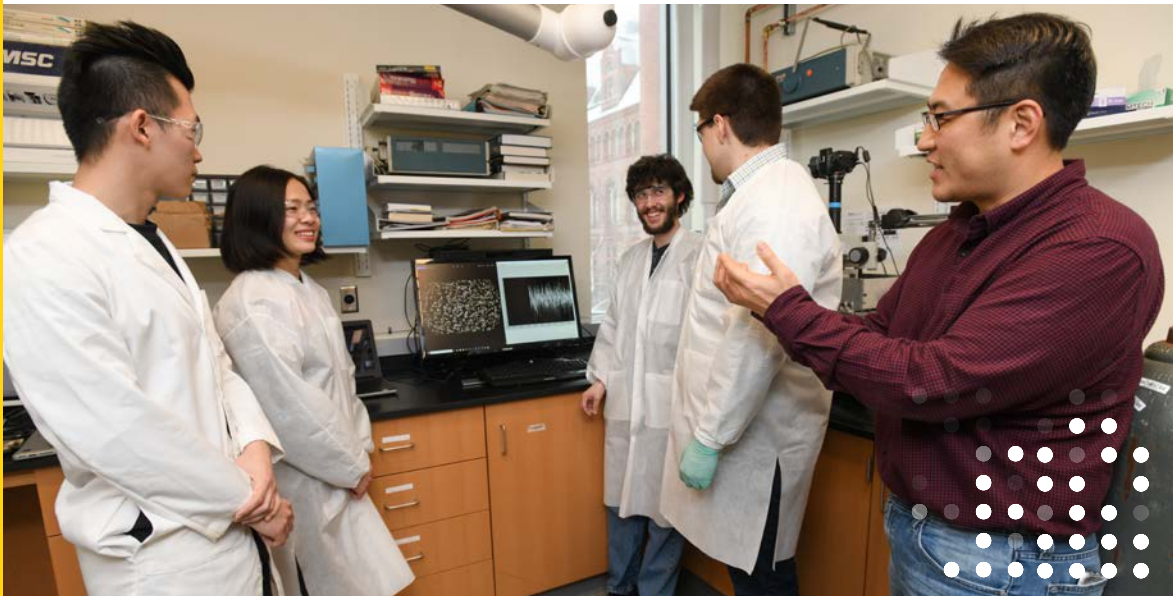
How CEMS-led research on smart and lightweight polymers are reducing cost and waste for the automotive and aerospace industries and beyond

"One word: plastics." Yes, that's what Dustin Hoffman's character famously hears in the 1967 film "The Graduate." Fast-forward 51 years and plastics are, well, still problematic. "Plastics have a bad name," says Assistant Professor Patrick Lee of the College of Engineering and Mathematical Sciences (CEMS), who is using a dynamic new lab in the recently unveiled STEM complex to give plastics a good name.

"My main focus is creating lightweight structures as well as smart structures," says Lee, citing key concepts in engineering and materials science. As Vinod K. Wadhawan writes in *Smart Structures: Blurring the Distinction Between the Living and the Nonliving*: "A structure is an assembly that serves a living function. A smart structure is one that serves this function smartly, i.e., by responding adaptively in a pre-designed useful and efficient manner to changing environmental conditions. Smartness is normally associated with living beings, because they have the tendency to adapt themselves to changing situations. Artificial smart structures are designed to mimic biological structures to a small or larger extent."

Smart structures are also intelligent for the livelihood of the natural world. Lee adds that by reducing weight and improving strength in plastics, he and his team can dramatically reduce wasted byproducts. "If we look at the plastics industry, up to 70 percent of the cost or resources are coming from raw materials. Foaming will use less materials and less waste, and the same is true for microfibers."

Saving natural resources synergizes well with the long-term vision of the state-of-the-art STEM complex, whose disciplines of science, technology, engineering and mathematics have been associated with promising opportunities in protecting the planet. The 266,000 square foot, $104 million complex consists of three buildings: Discovery Building, a new state-of-the-art research and lab facility to replace Cook, Innovation Building, a new



SOLVING FOR THE BIGGER PICTURE: Eric Kim, Selina Yao, David Bernier, Taylor Ducharme, and Professor Patrick Lee.
Photo: David Seaver

flexible and tech-equipped classroom and office building, and an extensively renovated Votey Hall.

The final stage of the three-phase, four-year project—identified as the highest priority construction in the University of Vermont's Capital Plan—will be the opening of the classroom and offices in Innovation in May 2019. Discovery opened for classes last summer and Votey renovations were completed in the fall.

Lee's lab is located in the Discovery Building, a new state of the art research a laboratory building. The lab is equipped with the latest tools to test boundaries while the design of the building allows for a productive workflow. "The cross collaboration with equipment is really helpful," says graduate student Taylor Ducharme. "Because of the ventilation, we have a lot more opportunities than our previous space." Working with plastics, he explains, produces off gases that must be ventilated properly.

Working in close proximity to Professor Sansoz and his lab creates an accelerated atmosphere of discovery. "It's really interesting sharing space with Professor Sansoz and his group, because they're mainly looking at the nanoscale of metals and how they form," says Ducharme, "whereas we're looking at an analog with plastics, so talking with their team is helpful, and the lab is really fun." Working alongside Ducharme in the Multifunctional Composites Manufacturing Laboratory are fellow graduate students Selina Yao, Eric Kim and Sandra Romera Diaz, plus undergrad David Bernier.

Their pioneering polymer research could have a big impact on the earth by reducing byproducts from the aerospace, automotive, biomedical and packaging worlds. "The strain hardening behavior of polymers has important roles in processing such as foaming, film formation and fiber spinning," write Lee and co-authors in a recent issue of *Polymer*. "The most common method to enhance strain hardening is to introduce a long-chain branching structure on the backbone of a linear polymer, but this method is costly and challenging to tailor the behavior."

"This could allow manufacturers to tune their process to create stronger lighter materials out of more environmentally friendly products," says Ducharme, "replacing the same products used with less materials that end up in landfills."

In another paper, Lee's team shows how an "innovative fiber reinforcement technology" can create up to a 145 percent increase in maximum bending strengths in concrete. That means that your future basement might be better able to withstand natural disasters, thanks to the research underway in the STEM complex. The Amazon box that arrives at your home may also become more lightweight, with its contents (say, a plastic Fujifilm Instax camera) using fewer natural resources. The car that you drive to an airport has better functioning parts, and the foam seats on your flight to Hawaii is smarter — all beginning with polymer experiments.

There's no crystal ball to guarantee the outcome of Lee's work, and the cross-collaboration with the Sansoz team, but by looking at crystals and gases in plastics, this CEMS subset is paving the way for a more promising future for the material.

WHEELS IN MOTION

ENGINEERING STUDENTS WORK WITH NASA TO DEVELOP NEW LUNAR ROVER WHEEL TECHNOLOGY

Liam McAuliffe, Liz Barrett, Adam Potasiewicz, Thomas Durivage, and Catherine Simpson. NASA Glenn Research Center, Lewis Field

BY SARAH TUFF DUNN

Does NASA really need to reinvent the wheel? When it comes to navigating the moon's surface, yes. It turns out that UVM is assisting the effort with cutting edge research from students who've been specially selected as participants in the highly competitive eXploration Systems and Habitation (X-Hab) 2018 Academic Innovation Challenge. UVM is one of just 11 university teams NASA chose to design systems and technologies that enhance the agency's ability to explore deep space.

Since early September 2017, engineering seniors Liz Barrett, Thomas Durivage, Liam McAuliffe, Adam Potasiewicz, Catherine Simpson and junior Boxiong Yang from the College of Engineering and Mathematical Sciences (CEMS) have been working to develop a single-wheel test bed that would aid NASA's Resource Prospector mission, which aims to be the first robotic rover to search for water ice trapped in the lunar soil. The team is designing a rover wheel testing device compatible with NASA's reduced gravity aircraft that allows wheel testing under simulated lunar gravity.

"This is by far the biggest project I've done," says Potasiewicz of the year-long effort, which is also a senior engineering capstone project.

"It's way different from internships in the past, in a way different environment, and it's helping me refine what I want to do in the future."

That different environment includes NASA's Glenn Research Center in Cleveland, Ohio, where, in November, the team presented the design concept "Reduced Gravity Airborne Mobility Testbed" that is now being built. The students are being advised by engineering faculty Professors Darren Hitt (Mechanical Engineering) and Mandar Dewoolkar (Civil and Environmental Engineering), along with Ryan McDevitt, PhD from Benchmark Space Systems, Inc. in South Burlington (a UVM adjunct who is also serving as an industrial mentor). The students have not only contributed to NASA research, but also reaped

SAND BED:
The UVM XHAB team resets the single wheel testbed in the Slope Lab at NASA Glenn Research Center after a trial.

WHEEL TEST:
"This test was run in the Slope laboratory's single wheel tester, which was actually built in house by some of the engineers we talked to, and learning about it was invaluable to our capstone project," explains team member Liz Barrett. (NASA Glenn Research Center)

Photos: Adam Potasiewicz

tremendous knowledge about practical applications.

After the NASA Glenn visit, Durivage and the team received feedback that gave them more perspective. "I had a preconceived idea of what it means to design something, so the NASA visit was invaluable," says Durivage, adding that the biggest challenge so far has been balancing the X-Hab project with classes. "For all intents and purposes, we are students, and these are real-world problems and criteria for NASA and the world."

"After our call for proposal, UVM had the most promising idea," says Paul Banicevic, a systems engineer at NASA Ames who is part of the Resource Prospector Team and the lead NASA mentor for the UVM X-Hab team. "And the process pivoted exactly how I hoped it would, growing from there being kind of new, and not really understanding, to really owning and providing great design. Sure, we had the idea of putting it on a plane, but the UVM students put their own custom stamp on it. The insight and the enthusiasm has carried over to my side, as well."

The X-Hab project is an outstanding opportunity for these UVM undergraduate students and is just one example of the opportunities generated by the Vermont Space Grant Consortium (VTSGC) founded in 1992 as a statewide initiative and now overseen by Hitt, a professor of mechanical engineering in CEMS. "I've made it a priority to expand undergraduate opportunities in aerospace science and engineering," says Hitt. Design competitions such as the X-Hab, weeklong summer workshops and NASA internships are among the ways that UVM students are finding a foot in the door at leading companies including Boeing, Blue Origin, the United Launch Alliance (ULA) and even SpaceX, which just sent a Tesla into space. "A number of our students have gone into aerospace engineering at high profile companies," says Hitt.

The work also reflects the interdisciplinary collaboration that happens across CEMS and UVM and is critical to the aerospace industry, adds Hitt.

"The teams really have to work and integrate together well, with very strong, meaningful communications with NASA mentors," he says. "The X-Hab (project) has very exact design specifications, and NASA has made some changes along the way, causing the students to quickly turn around and find a new design—it's amazing; they are so dedicated and hard-working."

Such a process has turned frustrations into tremendous rewards, report both the students and their mentors. Learning the agility to respond immediately, graciously and accurately to a new design demand or constraints is an invaluable lifelong skill, as is learning professional coping mechanisms to avoid becoming overwhelmed by expectations.

"It a unique opportunity in that it is truly going to pay off in their careers," says Hitt of the experience enjoyed by the students in the X-Hab 2018 Academic Innovation Challenge.

BIOMEDICAL ENGINEERING STUDENTS
DIVE INTO RESEARCH

An algorithm to help predict and maybe even prevent injury in athletes. A computer mode—built from scratch—to teach physicians about atrial fibrillation, one of the most common heart conditions in the country. Not only are students in the University of Vermont's Biomedical Engineering Program engaged in all of these projects, in many cases they're driving the conversation forward, looking at problems from new angles and solving them in creative ways.

BY SARAH TUFF DUNN

This dynamic approach to learning is no accident, says UVM Assistant Professor of Electrical and Biomedical Engineering Ryan McGinnis, who helped to design the program and now advises many of its students, in addition to teaching courses. The goal was to offer an undergraduate degree that hinges on real world application.

"I'm always amazed by the creativity students bring to projects," he says. "They find innovative solutions."

LARA WEED AND JORDYN SCISM
Photo: Ryan McGinnis

Created just three years ago, the Biomedical Engineering bachelor of science program has experienced dramatic growth, from 12 students in its first year to 60 students who have declared the major in the most recent incoming class. Students choose from three concentrations: Biosensing and Instrumentation; Cell, Tissue and Organ Biomechanics; and Systems and Network Biology.

From day one through graduation, the focus is on applied learning: in a first-year course titled Introduction to Biomedical Engineering Design, students collaborate with physicians at UVM Medical Center to solve a clinical problem. And, for their capstone projects as seniors, students choose from proposals made by physicians who want to work with a biomedical engineering student on a longer-term project, again focused on clinical challenges in need of a solution.

"There are very few places in the U.S. where you have an engineering school and a medical center on the same campus," says McGinnis. "This leads to unprecedented access to medicine."

UVM Professor of Medicine Peter Spector, MD, a cardiologist and researcher at UVM Medical Center, has made it a priority to bring students into his lab, where he focuses on a condition called atrial fibrillation. He feels his work benefits as a result.

"Students bring an enormous amount of enthusiasm," Spector says. "They make you stop and think things through."

Spector met Lara Weed '19, a junior in the Biomedical Engineering Program, after he gave a guest lecture in one of her classes. After her enthusiastic questions generated a conversation about research opportunities, a partnership was formed. She's now creating a genetic algorithm based on thousands of data points from real EKGs to visualize the electrical activity of the human heart. For Spector, Weed's work serves as the foundation for what stands to be an important teaching tool. And it's a great education for both mentor and mentee.

"We built this program from a blank sheet of paper," says Spector. "I believe that active learning is better than passive learning for faculty as much as students."

This experience prepares Weed and her classmates in the Biomedical Engineering Program for any number of careers. It provides a solid foundation for medical school, says McGinnis, as well as doctoral work in biomedical engineering. Tech companies large and small are also eager to hire graduates ready to dive in to new projects and challenges. With Burlington's growing tech scene, many students get plugged into these opportunities before they even graduate.

For Spector, the skills and aptitudes students develop set them up well for a rapidly evolving range of careers—and some that may not even exist yet.

"This type of education prepares you for whatever you want to do," says Spector.

OTHER STUDENTS IN THE BIOMEDICAL ENGINEERING PROGRAM ARE FORGING UNIQUE PATHS THROUGH THEIR FOUR YEARS OF STUDY:

KASEYA XIA
Photo: David Seaver

JORDYN SCISM '19

Presenting her poster at UVM's annual Student Research Conference helped Jordyn Scism '19 hone her public speaking skills in front of a large and diverse audience. "I was really nervous about it, but many people enjoyed listening to what I was working on," she says. "I was briefly interviewed by a radio station and a reporter on campus who wrote a review and summary of the conference."

Her research in the lab of Ryan McGinnis seeks to answer a vexing question for athletes in a variety of sports, from basketball to tennis: are there ways to predict, and therefore prevent, sports injuries? After creating an algorithm that processes wearable sensor data culled from a large sample of athletes' jump landings, Scism is using this information to pinpoint patterns that may lead to various injuries, like ACL tears or sprained ankles. Ultimately, the work could be a first step in a new way to prevent injury. For example, athletes could wear sensors that connect with tablets trainers have on the sidelines, giving them the information they need to spot the warning signs of potential injury.

Scism's Biosensing and Instrumentation concentration, with a minor in electrical engineering, sets the Olivebridge, NY, native up for a variety of careers. Not only has she taken a deep dive into advanced math, digital signal processing, synthetic biology and a variety of other subjects through her coursework and research, she's learned first-hand the importance of collaboration in science.

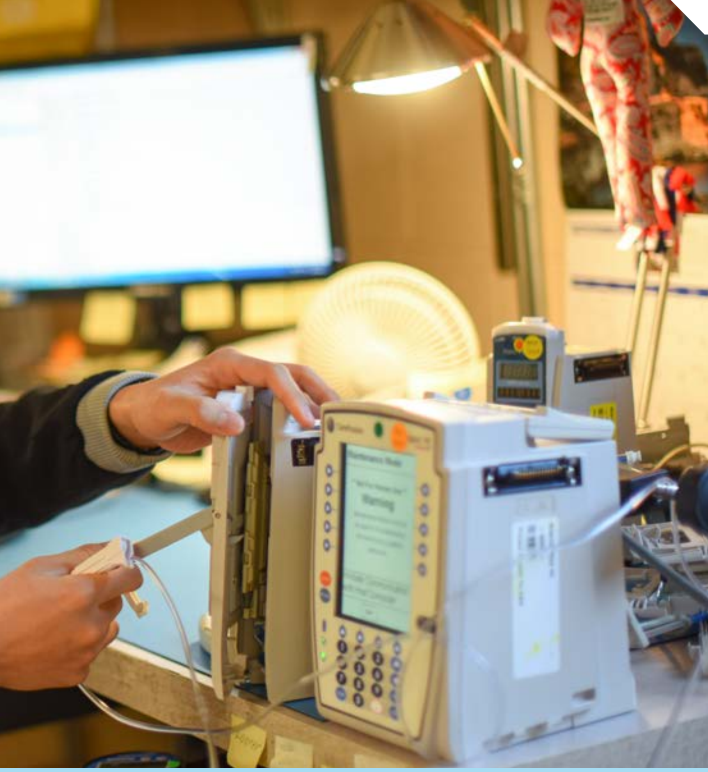
"The community is very welcoming and approachable," she says, "and everyone just wants to see each other succeed."

LARA WEED '19

As a student in the Cell, Tissue and Organ Biomechanics concentration who is also on the pre-med track, Lara Weed '19 has taken full advantage of the wealth of research opportunities at UVM. Some have led to national recognition: Her work with Ryan McGinnis on a validation study of an iPhone app that analyzes a person's gait led to an oral presentation at the 2017 Biomedical Engineering Society Annual Conference. She's also working with UVM Professor of Medicine Peter Spector, MD, on developing a model to find electrical activation cell sites in the heart using EKGs.

"CEMS is built around teamwork," she says. "Everyone works together to understand concepts and help other people understand."

Weed's leadership role as president of the new UVM Biomedical Engineering Society has prompted greater involvement with the Burlington community. The club has created a mentorship program at a local middle school to inspire students to pursue study in STEM fields. The Kingston, NH native says she's inspired by her classmates and the College of Engineering and Mathematical Sciences faculty as they tackle complex problems through cooperation.



SIERRA MCCONNELL
Photo: David Seaver

KASEYA XIA '19

A junior from Kunming, China, Kaseya Xia '19 came to UVM with a specific interest in sensor and signaling technology, a perfect fit with the concentration in Biosensing and Instrumentation. As a volunteer at Burlington Generator, a maker space and business incubator that features a laser cutter, 3D printer, wood and metal shops, a computer lab and more, he has found himself at the nexus of Vermont's creative economy.

"Sometimes by just talking to designers, I feel like there are so many things I can do in the future," he says. "This is a very valuable opportunity and resource I have for my college education."

Xia is also exploring the biomedical field through an internship with the Technical Services Partnership, a division at UVM that helps medical centers across New England incorporate and maintain specialized biomedical technology and devices. He has worked directly with physicians to provide technical support for their research, giving him a sense of the scope of career possibilities.

"This experience has expanded my view of what biomedical engineers do," he says. "It has also given me hands-on experience working on biomedical devices and understanding device inventory management."

SIERRA MCCONNELL '19

In her three years so far as a student in the Biomedical Engineering Program, Sierra McConnell '19 has already built an EKG machine from scratch and designed working spirometers to print 3D. And when she first arrived at UVM, biomedical engineering wasn't even on her list for potential majors. Getting to know fellow students in the program led her to declare a concentration in Systems Network Biology.

"Now it's clear to me that majoring in biomedical engineering was the best decision I ever made," says the Middlesex, VT native. "It challenges me every day, but with the support of faculty and other students at UVM success has always been possible."

Her ongoing role in the lab of UVM Assistant Professor of Mechanical Engineering Rachael Oldinski has introduced her to bench research at the cutting edge.

McConnell has also ventured out of the lab and into the biomedical workforce. Through her internship with Technical Services Partnership, a division at UVM focused on medical technology, she was able to author a report on cybersecurity recommendations for medical devices that she presented to the cybersecurity board at UVM.

Now she has a solid foundation into "how engineers play a crucial role in the safe delivery of medical care to patients."

STUDENT ENGINEERS HER FUTURE WITH HELP OF UVM's FAB LAB

BY JEFFREY R. WAKEFIELD

From the moment Claudia Benito Alston first peeked into the Fab Lab—a crowded room in Votey Hall full of 3D printers, laser cutters, micro-controllers and other high-tech gizmos—she was hooked.

"It had so many instruments for creating things, it just really looked cool," says the mechanical engineering major, who graduated in December.

That first look turned out to be a window on Benito Alston's future at UVM that the then-sophomore couldn't have imagined.

Following her initial encounter, Benito Alston landed a work-study job in the Fab Lab, which has since expanded to a large new space, where she took a particular interest in 3D printers, boxy machines of various sizes that create dimensional objects by building up film-thin layers of plastic, directed by a computer design program.

"I really started learning their capabilities," she says.

When a design project came along that would enable her to put her 3D printer chops to work and was related to an academic area she was interested in—biomedical engineering—she jumped at the chance.

The project, to develop a type of 3D printer called a "bio-printer," which used living material rather than plastic as its basic building block, had additional appeal for Benito Alston: it was centered in UVM's highly ranked on-campus medical school, where faculty often found time to work with and mentor undergraduates.

"When I saw that a doctor at UVM's medical school was heading up the project, I really wanted to get involved," she says.

The doctor was Dan Weiss, professor of medicine at UVM's Larner College of Medicine and a member of the Vermont Lung Center. His project was so provocative, it approached science fiction.

Weiss's goal, in partnership with a colleague at the medical school, was to use a 3D printer to bio-print breast implants made from a living material like collagen for women who'd had mastectomies. The material would also serve as a scaffold, in future stages of the research, for stem cells that would differentiate inside the body into living breast tissue. Weiss also wanted the device to print a variety of other living materials, which could serve as scaffolding, for instance, for lung tissue in patients with lung cancer.

Benito Alston was part of a student team led by postdoctoral student Robert Pouliot that "designed and wired up" an off-the-shelf 3D printer so it would serve the new purpose, Pouliot said.

The project was a major success. "Dr. Weiss is very happy," Benito Alston said. "Whatever further research he and his team do will require minimal engineering input."

"The sky's the limit in terms of what we'll be able to do with it," Weiss says.

The bio-printer success led to yet more 3D printer work for Benito Alston. A graduate student who knew of the project recruited her to work on another student team to develop a 3D printer that would extrude two different materials at the same time, a novel application Patrick Lee, a faculty member in the College of Engineering and Mathematical Sciences, needed in his research.

Art imitates Engineering. For Benito Alston—a dual citizen who grew up in an artistic household in Spain—the wonders of 3D printers and the

Claudia Benito Alston holds a skull she created in the Fab Lab.
Photo: Josh Brown

Fab Lab extended beyond engineering to the art classes she took as part of her art minor.

A true evangelist, Benito Alston reveled in showing her fellow art students how the Fab Lab could be used to make art—like a human skull she created with sections of corrugated cardboard cut by a laser printer, half covered with clay and half exposed—so her fellow students could behold the wonder of the Fab Lab-created architecture beneath.

Ultimately, though, she wants to attend graduate school and put her technical expertise to use in a biomedical engineering career, one for which UVM has given her unique preparation.

"When I apply, I'll have a lot of previous knowledge and a lot of technical information that other kids may not have."

Reliable Renewables: Continued from page 11

Frolik adds that Packetized Energy faces another hurdle: "Demonstrating the full capabilities of the technology requires we have thousands of devices, such as electric water heaters, under management, but that requires a project of that scale to be awarded. So we have a chicken and egg situation."

That situation was aided this summer when the National Science Foundation (NSF) awarded the company a $225,000 Small Business Technology Transfer grant. The NSF grant will allow Packetized Energy to more fully explore coordinating large numbers of solar panels and battery storage systems.

LaunchVT is the name of a community initiative powered by the Lake Champlain Regional Chamber of Commerce to recognize local businesses with exposure for their entrepreneurial efforts, and funds to support their efforts.

In May, Packetized Energy received $15,000 prize money in the competition. "It was a huge win for us," says Hines, who is using the funds to hire a software developer. More recently, in September, the company won the "Future Formula" pitch at the national Climate Economy Conference. Satisfaction comes in less tangible ways, too, such as fostering the friendships that enable growth. "There are certain risks that companies take to work with small, unknown entities," says Almassalkhi. "Luckily, Paul, over the last ten years, has established himself as a presence within the power systems community, and we can leverage those relationships."

Almassalkhi agrees that the LaunchVT recognition was "a fantastic reward," and a validation of the value of the concept of Packetized Energy Management. "This is just the beginning," he says. "We have a long road ahead of us." For his part, Frolik points to the company receiving its first seed investment and that NSF grant. "It's rewarding seeing others be excited about our approach," he says. "We aren't the only company trying to match electric energy demand to the availability of renewable energy, but I believe we are the only one with a solution that can scale to manage millions of devices in a way in which customers aren't bothered."

Keeping cool is key, says Hines, especially with the time crunches of serving as full-time professors while moving Packetized Energy forward into the future. A father of two, he likes to hike and bike in the Green Mountains, but much of his free time is spent investigating, estimating and measuring such concepts as cascading failure risk and the impact of network structures on global power use.

MADS ALMASSALKHI
Photo: Sally McCay

So while Homer Simpson may choose his nuclear station to cook hot dogs, Hines, Frolik and Almassalkhi are just heating things up. When asked if the three co-founders of Packetized Energy ever enjoy outdoor excursions or other diversions together, Almassalkhi laughs. "We don't do anything to blow off steam," he says. "We use steam to push us forward."

A NEW ANGLE ON GERRYMANDERS

BY JOSHUA E. BROWN

Professor Greg Warrington reviews research findings with Professor of Statistics Jeff Buzas, the chair of UVM's Mathematics and Statistics Department. The two collaborated on a forthcoming follow-up study.
Photo: Sally McCay

UVM mathematicians invent tool to judge when voting maps have been unfairly drawn

In 1812, the governor of Massachusetts, Elbridge Gerry, approved a narrow and winding voting district for the state senate that curved from Marblehead around to Salisbury. It looked like a long-necked salamander, Federalist newspaper editors declared. They labeled the district "The Gerry-Mander," and the *Salem-Gazette* warned that it was a "monster brought forth to swallow and devour your Liberties and equal Rights."

More than two centuries later, the fight over gerrymandering continues. Though there is general agreement that to gerrymander is intentionally drawing voting districts so as to advantage one group over another, the precise nature of, constitutionality—and ways to find and measure—this problem are hotly contested.

Now UVM mathematics professor Greg Warrington has developed a new tool to help ferret out gerrymandered districts. "It's called the declination," he says. "Because there is no single standard of what exactly gerrymandering is, there is no one way to test for it. But our measure is better in a lot of ways than the other approaches now being used."

Like the declination on a compass that shows the angle between magnetic north and true north, Warrington's declination is also a simple-to-compute angle. It can reveal when a voting district plan treats the 50% threshold of votes—which is the difference between winning and losing, of course—as unusually important. If a state's voting districts have been drawn without considering whether they will place a party over or under the 50% boundary, a plot of the districts from least Democratic voters to most (or vice versa for Republicans), should make a nice straight line. However, if the line takes a sudden turn at 50%, "watch out," says Warrington, that can be a signal that districts were drawn unfairly, to claim more seats for one party than the other.

In one example, Warrington has plotted out the results of the 2014 congressional election in North Carolina. The ten districts that were won by Republicans all hover in a close-to-flat patch ranging from above 30% to less than 45% Democratic votes, while the three seats that were won by Democrats were each captured by districts with well above 70% Democratic voters. The line to the "center of mass" of the Republican seats below the 50% line is shallow; above 50%, on the Democratic side, the line is steep. In other words, the strongly positive declination suggests that the districts in North Carolina were gerrymandered to favor Republicans.

Analyzing congressional elections since 1972, Warrington's method suggests that the most extreme gerrymander favoring Republicans was in the 1980 election in Virginia. For Democrats, it was the Texas election of 1976. His research was published March 12, 2018, in the *Election Law Journal* and could become increasingly important in the wake of a US Supreme Court case now being considered that might outlaw certain partisan gerrymanders.

"Just as one can be ill and yet not have a fever," Warrington notes, "so can one have a gerrymander without violating compactness."

Historically, gerrymanders have been pegged by their shape. Weird-looking, snaking districts that sprawl across the landscape have been viewed suspiciously. Some mathematical approaches have looked, therefore, for measures of compactness as protection against this. However, shape does not necessarily reveal a gerrymander. For example, districts drawn to disenfranchise African Americans and other racial minorities are outlawed by the 1965 Voting Rights Act. Some voting districts, therefore, have been drawn with complex, irregular shapes—like North Carolina's much-litigated 12th District—to secure minority representation. Sometimes, unlikely shapes promote the goals of democracy. And, conversely, recent research has made clear that gerrymanders can exist without contorted boundaries. "Just as one can be ill and yet not have a fever," Warrington notes, "so can one have a gerrymander without violating compactness."

While Voting Rights Districts have been upheld by the US Supreme Court, decades of cases built on a complaint of partisan gerrymandering—claiming that districts were drawn in favor of one or the other of the major US political parties—have been almost entirely unsuccessful in federal court. However, in 2016, a circuit court ruled in the case of *Gill vs. Whitford* that districts drawn in Wisconsin's state legislature were an unconstitutional partisan gerrymander—and the US Supreme Court took up the case last year. A ruling is expected this June. If the high court upholds the claim that the state's Republican-drawn voting maps are unconstitutional, it could redraw American political life.

A central part of the case, and topic of conversation among the justices during oral arguments, is a measure called the efficiency gap. Instead of focusing on the shape of voting districts, this analysis considers the distribution of votes. It's a newly developed mathematical approach that focuses on "wasted votes"—both those votes beyond what one party needs to win and votes cast for a losing candidate. As a recent report from the Public Policy Institute of California notes, " Partisan gerrymanders seek to foist more wasted votes on the other party," making their own votes more efficient. If the party drawing the voting districts succeeds in this aim, they will "pack and crack" the opposing party: packing their opponent's voters into a handful of districts that the opponent will win easily while evenly spreading—cracking—the rest of their opponent's voters across a large number of districts that they will lose by small margins.

While the efficiency gap has been at the center of the current Supreme Court debate, it "unfortunately, in its basic assumptions, requires proportional representation," Warrington says—and proportional representation is not a constitutional right. (Just consider that Vermont's Senate delegation has the same number of seats as California's.) Which is where Warrington's declination looks to be a better tool.

If the Supreme Court rules that some partisan gerrymanders are unconstitutional, the declination—in combination with measures of compactness, an assessment of the intent of those who drew the maps, and a look at the impact of the redrawn maps—could be a "manageable judicial standard," Greg Warrington says. Not only does it avoid "the constitutionality issue presented by the efficiency gap," he notes, but it also "does not rely on the shape of districts, is simple to compute, and is provably related to the 'packing and cracking' integral to gerrymandering."

In a forthcoming follow-on study, Warrington has collaborated with professor of statistics Jeff Buzas, the chair of UVM's Mathematics and Statistics Department. Using the declination measure, they estimate the number of seats won in the US House of Representatives due to "asymmetries in vote distributions." These asymmetries may indicate gerrymandering. Their results suggest that the number of US House seats showed biases in favor of the Democrats prior to the mid-1990s and biases in favor of Republicans since then.

PROFESSOR GREG WARRINGTON
Photo: Sally McCay

The University of Vermont

COLLEGE OF ENGINEERING AND MATHEMATICAL SCIENCES
109 VOTEY HALL, UNIVERSITY OF VERMONT
33 COLCHESTER AVENUE, BURLINGTON VT 05405
(802) 656-3392 | info@cems.uvm.edu | www.uvm.edu/cems

Non-Profit Org.
U.S. Postage
PAID
Wht Riv Jct VT
Permit 86

FRONT COVER
Taylor Ducharme, Selina Yao, David Bernier, Professor Patrick Lee.

Photo: David Seaver

Photo: Sally McCay