CU ENGINEERING

2021

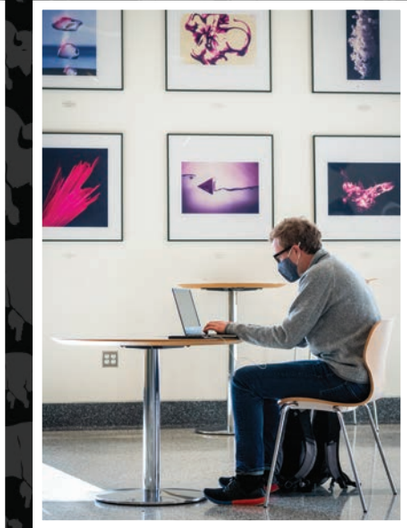
CS

CELEBRATING 50 YEARS

DEPARTMENT LEADS A GROWING COMPUTER SCIENCE COMMUNITY AT CU BOULDER

University of Colorado **Boulder**

PROTECTING OUR **ENGINEERING BUFFS**



Read about CU Engineering's research efforts and actions to help fight the COVID-19 pandemic:

- » Research breakthroughs
- » Return to Research series
- » Stories of resilience in the COVID-19 era series

colorado.edu/engineering/coronavirus

MESSAGE FROM **THE DEAN**

@KeithMolenaar

Dear CU Engineering community -

This edition of *CU Engineering* magazine commemorates the 50th anniversary of the CU Boulder Department of Computer Science. While the story on Page 14 charts many of the department's important milestones, I want to take a moment to celebrate the last 10 years in particular.

Over the past decade, the department has experienced transformational growth and increased its impact on our state and nation. It has added more than 20 tenure-track faculty, and the student body has grown by more than 300%.

At the same time, it has made impressive strides in student diversity. The department has grown from 17% to 21% women undergraduates and from 19% to 27% women graduate students. The number of undergraduate students from historically underrepresented backgrounds is also nearly seven times higher than it was in 2011.

That kind of thoughtful growth is no easy feat, and I would like to thank former and current department chairs James Martin, Liz Jessup, Ken Anderson and Bobby Schnabel for their dedicated and innovative leadership.

After an especially "virtual" year, it's hard to imagine where we would be without computing technologies. As you'll see throughout this edition, computing has become a vital part of nearly every engineering and science discipline. We're excited to give you a closer look at the contributions our faculty, students and alumni are making to this dynamic and ever-expanding field.

As we see the light at the end of an unprecedented year, we hope you and your families are staying safe and healthy, and we look forward to being able to welcome you back to Boulder soon.

Dean's search update

In February, Provost Russ Moore announced that our top candidate for the permanent dean's position decided to pursue another opportunity. We will begin a new search next academic year. While the news is unfortunate, we will not stand still. I am working every day with the faculty, staff and students to advance our vision for the college throughout the 2021—22 academic year, and continuing to build lasting relationships with our alumni, partners and friends. We are making extraordinary progress in new educational and research programs, as well as in advancing our inclusive culture. The pandemic and budget challenges may have disrupted our college and our campus, but they have also opened new possibilities for our future.

Go, Buffs!

Keith Molenaar
Interim Dean

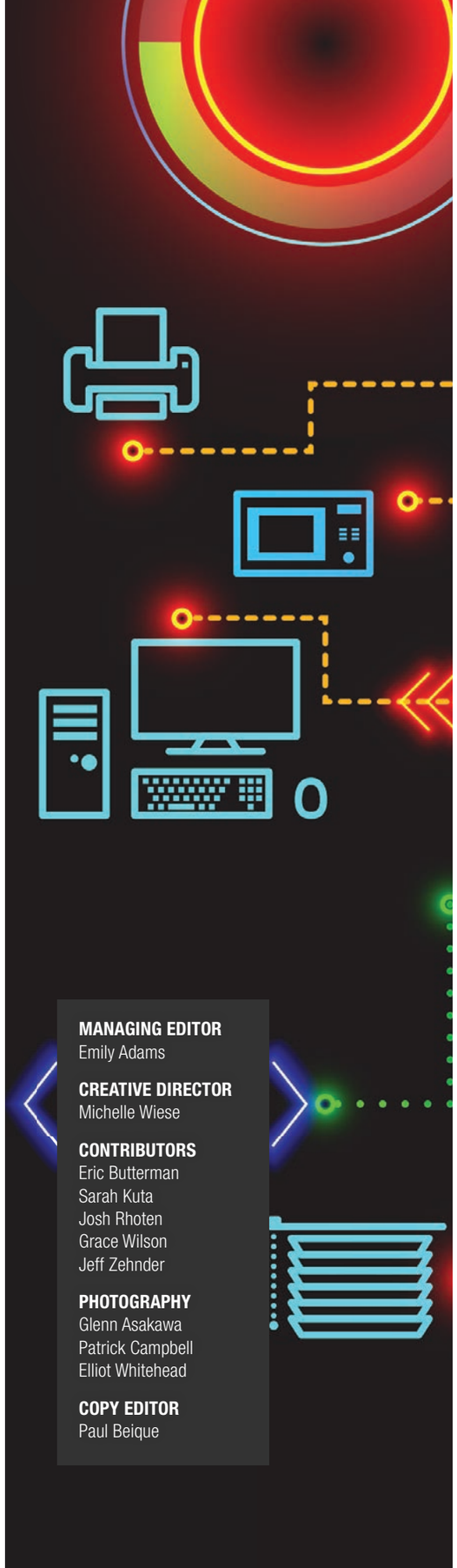
ABOUT INTERIM DEAN MOLENAAR
colorado.edu/engineering/interim-dean

CUENGINEERING

VOLUME 38 | ISSUE 1 | 2021

Students participating in HackCU at CU Boulder, Page 16.

FEATURES



MANAGING EDITOR
Emily Adams

CREATIVE DIRECTOR
Michelle Wiese

CONTRIBUTORS
Eric Butterman
Sarah Kuta
Josh Rhoten
Grace Wilson
Jeff Zehnder

PHOTOGRAPHY
Glenn Asakawa
Patrick Campbell
Elliot Whitehead

COPY EDITOR
Paul Beique

ALUMNI PROFILES

RESEARCH

NOTEWORTHY

Kiewit Design-Build Scholarship awardees, Page 7.

CUENGINEERING ONLINE
colorado.edu/cuengineering/2021

/cuengineering
@CUEngineering
@CUEngineering
@KeithMolenaar
University of Colorado Boulder College of Engineering & Applied Science

Some of the photographs in this issue were taken before the COVID-19 pandemic and may not depict current health and safety guidelines.

Past GoldShirt students bond during a summer bridge outing.

Engineering GoldShirt Program receives national recognition

The National Academy of Engineering has recognized the college's Engineering GoldShirt Program as an "exemplary admissions practice that promotes diversity in engineering."

The GoldShirt Program, housed in the BOLD Center, was created in 2009 to provide a path to engineering for students traditionally underrepresented in the college. It is modeled after the concept of redshirt athletes who spend time preparing and improving athletically before fully participating in all team activities.

Through the program, 374 students who would have previously been denied access to engineering have been admitted into the college.

"These students are incredibly driven academically to perform well," GoldShirt Program Manager Phil Courey said. "They also really take advantage of the opportunities available to get involved in extracurricular activities, to grow. They maximize their experience here in ways that definitely impact their peers and the broader work of faculty and staff in the college."

The NAE received 25 nominations from across the country and chose programs at eight universities.

> **"These students are incredibly driven academically to perform well."**

Phil Courey
GoldShirt Manger

40–45
Number of students who participate in the GoldShirt Program each year.

2
Weeks spent in Summer Bridge program to prepare students for classes.

374
Number of students who have been admitted to the program.

The first cohort of Kiewit Design-Build Scholars.

Kiewit partnership provides scholarships, career development

The nation's infrastructure challenges are the impetus for a new partnership between CU Boulder and Kiewit, one of the nation's largest construction and engineering organizations.

> **"The program will prepare our engineers for an exciting career that makes an impact on the quality of life in Colorado and throughout the nation."**

Keith Molenaar
Interim Dean

With the Kiewit Design-Build Program, the company has made a five-year commitment to support up to 40 students each year with significant annual scholarships as well as enhanced academic and professional development opportunities, including internships, service-learning experiences, research projects and mentorship. The program is designed to graduate well-rounded engineers and builders prepared to tackle our nation's infrastructure demands.

"This partnership builds on 50 years of construction engineering and management at the University of Colorado Boulder and accelerates our long-term relationship with Kiewit," said Keith Molenaar, interim dean of the college and a leader in design-build engineering. "The program will prepare our engineers for an exciting career that makes an impact on the quality of life in Colorado and throughout the nation."

The partnership, a novel model for university-corporate relationships, illustrates Kiewit's commitment to innovation and elevates the relationship between the university and a significant contributor to the Colorado economy.

The company awarded the first 16 Kiewit Design-Build Scholarships as part of the program launch. Twenty-six additional scholarships were awarded in the spring.

Longtime diversity champion helps renovate BOLD Center

CU Boulder alumnus **Marco Campos** (CivEngr'98) and his company, Campos EPC, have provided $1 million through the Campos EPC Foundation to allow for a transformational renovation of the BOLD Center.

Marcos Campos
Founder, Campos EPC

A longtime supporter of diversity and inclusion efforts within the College of Engineering and Applied Science and across Colorado, Campos said he felt called to make an immediate impact when the pandemic took hold last spring. He grew concerned that the pandemic was creating a greater burden among first-generation and underrepresented students. He felt that now, more than ever, these students needed an enhanced center of support and connection.

"We have to do something to help where we can," Campos said. "This isn't business as usual. People are suffering, and we have to consider the long-term effects of this crisis."

The renovation brings a dramatic improvement to the center's technological offerings, allowing for remote and in-person learning through lecture capture and enhanced digital displays. The transformation also will provide better lighting, more space for students, and opportunities for students to create cultural displays, engineering projects and artwork.

The BOLD Center seeks to broaden opportunities through leadership and diversity. Located in the heart of the Engineering Center, it provides a community space and affinity-based programming for students historically underrepresented in engineering.

USAID, NASA support Mortenson-led drought resilience technology

A CU Boulder co-led program committed to ending humanitarian drought emergencies in the Horn of Africa has gained support from the U.S. Agency for International Development and NASA, and recognition from leading nonprofits.

The Drought Resilience Impact Platform, or DRIP, combines the technical leadership from within the Mortenson Center in Global Engineering and across campus with water security actions taken by the Millennium Water Alliance, national governments, and local communities in Kenya, Ethiopia and Somalia.

DRIP will monitor water security in these three countries, create actionable drought forecasts, and incentivize water system operations to ensure that when rains fail, water access is secure and costly drought emergencies are prevented.

The program was recognized as an inaugural member of the Million Lives Club, which recognizes positive impact on at least a million people living on less than $5 a day. It was also honored as one of the 100 top-scoring finalists in a challenging vetting process from the MacArthur Foundation's 100&Change competition and at the 2020 San Francisco Design Week, with a first-place finish in the Internet of Things category.

Carrying water in Kenya.

Kristine Larson became the first GPS researcher to be inducted into National Academy of Sciences.

GPS pioneer inducted into National Academy of Sciences

When Kristine Larson began her research in the 1980s, GPS was little known to the public, and a single receiver cost $150,000.

"When I started, no one had heard of GPS. I couldn't tell my family what I did," said Larson, professor emerita in the Smead Department of Aerospace Engineering Sciences.

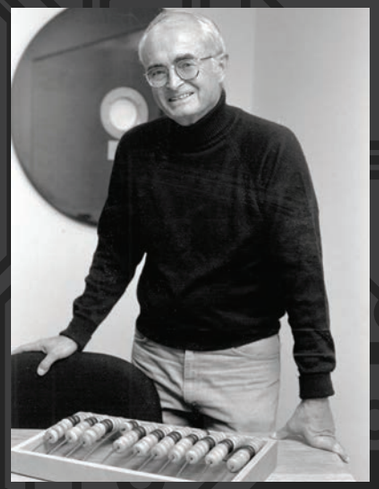
Today, GPS is everywhere, but Larson has stretched and reshaped the technology, inventing methods to use it for everything from measuring Arctic ice sheets to monitoring soil moisture on farms.

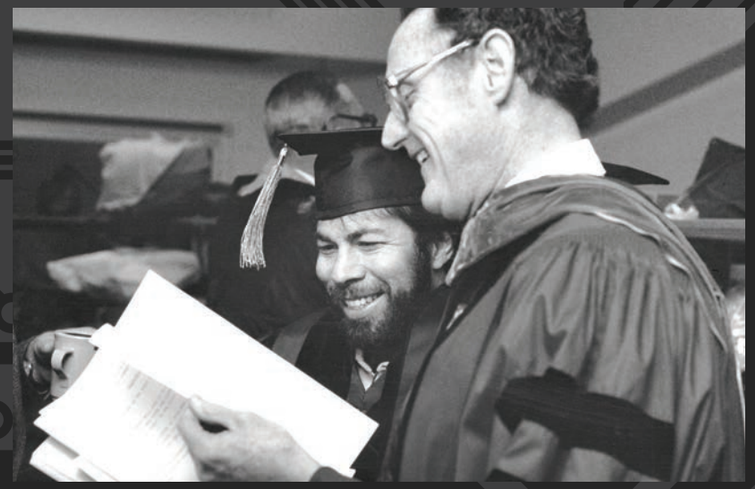
In 2020, she became the first GPS researcher to be inducted into the National Academy of Sciences. She sees the induction as a recognition not just of her work but GPS science as a whole.

"It was an unexpected and welcome acknowledgment of the research ideas that I pursued because they were fun and interesting. It's also a recognition of GPS and its importance," Larson said. "Thirty years ago, no one in the National Academy was talking about GPS. A lot has changed."

COMPUTER SCIENCE AT 50

By Emily Adams





Department has become known for championing collaboration and diversity in the computing field

When the Department of Computing Science — soon renamed Computer Science — was established at CU Boulder in 1970, no one anticipated how ubiquitous computing would soon become.

Fifty years later, computing is everywhere — in our pockets, our vehicles, our home appliances.

At CU Boulder, computer science is the second most popular major on campus, and the ATLAS Institute and College of Media, Communication and Information also offer computing degrees.

As they marked the department's 50th anniversary in 2020, Department of Computer Science Chairs Ken Anderson and Bobby Schnabel reflected on how the department has innovated and grown while still maintaining its early collaborative nature.

Ken Anderson
Chair

Bobby Schnabel
External Chair

"This has historically been a department that had a lot of collaborations pointing outwards versus inwards," Schnabel said. "We started out with strengths in numerical computation, and before too long we were working with the Institute of Cognitive Science. It has created a community that was always working with things outside the department."

Today, faculty also collaborate across campus with ATLAS, the BioFrontiers Institute, education, linguistics and information science, among others.

The department also has earned a reputation for championing inclusivity in computing education.

2004: Faculty and alumni secured a major National Science Foundation grant to create the National Center for Women and Information Technology (read more on Page 28).

2013: They teamed with the College of Arts and Sciences to introduce the Bachelor of Arts in Computer Science, allowing students with more diverse academic interests to pursue a CS degree.

2017: The introduction of the online post-baccalaureate degree made it possible for people with more diverse academic backgrounds to enter the field.

2018: The department launched a partnership with Western Colorado University, allowing students to earn a CU Boulder computer science degree from the Western campus in Gunnison.

As the computing community across campus grows, Anderson said, they're working to maintain that collaborative, inclusive nature.

"We acknowledge that computing is much broader than just any one department, and we're actively trying to foster that community across the units," he said.

Renovated Computer Science Education Lab (CSEL).

Department stats today

2,080 undergrads

335 graduate students

70+ faculty

20 staff

COMPUTER SCIENCE THROUGH THE YEARS

A LOOK AT JUST A FEW OF THE IMPORTANT EVENTS THAT HAVE SHAPED COMPUTER SCIENCE AT CU BOULDER

1962

» Institute for Computing Science is founded, uniting faculty from psychology, sociology, physics and electrical engineering

1970

» Regents approve a Department of Computing Science, soon adjusted to Computer Science
- Originally two CS faculty with affiliates from math, business, psychology and sociology
- Department offers only graduate-level courses and awards its first MS late in the year

1971

» Undergraduate-level courses are introduced

» CS follows the lead of the math department and joins the College of Arts and Sciences

1974

» First PhD awarded

1980

» CS moves to the College of Engineering and Applied Science

1983

» Circa 1983, the department purchases a VAX computer, its first real computer

1988

» First BS degree awarded

2013

» CS introduces a Bachelor of Arts option

2017

» CS launches an online post-baccalaureate Bachelor of Science degree

INNOVATION ALL-NIGHTERS

By Jeff Zehnder

HACKATHONS GIVE STUDENTS A CHANCE TO EXPLORE AND NETWORK, ALL IN A FUN ATMOSPHERE

The term "hackathon" might elicit images of people breaking into CIA mainframes, but the reality of these events is more like an all-night academic conference, networking event and party all rolled into one.

"It's essentially an invention marathon," said junior computer science major Zahraa Abbasi, director of HackCU, CU Boulder's largest hackathon. "Twelve to 36 hours of building and connecting with other developers."

Most events focus on using technology to solve problems. At HackCU's 2019 event, for example, participants could choose from different tracks, including health care, virtual solutions, education and social justice. Students worked in teams to identify a problem in a selected field and then design and prototype solutions.

Projects run the gamut from video games and software that compares car accidents caused by weather versus distracted driving, to emergency multipoint Wi-Fi systems for use during disasters when other wireless communication systems fail.

As a student, **Cassandra Goodby** (TAM'18, MTechMedSoc'20) was lead organizer for T9Hacks, a hackathon for women and nonbinary students. She said hackathons offer a chance to explore.

"I love user-experience design, and T9Hacks was my first opportunity to work on wireframes that led me into the field," Goodby said. "Hackathons are a way to look into something you're interested in versus a class or job where you have specific, regular assignments."

They're also an excellent way for students to build a professional network for jobs and internships. Events typically have business sponsors who hold educational workshops, host tech challenges and provide ever-important snacks.

Zahraa Abbasi
Director of HackCU

"It's essentially an invention marathon. Twelve to 36 hours of building and connecting with other developers."

"Hackathons show you're passionate about technology and the field, and it gives you a portfolio piece you can show employers," Goodby said. "One of my friends got an internship through T9Hacks, and a lot of people find mentors."

T9Hacks typically draws more than 125 people, while HackCU can attract as many as 700 attendees.

"People really love these events. They're always excited to come," Abbasi said. "It's not just CU Boulder. We draw people from all over Colorado. A couple years ago we even had attendees from Canada and Spain."

The length of these events can vary, but 24 hours is common.

"We've had a couple shorter 12-hour hackathons. You can learn a lot, but you're not really developing a project," Abbasi said. "It's just more fun with a full event. The sleep deprivation and antics add to the experience."

Although attendees face real deadlines, fun is the order of the day (and night).

"It's a time to explore technology. T9Hacks was the first big event I went to on campus," Goodby said. "It was 24 hours to build and connect. I knew I was in the right place."

Taking Ownership

By Grace Wilson

ETHICAL TECHNOLOGY REQUIRES NEW APPROACHES TO EDUCATION, RESEARCH AND INCLUSION

> "OUR AUTONOMOUS SYSTEMS WILL HAVE BIASES AS BAD AS OURS, IF NOT WORSE."

For the first few decades of the computing age, computers were monolithic machines in big places, out of reach for most of the general public.

When personal computers came along, everything changed, according to CU Boulder's Bobby Schnabel. Since then, the growing ubiquity of computing has compounded both the number of devices and the ethical issues inherent in their development and use.

"When people started being able to interact with those computers, they became two-way devices," said Schnabel, external chair of the Department of Computer Science and former CEO of the Association for Computing Machinery. "All sorts of things have arisen that impact people's lives."

Today, the field is grappling with many of those impacts, like bias in machine learning algorithms and social media networks that are easily manipulated.

"As a discipline, we need to take ownership of that and go fix it," said department Chair Ken Anderson. "Computer science has to mature as a discipline and start to say, 'How do we bake in discussions of what's important first before the technology starts to roll out?'"

'Biases as bad as ours'

At CU Boulder, some of those discussions are happening at the research stage.

Chris Heckman
Assistant Professor

Assistant Professor Chris Heckman works with advanced autonomous systems as director of the Autonomous Robotics & Perception Group. Though he sees great promise in technology as an augmenter of human ability, he is concerned by the use of AI to make moral decisions.

"I can't say that humans are beyond reproach when it comes to this decision-making, and our autonomous systems that we build will have biases as bad as ours, if not worse," Heckman said.

For technologists, dual-use concerns are often

> IT IS AN ORGANIZATIONAL PROCESS THAT NEEDS TO ENSURE THAT AUTONOMOUS SYSTEMS ARE ACTUALLY BEHAVING ACCORDING TO THE VALUES AND THE MISSION THAT WE HAVE AS A SOCIETY.

brought to the forefront. A system designed to connect can isolate. A system built with good intentions can be weaponized. Unfortunately, human ingenuity makes the task of designing meaningful technology that could never be used in a dangerous manner next to impossible.

Technologists can, Heckman argues, choose what systems they do or do not work on and choose to partner or not partner with certain entities, but once the technology floats further downstream, it becomes the responsibility of managers and end-users.

"It is an organizational process that needs to ensure that autonomous systems are actually behaving according to the values and the mission that we have as a society … and that means a much more robust education for organizations and end users," he said.

Educational opportunities

But what about technologists like Elon Musk, Jeff Bezos and Mark Zuckerberg, who are engineers-turned-business-leaders? When you create a technology and also implement it, how do you develop that ethical foundation?

Shilo Brooks
Director, Engineering Leadership Program

Since 1989, CU Boulder has been answering that question with a program that educates engineers in both ethics and technology, the Herbst Program for Engineering, Ethics & Society. The program introduces the "great books" of Western civilization, which have been used in the humanities for centuries to spark inquiry into ethics.

From the Herbst program tradition also came the Engineering Leadership Program, led today by Shilo Brooks. Brooks believes that in the modern era, engineers often become leaders in business. To that end, looking at classical ethical dilemmas helps them make better decisions in the future.

"The best way to equip these future leaders is to think through some of these problems. It gives a foundation of curiosity and an intellectual agility that provides a map for how they ought to think through problems confronting them," Brooks said.

The value of varied perspectives

As valuable as the age-old struggle for moral excellence is, it is also important to consider what viewpoints have been left out that provide valuable context for difficult ethical dilemmas we face today.

Shaz Zamore
Head of STEAM outreach at ATLAS

For Shaz Zamore (they/them), head of science, technology, engineering, art and math (STEAM) outreach at the ATLAS Institute, the greatest ethical question today is how to increase space for different, equally valued perspectives.

"When you're all working together in an equitable system with parity, with everyone's background, experience and knowledge valued equally, that is where you're going to see truly genius developments and life-changing knowledge come about," Zamore said.

Zamore thinks about ethics in relation to who has access. Who can make technology? Who can use it? Who learns about it, and how?

"When it comes to outreach and engagement, one of the biggest barriers with underrepresented and severely underserved populations is that they are not told what their options are," they said. "They don't know that you can ask questions and do experiments and get paid to do it."

If students with different backgrounds are continually left out of the tech pipeline, their valuable insights are minimized, and the technological considerations built will not be as robust, Zamore said.

Anderson agrees and said that's why the department has invested so heavily in diversity efforts, like creating the Bachelor of Arts in Computer Science, building logic and ethics courses into its curriculum, and partnering with groups like ATLAS and the National Center for Women and Information Technology.

"It's all intertwined," Anderson said. "The diversity programs that we started are going to help us change these things over time so that the systems, as they're being designed, have more diverse thinking behind them. We're going through this phase in which the exclusionary practices that made this a white man's world, people are now working to try to dismantle those as best they can."

> ONE OF THE BIGGEST BARRIERS WITH UNDERREPRESENTED AND SEVERELY UNDERSERVED POPULATIONS IS THAT THEY ARE NOT TOLD WHAT THEIR OPTIONS ARE.

Bri-Mathias Hodge and Kate Doubleday outside the NREL Flatirons Campus.

ON THE GRID

By Josh Rhoten

Researchers tackle climate change with algorithms to optimize energy use

When we flip a switch, the light bulb comes on. We don't think about whether that electricity was made by solar power or fossil fuels. We don't think about the distance it travels across power lines to be delivered to our homes. And we certainly aren't thinking about what switches our neighbors have on and how the combined requests may strain the energy grid.

We just expect the bulb to shine bright.

But if city, state or international goals — like transitioning to 100 percent renewable energy — have any hope of being met, that journey will have to be streamlined while also accounting for things like user habits, weather conditions, market costs and other variables.

That kind of optimization work is a key aspect of addressing climate change on a large scale and something Kaitlyn Garifi, a recent PhD graduate in electrical engineering, worked on every day.

Garifi's work focused on designing algorithms to optimize the amount of renewable energy used in the power grid, which decreases the amount of fossil-fuel-based electricity generation needed to satisfy the demand at any given time. In one recent project, she designed an algorithm to reduce the wasting of power produced by large wind farms far away from city centers by temporarily and safely increasing the capacity of large transmission power lines at key times.

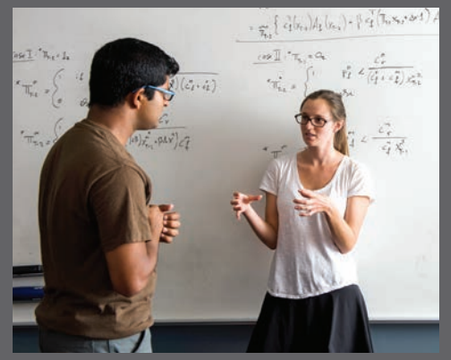
> "WE HAVE A UNIQUE AND VALUABLE OPPORTUNITY TO COLLABORATE WITH THE NATIONAL RENEWABLE ENERGY LABORATORY."

"That allows the powerlines to transport a larger amount of wind power from where it is created to areas of higher population density and electrical demand, instead of using fossil fuel-based generators," she said. "Ideally, we could dispatch the generators at lower amounts at those times, using more wind energy instead — even planning ahead and optimizing using forecasts. Meaning we don't need to burn as much gas or coal."

Garifi worked in Assistant Professor Kyri Baker's lab, where researchers are tackling many problems related to climate change through interdisciplinary work.

"At CU, we have a unique and valuable opportunity to collaborate with the National Renewable Energy Laboratory, and many of my students have worked or currently work part time at NREL," said Baker, who is based in the Department of Civil, Environmental and Architectural Engineering. "This exposes them to cutting-edge research from multiple perspectives, and helps them become well-rounded engineers ready to tackle problems in power and energy."

Associate Professor Bri-Mathias Hodge's lab also has a deep connection with NREL, where he serves as the chief scientist in the Power Systems Engineering Center. His student Kate Doubleday will soon complete her PhD in power systems engineering, focusing on how to integrate renewable energy into existing power grids.



Kaitlyn Garifi in the classroom.

"Because they are mandated to always provide reliable electricity to their customers, (utilities) tend to have a more conservative mindset," she said. "With the large-scale changes to their generation sources that are going on, they tend to err on the side of too conservative, which has high cost impacts and doesn't take full advantage of carbon-free electricity."

New field applies machine learning to climate change

The energy grid isn't the only opportunity to use algorithms to battle climate change. Associate Professor Claire Monteleoni's lab uses machine learning to explore how extreme weather events are related to climate change.

The projects she leads are part of a new interdisciplinary field called climate informatics. It's a discipline she helped create wherein researchers apply approaches from artificial intelligence, machine learning, statistics and data science to the field of climate change with fascinating results.

'IT KEEPS YOU HUMBLE'

By Josh Rhoten

Michael Ohradzansky at the starting line of the Washington challenge course.

High-stakes Subterranean Challenge puts CU Boulder robotics team to the test

For mechanical engineering PhD candidate Michael Miles, participating in the national Subterranean Challenge robotics competition has provided real-world experience he might not otherwise have gotten during his graduate studies.

"Normally, you are making a robot that just has to work enough for a 3-minute video," he said. "Then you publish a paper and visit a conference, and you are done. But running these complicated systems for over an hour in tough conditions? That is unlike robotics anywhere, and it keeps you humble."

CU Boulder is one of several funded teams in the Sub-T Challenge, a high-stakes competition launched by the U.S. Defense Advanced Research Projects Agency to test ideas around autonomous robot use in difficult underground environments during search and rescue.

CU's team is dubbed Multi-agent Autonomy with Radar-Based Localization for Exploration (MARBLE) and includes engineers from CU Denver and Scientific Systems Co. Inc.

Each leg of the multiyear challenge tests how autonomous robots acting as first responders approach tunnels, caves and urban environments. That includes handling environmental factors like difficulty communicating through walls or unseen dangers like spilled hazardous material. MARBLE's team of drones could provide answers to those issues by searching quickly, independently and without fear of the personal physical harm a human would have to consider.

The competition's second challenge was in February 2020 near Seattle, with the October 2020 challenge shifted to a virtual setting. The final event is scheduled for this summer.

Sean Humbert, a professor in the Paul M. Rady Department of Mechanical Engineering, leads the CU Boulder team. The students range from undergraduates to PhD candidates and come from computer science, mechanical and aerospace engineering.

"This competition is good company to be in," he said. "The top teams in this challenge are well funded and have 30 or more professional engineers, researchers and students, where the core of our team is 10 to 15 graduate students. So our ability to rise to the occasion and compete is something we are truly proud of."

> **"Our ability to rise to the occasion and compete is something we are truly proud of."**

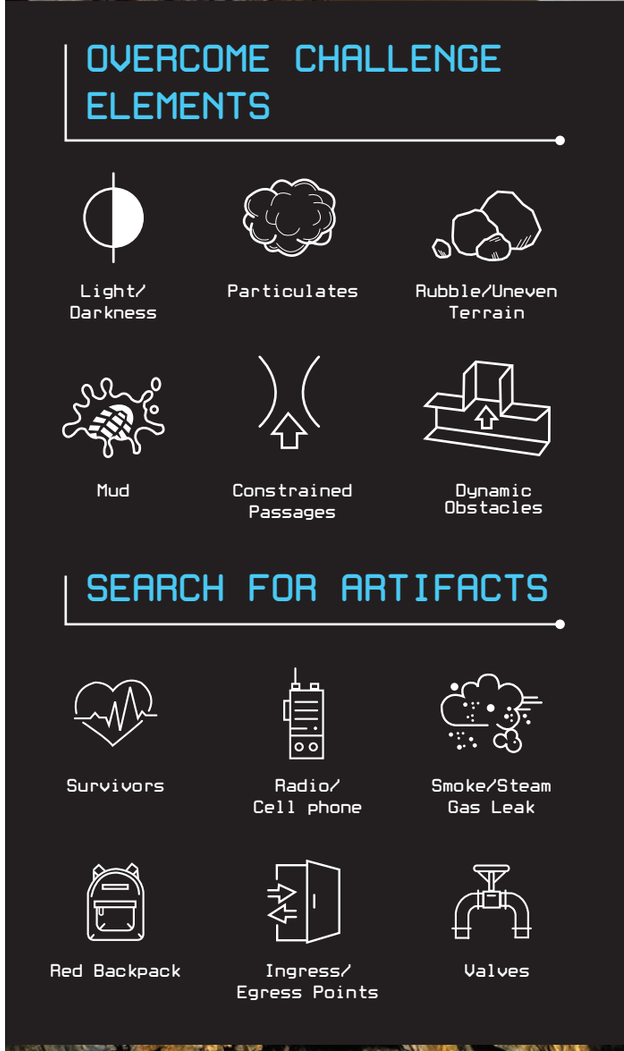
In a typical hourlong run, the team's autonomous robots enter the course, scanning for "artifacts," such as cell phones, hazards or dummies representing survivors. When they find something, they report their location. Because conditions limit the use of GPS, the MARBLE team is using a traditional camera, radar and a laser-based system called LIDAR (light detection and ranging) to build a virtual map. That map is then shared with a human controller and other robots to help decide which sections to explore again before time runs out.

Identifying, understanding and solving the problems encountered during runs is a difficult and time-intensive process. However, PhD candidate Michael Ohradzansky said it is one of the most satisfying parts of the work.

"I am working on the lower-level control of the vehicle, and I interface with the guys who do planning. We also have people who are working on perception, mapping, artifact detection — all of these pieces have their own system requirements, both physical and in code," he said. "Everyone comes from a different background and has their own perspective, which is exciting and leads to lots of unique solutions."

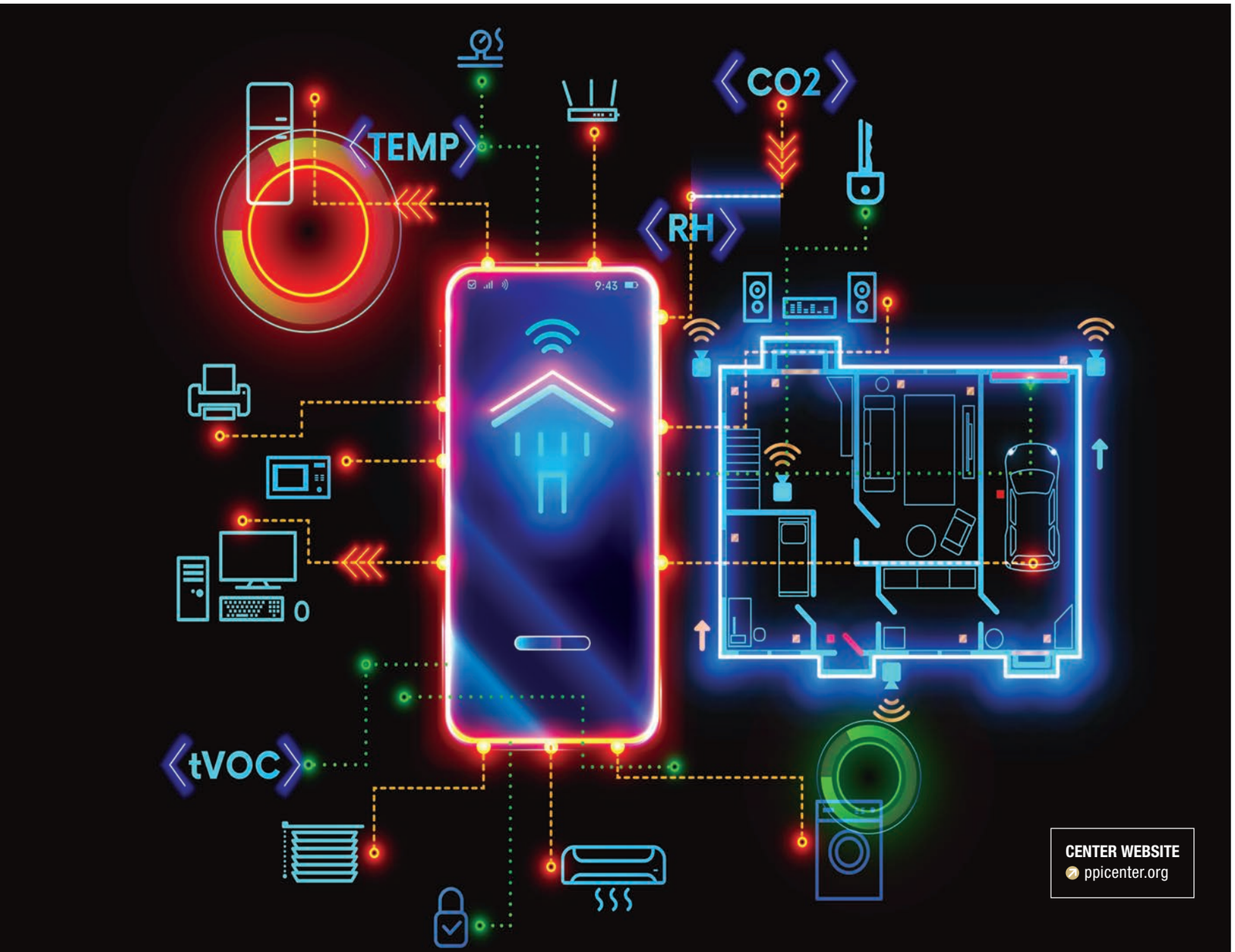
Assistant Professor Chris Heckman of computer science is part of the team's leadership. He said the challenges students face in the competition push the boundaries of several disciplines.

"Fifty years ago, it would have been crazy to think that computer scientists would be working side-by-side with engineers, applying techniques they were developing to robotic autonomy," he said. "Now, all of our work is interdisciplinary, and I think we're developing students who will be well positioned for where our field goes over the next 50 years."



IoT Think Tank

By Eric Butterman



CENTER WEBSITE
ppicenter.org

Industry-academic research collaboration looks to the future of Internet-connected devices

Every second, 127 new Internet of Things devices — thermostats, TVs, medical devices and much more — are connected to the Internet. By the end of this year, it's estimated that 35 billion IoT devices will be installed worldwide.

Those smart devices come with great convenience, but also with many security and privacy concerns.

Danny Dig
Executive Director

The new Center on Pervasive Personalized Intelligence, based at CU Boulder and Oregon State University, wants to be part think tank and part protector when it comes to this technological future.

Shivakant Mishra
Professor

The center's name breaks down two important facets of IoT technology, with an eye toward how the field may develop in the future, said Executive Director Danny Dig, an associate professor of computer science at CU Boulder.

Bor-Yuh Evan Chang
Associate Professor

"Personalized means intelligence that adapts, and pervasive means it doesn't have to be in the cloud or computer infrastructure. It's pervasive on the edge of network infrastructure, whether smart devices, interactives or other areas," he said. "It's how can we learn from the distillation of the world around us, how can we predict future needs and future resources, and how can the systems adapt to our human needs?"

The center is partially funded by the National Science Foundation as an industry-academic research collaboration, which looks to enable long-term partnerships among corporations, startups, universities and government agencies. More than 60 companies have participated in initial center organizational meetings.

Bor-Yuh Evan Chang, associate professor of computer science and co-director for the CU Boulder site along with Professor Shivakant Mishra, sees that as an immense opportunity.

"Bringing machine learning experts and security and privacy experts to think about fostering interdisciplinary projects wouldn't happen necessarily without the center," Chang said. "We want to be part of an open forum, be a meeting point and hub."

He used an example of two companies that are interested in the same development project, but which might pursue them separately without a bridge to help them engage.

"It can generate follow-up, and there can be an amplifying effect," he said. "We expect to grow through welcoming members, university institutions and their complements. The potential is huge."

For students, the center could provide new educational opportunities and connect them with industry through internships and employment.

As IoT has developed, much of the focus has been on how to get software onto devices and send data to the cloud, Chang said. That misses some important steps, including data protection and privacy, which are being addressed reactively instead of proactively.

"The thrust of the center is not just out of thin air but for discussions on pressing underlying issues of next-generation tech," he said. "With so much more software and devices in our everyday lives, how can we shape that track so data is used responsibly? A transformation can be positive instead of being imposed on us."

Terry Hogan

Lucy Sanders

Computing For All

By Sarah Kuta

CU alumni Terry Hogan and Lucy Sanders are leading the National Center for Women and Information Technology

For as long as she can remember, **Terry Hogan** (CompSci'94) has advocated for women achieving financial self-sufficiency, and she believes technology is the most powerful path to that goal.

Then Hogan met **Lucy Sanders** (MCompSci'78) and realized she could put this passion into action, empowering girls and women to succeed in the field of computing while at the same time making workplaces and schools welcoming to all.

Today, Sanders and Hogan are leading a charge to make computing more inclusive at every level. Sanders is the chief executive officer and co-founder of the National Center for Women and Information Technology (NCWIT), and Hogan is the organization's president and chief technology officer.

"Real change is happening because the organizations we work with are making change," Hogan said. "They're figuring out how to have more inclusive environments. NCWIT is there to help them do the work that needs to be done in their organizations. That's the way real change happens — one organization at a time."

The nonprofit, founded at CU Boulder in 2004, helps its 1,400 member organizations, including private companies, universities, nonprofits and government organizations, recruit and retain girls and women in computing. NCWIT offers help at every level of the computing pipeline, from K–12 education all the way through academia and the workforce. NCWIT's 200-plus resources are backed by research, with social scientists developing comprehensive change models and best practices.

Hogan and Sanders had surprisingly similar paths to computing.

Hogan's journey started in high school in Denver, when she read a newspaper article about engineering degrees leading to well-paying and stable careers (she was so inspired she cut it out and hung it inside her locker). After learning basic programming from a female math teacher, she set her sights on studying computer science at CU Boulder, where she was one of just a handful of women in the major. Before joining NCWIT in 2012, Hogan had a successful career in industry, working for U.S. West, MediaOne and Gartner Group, among others.

> "ALL OF THE THINGS WE WORK ON MAKE THE CLASSROOM AND THE WORKPLACE FOR EVERYBODY."

Sanders grew up around computing in Louisiana, where her father worked in the early data centers of Western Electric. She, too, learned Fortran and other basic programming skills from a female high school math teacher and decided to major in computer science at Louisiana State University. She enrolled in graduate school at CU Boulder along with her husband, **Bruce Sanders** (MCompSci'78), to continue her computer science studies. Sanders spent her career at AT&T Bell Labs, Lucent Bell Labs and Avaya Labs, working her way up to vice president of research and development.

When she retired from industry, Sanders found her way back to CU and began working on technology outreach and diversity in the ATLAS Institute. The idea for NCWIT began to germinate there during conversations about the declining participation of women in computing. Sanders and colleagues Bobby Schnabel and Telle Whitney submitted a proposal and secured a National Science Foundation grant to create a research-based center, and NCWIT was born.

The organization's mission has never wavered in its 16 years, but its reach and impact have grown exponentially. By working to remove bias at all levels of the computing ecosystem, this national community of change leader organizations has improved the field for everyone.

"All of the things we work on make the classroom and the workplace for everybody — all underrepresented groups, as well as majority groups," Sanders said. "We're helping enhance and reshape cultures for everybody."

NCWIT'S ACCOMPLISHMENTS

- Has grown from 50 member organizations in 2004 to more than 1,400 members today
- Maintains a community of 20,000 high school and college students around the world, with an 82% persistence rate from high school to college in computing or STEM fields
- Helps co-fund numerous scholarships for women in computing
- Conducts research on underrepresented students in computing at community colleges

MAPPING A VISION FOR UAVS

By Eric Butterman

Recent Alumni Award winner finds success with robotics startup

Like many kids, **Nima Keivan** (PhDCompSci'17) enjoyed music.

Well, destroying it, anyway.

Some children might have seen a record player and thought, "Let me play something loud." Keivan, on the other hand, preferred to silence the music.

"I loved to pull machines apart to see how they worked — and it was one of these players with the vacuum style," he said. "My parents were fine with it as long as I was able to put it back together. That second part was in doubt."

Luckily, the family was soon able to enjoy tunes again in their Brisbane, Australia, home.

"I was happy I was able to get it to work again," Keivan said with a laugh.

There would be more difficult nuts to crack in the machine world, including unmanned autonomous vehicles (UAVs). In many ways, they were still in their infancy when he was an undergraduate student at the University of Queensland. He was team leader for Project Andromeda, which set out to expand the future of UAVs.

The project didn't succeed financially, but gave him knowledge he could take to his next destinations.

"At the University of Colorado (continuing on a lab from George Washington University), my focus was on research and using cameras and initial sensors to build maps of the environment and determine where a robot is," he said. "The influence of this work continues to this day and helped at CANVAS."

Keivan is the chief technology officer and co-founder of CANVAS Technology, along with lab-mate **Juan Falquez** (PhDCompSci'18). The company created an autonomous cart that was acquired by Amazon in 2019.

"The carts primarily used computer vision and cameras to build continuously updated maps of the environments they operated in so they could estimate their own location," Keivan said. "Images from the cameras were also used to detect and avoid obstacles along the carts' path. Operators could configure waypoints and routes through a web-based interface, allowing them control over the actions of the fleet of carts."

> "I'M ATTRACTED BY THE CONCEPT OF BUILDING THINGS THAT LAST WITHOUT HAVING TO BE REPAIRED OR FIXED OR UPGRADED."

For Keivan, the highlight of CANVAS was being a part of the team, complementing each other and guiding each other forward.

"I'm attracted by the concept of building things that last without having to be repaired or fixed or upgraded," he said. "Making something truly useful is hard to do, and they have to be properly designed to be functional. The (Amazon) purchase was a nice point of validation for us and is exciting. ... It has potential for a great partnership."

Where can autonomous robot technology lead? It's tough to say, but Keivan is excited to find out.

"It's in the zeitgeist, and you can see the benefits," he said. "They are mostly in being able to cut the expense of doing, making and transporting. Historically, it has led to improvement in quality of life, but we still need to continue to have an awareness to do it responsibly and be aware of consequences. But that itself is in the zeitgeist, too."

Cracking the Code

Check out how our faculty members are leveraging computing in innovative research projects across engineering disciplines

College announces three new interdisciplinary research themes

The College of Engineering and Applied Science recently launched three interdisciplinary research themes as part of a broad push into growing and critical areas of study. The new themes — Hypersonic Vehicles; Resilient Infrastructure with Sustainability and Equity; and Engineering Education and AI-Augmented Learning — will explore vitally important work and help advance the college's long-term research vision.

Hypersonic vehicles are used for space exploration, national security and perhaps for passenger transport in the future. The design of these flying vehicles involves consideration of a number of complex, closely interrelated areas, including aerodynamics, propulsion, materials, structures, controls and optimization.

The Resilient Infrastructure with Sustainability and Equity group will explore holistic actions to address the many drivers of urban disaster risk worldwide while simultaneously addressing environmental sustainability and social equity challenges.

The scope of the Engineering Education and AI-Augmented Learning theme includes research in engineering and computing education and assessment, as well as AI/machine learning and the convergence between those areas. One key goal is to develop the theories, technologies and know-how for advancing student-centered learning environments in K–16, graduate, and professional engineering and computing education.

The college launched its first six interdisciplinary research themes in 2018. The goal of the IRTs is to aid faculty teaming on larger projects, build up shared facility resources and provide internal seed grants to propel research in crucial topic areas. From that original group, the Autonomous Systems and Multi-Functional Materials themes will continue for the next two years.

Hypersonic Vehicles

Resilient Infrastructure with Sustainability & Equity

Engineering Education & AI-Augmented Learning

Kyri Baker (second from left) with her research team.

A smarter power grid starts with education

Kyri Baker | Department of Civil, Environmental & Architectural Engineering and Department of Electrical, Computer & Energy Engineering

Buildings and the power grids they are connected to are traditionally designed and operated separately. The topics are usually taught separately, too, with architectural engineers learning to design every aspect of a building, and power systems engineers learning to operate grids effectively. But in modern practice, the line between the two areas is increasingly blurred, thanks to new green power sources, smart home devices and the energy purchasing options available to end users. Assistant Professor Kyri Baker and her team are studying this shift in a variety of ways, and she recently began teaching a course in grid-connected systems — one of the first of its kind in the world. The course integrates current events, coding skills and group learning activities. Students explore the city of Boulder's move toward a municipal electric utility and learn to use Python to simulate cost-effective electric vehicle charging under different electricity pricing frameworks. To pursue a clean energy future,

she said, grid engineers and building engineers need to collaborate more and develop a better understanding of how one system can help and interact with the other.

Designing computer architecture for security

Tamara Lehman | Department of Electrical, Computer & Energy Engineering

Tamara Lehman
Assistant Professor

Computer architecture is a discipline that studies how to best assemble, link and organize interconnecting hardware components to create computers that meet our needs. But the emergence of cloud computing and the Internet of Things has made modern computer architectures inadequate to address users' security and privacy concerns. That's because those applications require users to relinquish physical control of their systems, making them vulnerable to attacks that software alone cannot protect against. Sharing hardware resources in the cloud also makes systems vulnerable to attacks that exploit the hardware state.

Clockwise from top left: Tamara Lehman, Sylvia Llosa, Jinpeng Miao, Zack Mckevitt, Rhett Hanscom and Ange-Thierry Ishimwe

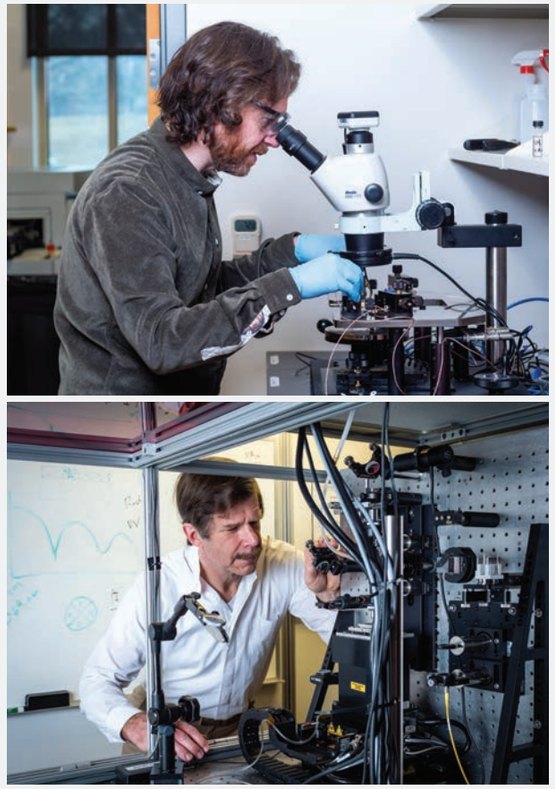
Assistant Professor Tamara Lehman and her team are studying this issue in a variety of ways, working to secure your computer from the hardware up by designing computer architectures with security and performance as priorities. This includes securing memory where delays, space and energy use have caused problems in the past and adding security discovery to verification tools so hardware vulnerabilities are found before it is too late. Lehman's industrial engineering background gives a new perspective on ways to improve systems, and she said she enjoys working in the security space because it is one of the most challenging problems facing the industry.

Laura Devendorf

Weaving together humans and computers

Laura Devendorf | ATLAS Institute and Department of Information Science

Assistant Professor Laura Devendorf is designing smart textiles to better understand how technology shapes our relationships with people and the world. In her latest research, funded by a National Science Foundation CAREER Award, she is bringing together weavers and engineers to invent new tools and programs for integrating smart and functional materials at the yarn level. When textiles like clothing, blankets and upholstery are made with materials that are conductive, can sense and move, or are responsive to the environment, an ordinary object can become a display surface, power generation system or sensor network. One of Devendorf's designs is a poncho called the Exoskeleton for Sedimentation that measures applied forces with 13 embedded force sensors. When she holds her child or leans against a chair, the force applied to her body is recorded as an image. "You might think about the different ways we form one another," she said. "It helps us remember the many ways that we are connected to other people and things." Devendorf said her research will also lead to programs for broadening participation in STEM through integration of research with university teaching, artist residencies and multigenerational design workshops.



Gregory Whiting (top) and Robert McLeod

The Internet of Living Things

Gregory Whiting | Paul M. Rady Department of Mechanical Engineering
Robert McLeod | Department of Electrical, Computer & Energy Engineering

Across vast areas of land and crops, hundreds of sensors reporting crop data such as nutrient or water intake are becoming what researchers refer to as the Internet of Living Things. The sensors create a network that can help growers make better decisions about what crops need to flourish. Associate Professor Gregory Whiting and other researchers are using 3D printing to make electronic sensors small enough to embed in a plant, cheap enough to produce and replace, and suitable for use in a variety of outdoor conditions. "If you build sensors in the conventional way, you would potentially have thousands of devices spread out over a field that would likely be very expensive, require significant maintenance and would create a lot of electronic waste," Whiting said.

Whiting said it would not have been possible to get to this point without the work in Professor Robert McLeod's lab, where researchers developed organic electronics that could be used for sensing in human tissue. As they move the technology forward, they hope this could one day help solve global problems of food and water shortages, as well as energy use.

Simulating fire dynamics and real-world events

Peter Hamlington | Paul M. Rady Department of Mechanical Engineering

When a problem is too expensive, time-consuming, difficult or dangerous to examine in the real world, computers and numerical simulations become the ticket to a better understanding. Associate Professor Peter Hamlington uses computers to study fire dynamics, combustion, industrial systems, the ocean, turbulent flows and wind energy. His research group writes and uses open-source software to reproduce real-world events as accurately as possible. "Many of our simulations are performed on supercomputers using thousands of processors," Hamlington said. "Once the simulations are complete, we spend a substantial amount of time analyzing the resulting datasets, often tens or hundreds of terabytes in size." The group uses fire simulations to predict where a fire will go, both in buildings and natural environments. By taking a closer look at how fuel type, fuel geometry, terrain and atmospheric conditions affect fire behavior, the group can determine more effective mitigation efforts, such as optimal placement of fire sprinklers in a building. Beyond fire dynamics, Hamlington's group simulates destructive detonations in high-speed propulsion systems, ocean carbon cycles for improved long-term forecasts of the global carbon cycle and climate, and turbine placement in a wind farm to increase power output, reduce undesirable loads and increase turbine lifetime.

Peter Hamlington
Associate Professor

DISTINGUISHED ENGINEERING ALUMNI AWARDS

The Distinguished Engineering Alumni Awards (DEAA) are granted annually to graduates who have distinguished themselves through outstanding personal qualities, knowledge and significant contributions to their fields. The Recent Alumni Award recognizes exceptional alumni for early career achievements, continued involvement with the university and college, and outstanding personal qualities within 10 years of graduation.

Paul Brinkman
(CivEngr'96)

Co-founder, Brinkman Partners

Distinguished Engineering Alumni Award: *Industry & Commerce*

In 2005, Paul Brinkman co-founded Brinkman Partners, an integrated real estate company, with his brother, Kevin. Together, they led the Fort Collins-based commercial development, real estate and construction company to what it is today — a highly respected company with more than 150 employees and well over $250 million in annual revenue.

While CEO, Paul Brinkman was honored as one of the Top 25 CEOs in Colorado by *ColoradoBiz* magazine and was named the Everitt Real Estate Center Entrepreneur of the Year. He was inducted into the Real Estate Hall of Fame and was one of *BizWest*'s Top 40 Under 40 professionals.

Brinkman volunteers a significant amount of time to better the College of Engineering and Applied Science, including serving as a mentor for several students and on several advisory boards, including the Engineering Advisory Council.

Nancy Eckman Clanton
(ArchEngr'75)

Founder and CEO, Clanton & Associates

Distinguished Engineering Alumni Award: *Industry & Commerce*

Nancy Clanton is a pioneer in the illumination engineering field. A registered professional engineer, she is the founder and CEO of Clanton & Associates, a prominent lighting design firm that regularly employs University of Colorado graduates and interns.

Clanton's efforts as lighting leader for the Greening of the White House, Greening of the Pentagon and Greening of Grand Canyon National Park are remembered as foundational moments in the history of sustainable design and led to the creation of the U.S. Green Building Council.

Clanton also donates her resources, time and energy to the CU Boulder Lighting Program. She guest lectures in lighting classes, speaks at IES student chapter events and provides support for the CU Solar Decathlon Team, as well as acting as a mentor for emerging professionals and students.

Scott Hartman
(AeroEng'89)

NASA, retired U.S. Navy

Distinguished Engineering Alumni Award: *Government Service*

Scott Hartman has had a multifaceted career, highlighted by distinguished service in the U.S. Navy and more than 25 years with NASA in the International Space Station Program Office, the Flight Operations Directorate and the Commercial Crew Program.

Hartman participated in Navy ROTC while at CU Boulder and, upon graduation, received a commission as an ensign in the U.S. Navy. In 2019, Hartman completed a 30-year career as a naval officer, including active and reserve duty.

In his roles at NASA, he performed as an ascent/entry guidance and procedures officer for space shuttle launches and landings, monitoring guidance and navigation from Mission Control for more than 40 space shuttle flights. He currently serves as the entry, descent and landing lead for the Commercial Crew Program.

Nima Keivan
(PhDCompSci'17)

Co-founder, CANVAS Technology

Recent Alumni Award

Nima Keivan conducted his doctoral research on the leading edge of robot perception and autonomy. The importance of his work was recognized by corporations including Google, Toyota and DAQRI, which recruited him to help envision the next generation of autonomous driving and augmented reality capabilities.

Keivan's most noteworthy achievement to date is the co-founding of robotics company CANVAS Technology, for which he was chief technology officer and lead engineer.

On top of a demanding professional career, Keivan has stayed closely connected to CU. He finds time to engage actively in robotics research at CU Boulder — working with and mentoring students, co-authoring research publications, giving guest lectures and promoting robotics-industry employment opportunities in the area. Keivan recently joined Xplorer Capital as a venture partner.

LEADERSHIP UPDATE

Mark Borden

Director, Biomedical Engineering Program

Mark Borden, professor in the Paul M. Rady Department of Mechanical Engineering, is the inaugural director for the college's Biomedical Engineering Program. He led 26 faculty from across four departments in launching the program in August 2020.

Borden has served as the director of the biomedical engineering minor since 2018 and has been a member of the mechanical engineering faculty since 2010. He is also a fellow of the Materials Science and Engineering Program. Borden is a leading expert in the field of microbubble engineering for biomedical applications, and his lab has already launched two biotech companies in Boulder.

Borden received a BS from the University of Arizona and PhD from the University of California, Davis, both in chemical engineering. Before joining CU Boulder, he was an assistant professor of chemical engineering at Columbia University.

Christy Bozic

Director, Engineering Management Program

Christy Bozic has been named the new faculty director of the Engineering Management Program. She joined CU Boulder in 2015 as a scholar in residence and EMP's associate faculty director of undergraduate education.

In her academic career, Bozic has held faculty and administrative positions at Purdue University. Her corporate experiences include global business manager at TDK Corp. of America and sales engineer for Federal Mogul Automotive Division.

With an undergraduate degree from Purdue and an MBA from Butler, Bozic earned her PhD from Purdue in curriculum and instruction. Her focus on research and teaching is engineering management with a specific interest in curriculum development to support multiple ways of teaching.

Will Medlin

Chair, Chemical & Biological Engineering

Will Medlin, Denver Business Challenge Endowed Professor in the Department of Chemical and Biological Engineering, has been chosen by his fellow faculty to lead the department as it continues to grow its reputation as a world-class center for chemical and biological engineering education and research.

Medlin has been a member of the department faculty since 2003 and served as associate department chair from 2012 to 2016. He was also a visiting professor at the Swiss Federal Institute of Technology in Zurich in 2010–11 and at Chalmers University in Sweden in 2017–18.

He earned his BS in chemical engineering from Clemson University and his PhD from the University of Delaware.

Charles Musgrave

Associate Dean for Graduate Education

Following an internal search, Charles Musgrave has been named associate dean for graduate education for the college.

Musgrave is a professor of chemical and biological engineering and professor of chemistry by courtesy. He served as chair of the Department of Chemical and Biological Engineering from 2016 to 2020.

Musgrave joined CU Boulder in 2008 as an associate professor. He is a fellow of the Renewable and Sustainable Energy Institute, and his research involves the application of a wide variety of quantum mechanical modeling methods to problems in energy and materials sciences.

Musgrave received his PhD and MS in materials science from the California Institute of Technology and his BS in materials science and engineering from the University of California, Berkeley.

Chris Myers

Chair, Electrical, Computer & Energy Engineering

After a national search, the Department of Electrical, Computer and Energy Engineering has welcomed Chris Myers as Palmer Leadership Chair. He comes to CU Boulder from the Department of Electrical and Computer Engineering at the University of Utah, where he was a professor and associate chair.

Myers received his BS in electrical engineering and Chinese history in 1991 from the California Institute of Technology, and his master's and doctorate from Stanford University in 1993 and 1995, respectively.

He is the author of over 180 technical papers and the textbooks *Asynchronous Circuit Design* and *Engineering Genetic Circuits*. He is also a co-inventor on four patents.

Diane Sieber

Director, Herbst Program for Engineering, Ethics & Society

Associate Professor Diane Sieber has taken the helm of the Herbst Program in Engineering, Ethics and Society. She joined the faculty of CU's Department of Spanish and Portuguese in 1993 and migrated to the Herbst faculty in 2004.

While serving on the Herbst faculty, she co-directed the ATLAS Institute beginning at its inception in 2000 and started the Technology, Arts and Media program during that time. From 2007 to 2012, she directed the Herbst Program, then served for four years as associate dean for education in the College of Engineering and Applied Science, where she helped to launch the Idea Forge.

Sieber was the founding faculty director of the Global Engineering Residential Academic Program and lived alongside undergraduate students in Kittredge Central for seven years.

Terri Wright

Assistant Dean for Access, Inclusion and Student Programs

Terri Wright has joined the college as assistant dean for access, inclusion and student programs, where she is charged with leading teams responsible for recruiting; career and professional development; scholarships and college affordability; collegewide diversity, equity and inclusion strategy; and the BOLD Center.

Wright has more than 16 years of teaching, research and program management experience in higher education. She began her professional career as a consultant in the chemicals industry at Accenture Ltd. before returning to academia in 2004.

Over the course of her career, she has provided underrepresented and low-income students in STEM disciplines with targeted academic advising, academic enrichment and undergraduate research opportunities.

University of Colorado Boulder
College of Engineering and Applied Science
422 UCB
Boulder, CO 80309-0422