Penn Engineering

Inspired by Nature

UNIVERSITY OF PENNSYLVANIA | FALL 2019

Scramblin' Band

Unlike your typical and highly regimented collegiate marching band, the Penn Band embraces eccentricity. Members don't march, they scramble. During performances in support of Penn Athletics, members run in all directions between set formations, sometimes stealing one another's instruments along the way. As the name implies, this "scramble band" is a community of like-minded students who value high spirits over marching prowess.

Penn Engineering students make up one-third of the Penn Band, balancing musical performances and heavy coursework. These devoted members say that the raucous routines alleviate stress and provide a supportive community on campus.

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Penn Engineering / Fall 2019

University of Pennsylvania
School of Engineering and Applied Science

ON THE COVER

EVERY PART OF EVERY LIVING CREATURE IS THE PRODUCT OF MILLIONS OF YEARS OF TRIAL AND ERROR, RESULTING IN COMPLEX SYSTEMS THAT ARE PERFECTLY SUITED TO THE ENVIRONMENTS IN WHICH THEY LIVE. ENGINEERS TAKE A MORE DIRECT APPROACH TO PROBLEM SOLVING, BUT HAVE MUCH TO LEARN FROM THE NATURAL WORLD. INSPIRED BY THE REAL THING, PROFESSOR JAMES PIKUL IS DEVELOPING "ROBOTIC BLOOD" FOR UNDERWATER MACHINES.

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alumni@seas.upenn.edu
215-898-6564
www.seas.upenn.edu

Vijay Kumar
Nemirovsky Family Dean

George W. Hain III
Vice Dean, External Affairs
Development and Alumni Relations

Joan S. Gocke
Director of Communications
Editor

Evan Lerner
Olivia J. McMahon
Associate Editors

Design
Kelsh Wilson Design

Photography
Kelsh Wilson Design
Priyanka Pardasani

From left: Penn President Amy Gutmann, Penn Engineering Overseer Harlan Stone and Nemirovsky Family Dean Vijay Kumar

Empower, Inspire and Elevate

The processes of discovery, research and development, technological innovation and education no longer rely only on first-principles, model-based methods that have been developed over the last three centuries. These approaches are being completely transformed by data-driven methods enabled by low-cost, ubiquitous sensor technology, affordable connectivity with high bandwidth and novel statistical machine learning algorithms. The importance of the field of data science cannot be overstated. Indeed, data science is changing so many aspects of our lives in addition to our professions.

In October, Penn Engineering celebrated a transformational gift that marks a new era for our School. It is, in fact, the largest gift in our history and the naming gift for a new data science building. The vision and generosity of University alumnus and proud Penn Engineering parent Harlan Stone will empower us to continue to be at the forefront of the data science and AI revolution and will elevate data science and engineering at Penn through this expansion of our physical footprint on campus.

This new educational and research facility, to be located at 34^{th} and Chestnut Streets, will leverage existing strengths in our School and foster and cultivate new strong interdisciplinary collaborations that build on excellence in business, social science, arts and humanities, communication and health science across Penn.

As dean it has been one of my greatest honors to witness firsthand the engagement of our alumni community. I am continually moved by the connections across the world and the vested interest that our graduates have in the sustained success of the School and one another. I am proud to be a member of the Penn Engineering community and deeply grateful to Harlan for this opportunity to lead the School in this new endeavor. With this gift, Harlan has empowered and inspired our community, and together we will continue to elevate Penn Engineering from excellence to eminence.

FASTER TOGETHER

Firooz Aflatouni's Electronic-photonic Innovations

The first-ever image of a black hole, published earlier this year, was constructed from five petabytes of data. These files were so large that they had to be flown to data analysts in giant stacks of hard drives; a plane ride from Hawaii was faster than the internet. Thankfully, Firooz Aflatouni is improving the fundamentals of data transfer to make sharing information about black holes—or just texting a friend—a faster, more efficient process.

Aflatouni, Skirkanich Assistant Professor in Electrical and Systems Engineering, has built his career on designing clever combinations of electronic and photonic technology with applications from laser-based 3D imaging, to microwave "cameras" that can see through walls or into tumors, to brain-machine interface systems. One current project, funded by the Defense Advanced Research Projects Agency (DARPA), focuses on making an electronic-photonic chip that can transfer tens of thousands of times more data per second than those found in current modems.

AFLATOUNI IS IMPROVING THE FUNDAMENTALS OF DATA TRANSFER TO MAKE SHARING INFORMATION A FASTER, MORE EFFICIENT PROCESS.

Right now, many systems are switching from sending information electronically to using fiber optics, which encodes information in the amplitude of light waves. Because light waves have a much higher frequency than electrical signals, fiber optic cabling is already making ultrafast connections between computers, and optically connected CPUs have the potential to make the computers themselves much faster. As of now, systems can't quite make the most of this speed. Currently, there are separate chips to deal with electronic and photonic information, and communication between these chips is costly.

Transferring data from the electronic domain to the optical domain and back takes valuable time and energy. Aflatouni's Electronic Photonic Microsystems Lab constructs chips that handle electronic and photonic information in the same place—an approach called "electronic-photonic co-design."

"Our system has electronic and photonic devices co-integrated next to each other on a single chip," says Aflatouni. "Electronic circuits control the optical devices and take massive amounts of data, organize it in a certain fashion and place it on optical signals. But it's all done on the same chip."

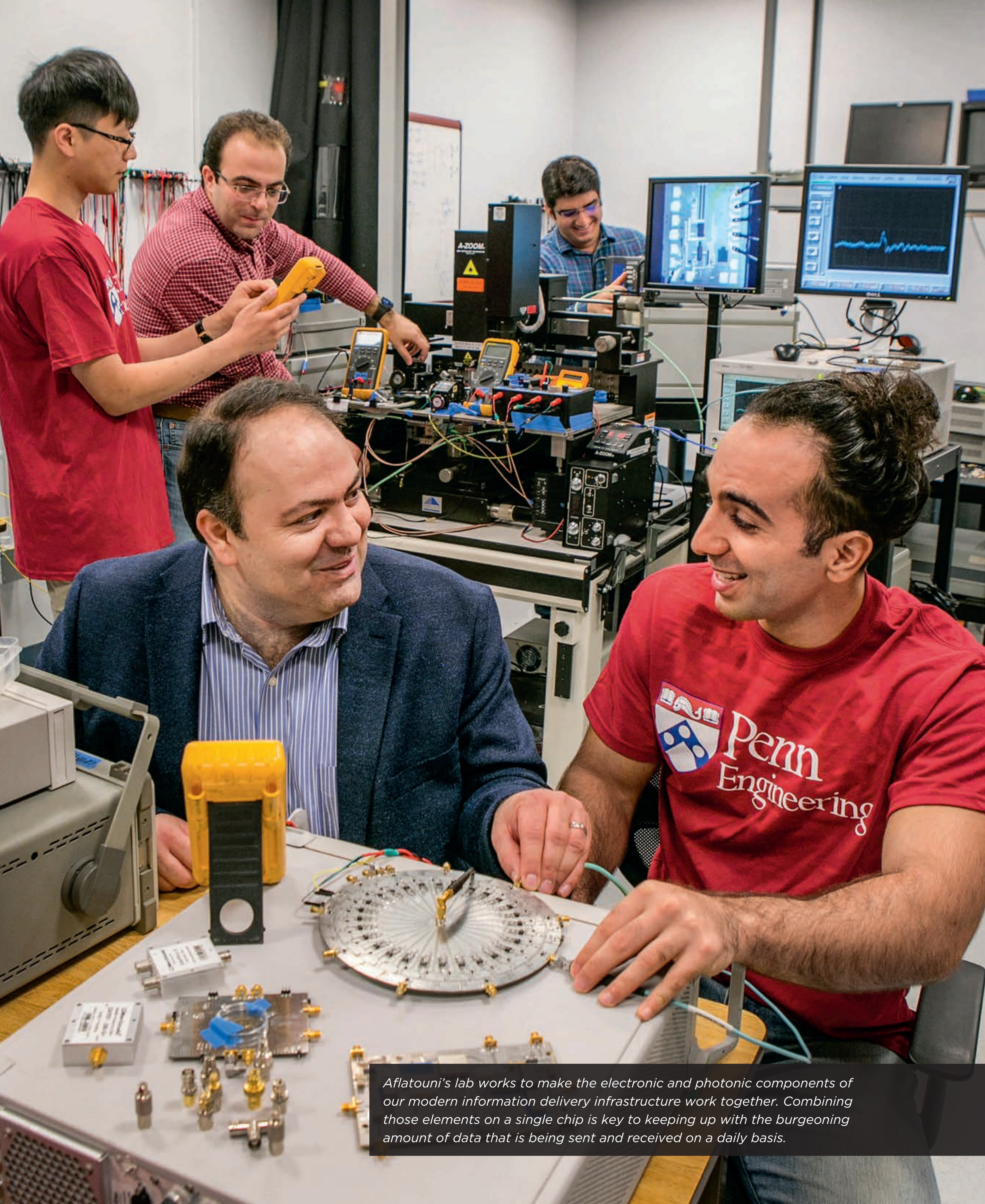
Implementing the entire system on a single chip through electronic-photonic co-design enables data transfer at a very high rate while using less space and energy than systems that require multiple electronic and photonic chips with complex chip-to-chip connections. For example, the newest televisions rely on fast fiber optic networks to stream content in "8K" resolution; if those enormous files were to come in through cable boxes outfitted with Aflatouni's technology, no energy would be wasted juggling data between different chips.

For the satellite communication that many systems depend on, Aflatouni has a similar electronic-photonic co-design solution. While microwave signals are typically used for satellite communications, in a project funded by NASA, Aflatouni is replacing these microwave signals with laser beams. By switching from microwaves to light waves, more information can be transferred per second using much less energy.

DROWNING IN DATA

When it comes to limitations in transfer speed, astrophysics isn't the only field struggling. The human brain, for example, contains approximately 75 billion neurons, each of which could be firing at any given millisecond. With currently available technology, large-scale neural recordings produce more data than is possible to gather and transfer.

FIROOZ AFLATOUNI
Skirkanich Assistant Professor
Electrical and Systems Engineering



Aflatouni's lab works to make the electronic and photonic components of our modern information delivery infrastructure work together. Combining those elements on a single chip is key to keeping up with the burgeoning amount of data that is being sent and received on a daily basis.

When collaboration opportunities with researchers in biology arose, Aflatouni recognized the interdisciplinary potential of his work. For one project, he is working to make a chip that can record neural activity, classify the recorded electrical pulses and transfer that data while consuming very little energy. In the future, this low-energy, implantable brain monitoring system could help diagnose and control certain neurological disorders such as epilepsy.

Other examples of Aflatouni stepping outside of his engineering wheelhouse include designing electronic and photonic chips to detect hint traces of biological indicators of disease in blood, a handheld microwave imaging system that can see through walls or skin, a high-frequency drone-to-drone communication system, and electronic control chips for quantum computing.

"I'm generally open to pursuing 'out-there' opportunities, so my work builds off of my core electronic-photonic area and is pretty diverse. My research has benefitted significantly from Penn's culture of collaboration," says Aflatouni.

INDUSTRY TO ACADEMIA

Being able to collaborate and step outside of his comfort zone is part of what drew Aflatouni away from industry and into academia. Before embarking down the path to his doctorate and current position at Penn, Aflatouni was fully immersed in the business world. After graduating from college, he started his own company, where he served as the CTO for six years.

As an undergraduate student in Tehran, Aflatouni was already thinking about emerging problems in the satellite communications that he's currently transforming with lasers. These satellites rely on two main mechanisms to function in space: The first is their capacity to relay data using microwave signals and the second is their ability to maintain a geostationary orbit, meaning their position appears fixed relative to a reference point on Earth. The former ability is powered by solar panels, but the latter is enabled by thrusters with a limited amount of fuel. When this fuel runs out, satellites enter an "inclined" orbit that wobbles through the sky. This means that signals from that fixed reference point no longer hit their target.

Aflatouni's startup sought to fix this problem by creating an affordable satellite tracking system. His company's system allowed reliable, uninterrupted communication once a satellite started wobbling, meaning that companies kept turning a profit and customers' technology kept working. But eventually, Aflatouni left industry to pursue a doctoral degree.

"One of the reasons that I moved from industry to academia is that I felt kind of limited. Especially as a startup, if you try something new and it doesn't work, you may lose the market," says Aflatouni. "In academia, the tolerance for uncertainty is much higher. You can try riskier ideas."

KNOWLEDGE TRANSFER

Growing up, Aflatouni developed an early interest in electronics. He remembers tinkering with electronics kits that his father and sister bought him, trying to understand how devices work.

> "I WANT STUDENTS TO KNOW WHAT'S HAPPENING IN THE WORLD, SO THEY CAN IDENTIFY IMPORTANT PROBLEMS," SAYS AFLATOUNI.

"When I was fourteen or fifteen, I built a device to voice control the lights in our house," Aflatouni says. "Creating these sorts of devices, I got electrocuted a few times. But the first time I got a very simple electronic circuit to work, it was such a huge reward. It gave me some confidence."

Aflatouni has passed this spark of interest down to another generation. Each summer, he collaborates with his daughters, currently six and nine years old, on an engineering project. Last summer, the family team built a robot from scratch, with Aflatouni's older daughter picking up some basic scientific thinking as well as coding skills in the process.

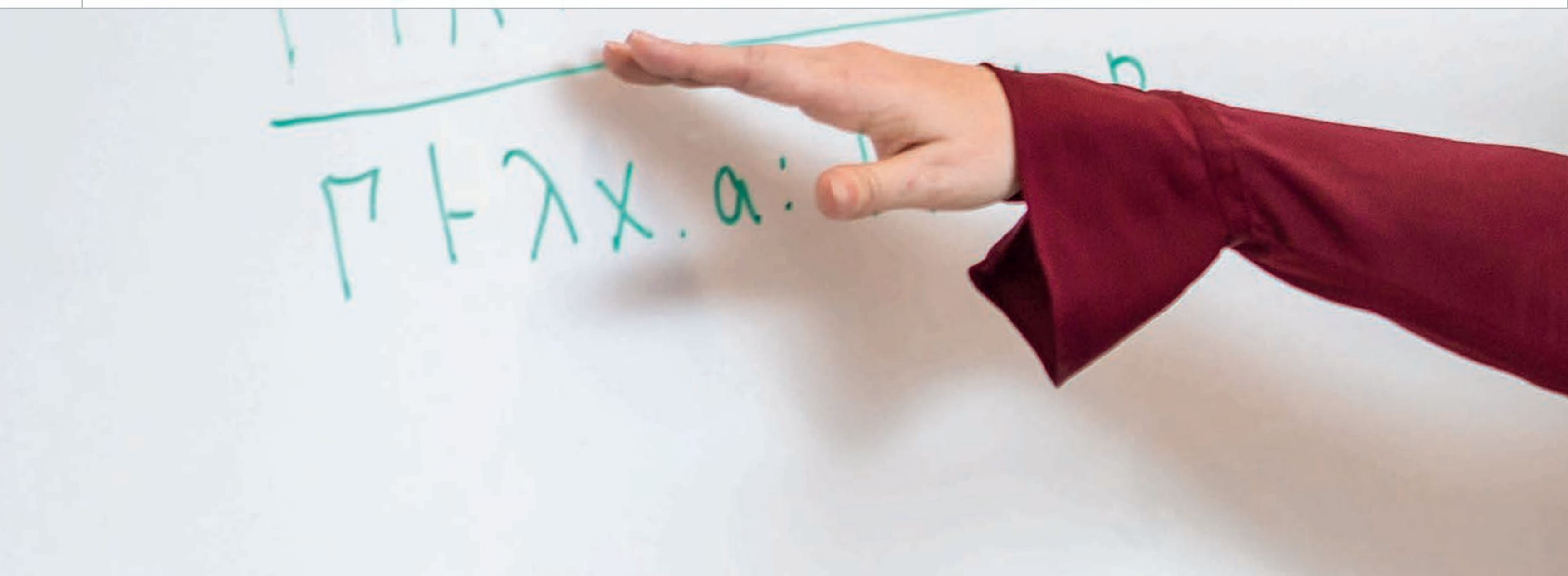
From his daughters to his graduate researchers, Aflatouni likes to teach his students to keep pushing the boundaries of their knowledge. At weekly lab meetings, his students partake in the usual research updates but also in cultural presentations, where students talk about the customs, food or tourist attractions of the places they're from, and participate in interdisciplinary science presentations.

"I want students to know what's happening in the world, so they can identify important problems," says Aflatouni. "We've had presentations about gravity wave measurements, the first image of a black hole and Amazonian ant behavior. Whatever it is, it's not directly relevant to their research. We learn collectively. We get a chance to see problems and see if we might be able to contribute."

By Lauren Salig

Correct Code

Stephanie Weirich Designs Tools for a Safer World



New cars are packed with helpful technology. Downward-facing cameras help drivers stay within lanes, and adaptive cruise control can brake and accelerate a vehicle based on other drivers' speeds. Likewise, banks use encryption software that changes your banking information into code that only your bank can use and read, and bank software even analyzes financial markets to make investments.

These features are based on software systems that rely on over 100 million lines of code, with separate programs for each component of each system. But as technology evolves, the software behind these systems needs to keep up.

Stephanie Weirich, ENIAC President's Distinguished Professor in Computer and Information Science, aims to make software systems more reliable, maintainable and secure. Her research improves tools that help programmers to determine the correctness of their code, which is applicable to a broad scope of software. Specifically, Weirich researches and improves Haskell, a programming language that places a lot of emphasis on correctness, thanks to its basis in logic and mathematical theories.

"People might not realize how much computational power underlies our society," Weirich says. "Cars, for example, possess very strong correctness requirements as they have become so reliant on computation. If banks mess up their code, it can cause disaster for our financial systems. The security and correctness of these programs is very important."

If a hacker goes after the software behind a less-correct (and thus less-protected) component of a car, such as the brakes, the results could be dangerous and devastating. Not only could the hacker gain control, but because each individual system is interconnected as a whole, the other programs for different components could be prone to errors as well. Similarly, if a driver is using lane-keeping assist and adaptive cruise control on the highway, a bug in a less-correct braking system might tell the adaptive cruise control that the car is braking when in fact it isn't, which could be deadly.

"Automation is everywhere. Cars today are just computers that have a steering wheel instead of a keyboard," says Antal Spector-Zabusky, one of Weirich's doctoral students. "It's very important that these computers are as reliable as possible so that

everything functions correctly, along with every other interlocking system, to prevent software from crashing and to ward off hackers."

TRAVELING ACROSS LANGUAGES

Programs for embedded systems, like those found in cars, are typically written in a programming language called "C." Programmers make sure that their software will use data correctly by combining relevant variables into classifications known as "data types." Types are what allow a programmer to assign rules to all of the different components of a computer program.

Weirich focuses on Haskell because she uses it to improve the type system of the language itself, which leads to even more extensive correctness for programmers. She's making the types more expressive, and as a result, programmers can make better use of the type system to help them develop correct code. For example, you could represent a date, such as February 29, 2019, using three integers: 2, 29 and 2019. However, the non-expressive "integer" type does not capture the relationship between these numbers. A more expressive type used for storing dates would flag this value as invalid by encoding the fact that February only has 28 days in non-leap years.

While these tools and systems are not directly usable across different languages, the ideas are. For example, Weirich says Mozilla's Rust language, a new programming language similar to C, draws from research on type systems, such as the type system research in the Haskell community. Wherever they're implemented, the more expressive the type system, the more it can check complex, intricate relationships between components of a program. By contrast, a less expressive type system might not be able to detect when such relationships are violated when the program is compiled, resulting in errors and incorrect behavior at runtime.

Stronger types and better system verification software allow programmers to ensure they're writing code correctly. Weirich has also worked with Spector-Zabusky to improve Haskell's compiler,

Professor Stephanie Weirich leads a spirited discussion in CIS 552: Advanced Programming as students use pair programming to work through an exercise based on the topic of the week.

which is what turns the Haskell language into a language used by computers.

“Instead of getting rid of bugs afterward, you get rid of them in the first place,” Weirich says. “The idea is that since you’re ruling out bugs at the beginning by how you are defining your types, you might be shortening development time. Also, because you don’t have to implement a wrong program and then redo that program, you’re shortening the maintenance time, because the compiler can help you figure out what part of the code can be changed.”

DEEPSPEC

Many professors and students in the Department of Computer and Information Science collaborate in a group called Programming Languages @ Penn, or PLClub. This includes Weirich and Spector-Zabusky, who have been working on a project called DeepSpec, a National Science Foundation flagship program, more formally known as “Expeditions in Computing: The Science of Deep Specification.” The DeepSpec project is a collaboration between Penn, MIT, Princeton and Yale.

“DeepSpec is examining this question: What does it really take to specify software correctly?”, says Spector-Zabusky. “We want to specify software that is used in the real world.”

To specify software is a fundamental component of ensuring that a program is as correct as possible. Specifications range in intensity, all the way from simple specifications, such as ensuring that an application won’t crash when it is used, to deep specifications, which could include ensuring that a complex numerical simulation computes correctly.

Weirich’s research directly informs the DeepSpec project, particularly her work with Spector-Zabusky to verify the Haskell compiler. The group aims to develop computer system verification for an entire computer system, which includes the operating system, hardware code and every other component. This takes correctness properties a

step further, or deeper, than types can, resulting in a higher degree of confidence in these systems.

COMPLEXITY IN CS

Computer science's complexity is what originally attracted Weirich to the field.

"Everything changes rapidly, and there's always new stuff," she says. "Computer science is very broad, so it would be impossible to keep up with every aspect of every field. It makes more sense to gain expertise in specific areas."

Weirich has been accumulating expertise in statically typed programming languages like Haskell for over twenty years. She continues to do so, and students from all corners of the University, from freshmen to doctoral candidates, benefit tremendously.

This semester, Weirich is teaching CIS 552: Advanced Programming to graduate students and select undergraduates.

"In Advanced Programming, I demonstrate ideas that are most expressible in the Haskell language," Weirich says. "I take ideas from my research and get to teach them to people who want to become software developers. This gives them not only a new way to develop code, but also a new perspective on programming."

In CIS 120: Programming Languages and Techniques, which Weirich will teach in spring 2020, she introduces freshmen to computer science through program design. She says she enjoys teaching this course, partly because she sees students progress from battling the difficult content to understanding it.

"Overall, undergraduates recognize that so many different fields now rely on computation," she says. "There's a big distribution in skill level and understanding, so throughout the semester, it's rewarding to see that switch to understanding at different points for different students."

By Jacob Williamson-Rea

David F. Meaney

Cadence for Creativity and Discovery

For insight on ways to nurture productivity and discovery, consider David Meaney's pace, varied focus and core values during one sunny Friday in September.

From predawn to the late afternoon spin class he leads on Fridays for Penn students, Meaney's day reflected his expansive priorities and lifelong quest to understand and mitigate biomolecular mechanisms in concussion. "People can become much less productive if they're hyper-focused," says Meaney, Solomon R. Pollack Professor in Bioengineering. "In this rigorous environment, you need other activities to keep you grounded."

Meaney's focus will expand further in January when he begins a new leadership role as Penn Engineering's senior associate dean. "Guided by Dean Vijay Kumar's vision, I'm excited to help shape and implement the next phase of engineering research and education at Penn," says Meaney, who chaired the Bioengineering department for the past 12 years and helped to recruit his successor.

He continues to lead his Molecular Neuroengineering Lab as it races to advance recent breakthrough findings (see 10:05 a.m. and 2:00 p.m.). Meaney seeks to someday defuse the "ticking time bomb" of concussion injuries by helping to develop urgently needed new methods to forecast cognitive outcomes, and to assess and improve treatment efficacy.

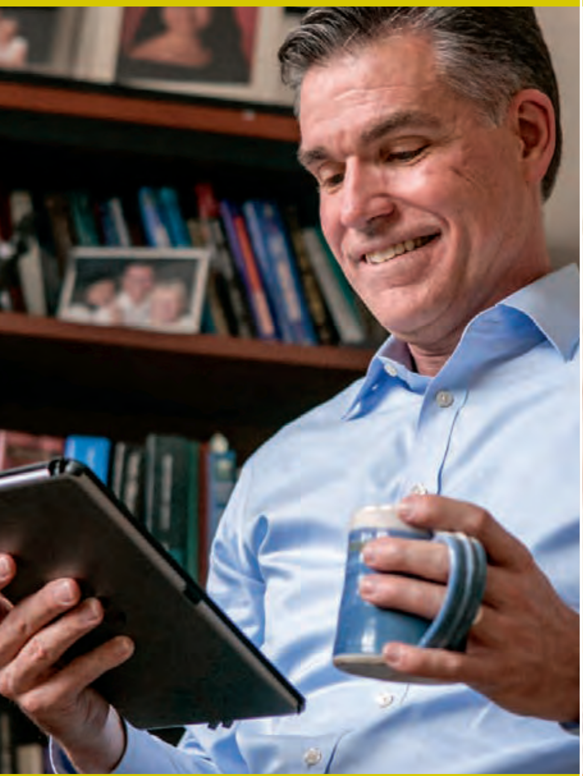
His filled-to-the-brim schedule this fall also includes teaching a popular introductory bioengineering lab course and leading what may be the world's first-ever spin class taught by an engineering professor. "I love teaching and mentoring," he says. "These parts of my job help me to stay connected with students and are also how I honor my late father, for whom college was so transformative."

By Jessica Stein Diamond

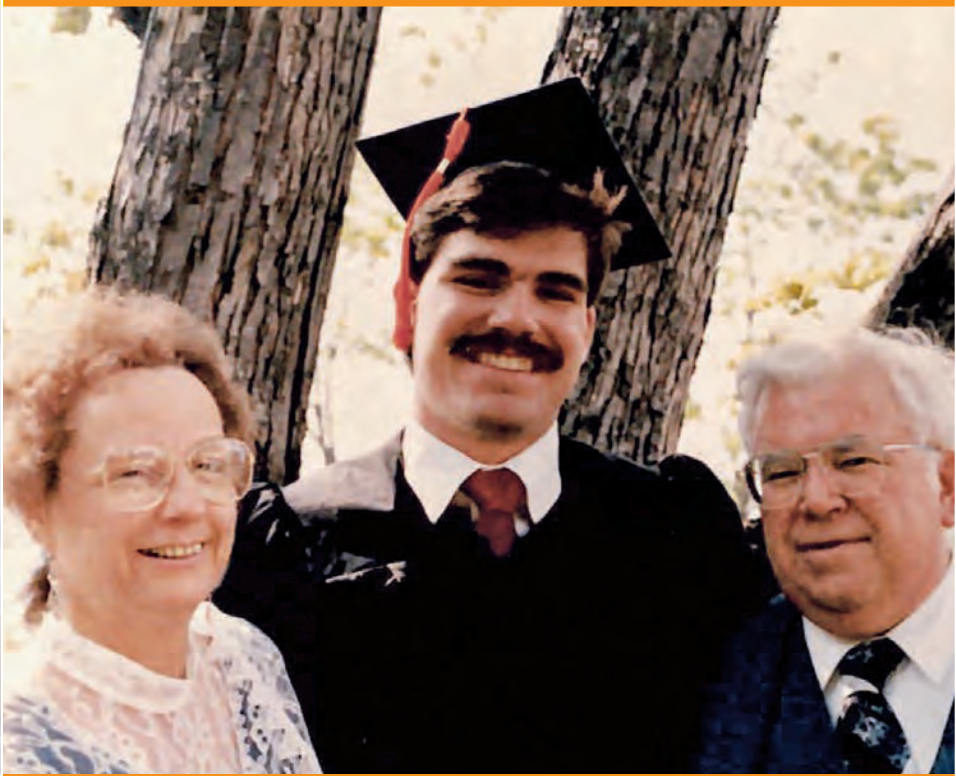
4:20 a.m. Meaney begins his day with a double espresso with milk and sugar and buttered whole wheat toast with cherry jam. He scans *The New York Times, The Washington Post, The Chronicle of Higher Education, Inside Higher Education* and occasionally *The Buffalo News* (to follow his childhood hometown football and ice hockey teams).

9:00 a.m. "I've learned that I need buffers in my schedule. So I keep Friday mornings unscheduled," Meaney says. He catches up on to-do items, reviews data, writes recommendation letters, holds office hours for students in his lab course and offers guidance on problem sets and lab reports. Students and colleagues alike enjoy the dark chocolates on his windowsill that invariably expand conversations beyond transactional topics and break the ice at research meetings.

6:07 a.m.



9:45 a.m.



6:07 a.m. On Fridays, Meaney catches the 6:07 a.m. SEPTA train, large coffee in hand, arrives at University City by 6:40 a.m. and walks to his office. In the early morning quiet, he handles his most urgent tasks and items that require sustained focus. Students in his research group know this is a good time to drop by with questions or requests. "It's a quick but useful meeting," he says. "Most times it's reminding me to do something."

9:45 a.m. Meaney ponders the experiences he'll share the following week at his "Growing Up in Science" talk (at which career scientists share how they overcame early challenges). "I hope threads in my story will be helpful to all students, including first-generation college students, who may worry if they belong at Penn," says Meaney. He vividly recalls how intimidating college felt after his academically weak high school, and how his loan debt grew during his junior year after his dad lost his job.

1:00 p.m. Doctoral student Erin Anderson and Meaney banter about his use of the relic EOM (End of Message) in emails, discuss using Twitter for lab recruiting (her idea) and refine her plans for future experiments. "I chose Dave's lab because he gives people autonomy," she says. "If you have an idea, he helps you chase it down."

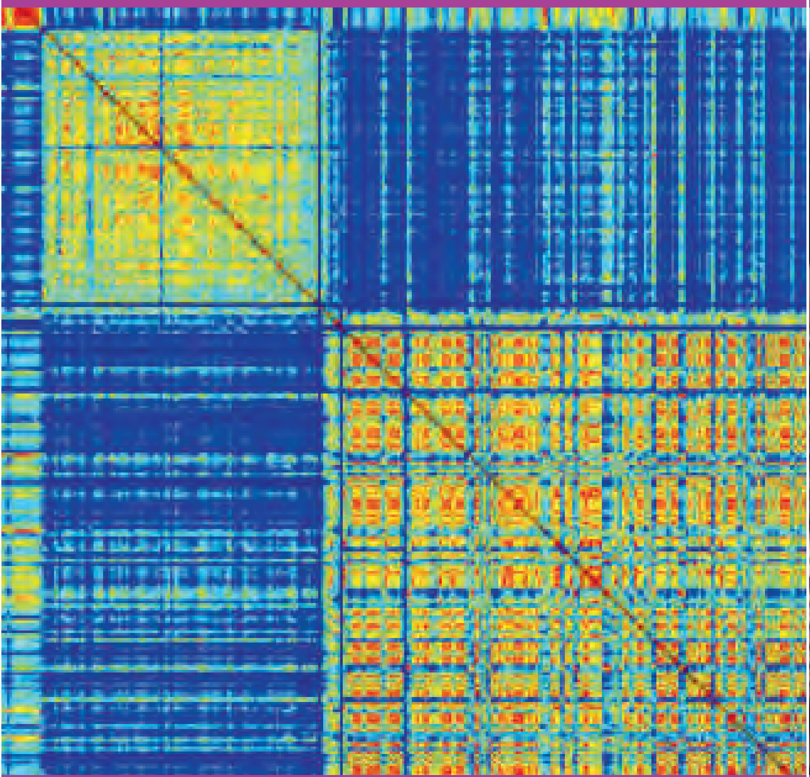
10:05 a.m. There are nearly four million concussions in the U.S. annually, and 20 percent of those people have problems six months later. "If we succeed, we could eradicate most of those problems," says Meaney. His 2018 papers with David Issadore, Bioengineering associate professor, synthesize data from blood samples and a diagnostic chip with machine learning to identify the microRNA signature of brain injury and predict injury intensity. Meaney plans related experiments to advance research he believes could potentially yield new methods to reduce concussion injuries and symptoms within a decade or so.

2:00 p.m. Doctoral student Kryshawna Beard leads a lab meeting about recent results. Her co-advisor, David Issadore, suggests she start writing the paper. "I've written the introduction already and am working on the rest," Beard says.

"Awesome," Issadore replies. The team's results further validate the diagnostic tool Issadore developed (Chip Diagnostics) to help doctors identify which concussion patients are at risk of a brain bleed and need a CT scan.

"Doctors need this," says Meaney. "They don't want to expose people to that radiation unless merited."

10:05 a.m.



2:00 p.m.

Noon Meaney dashes to the weekly lab lunch he hosts. "Having time to do things with and for other people is important," he says, recalling childhood meals with his six siblings. Over rigatoni and salad, students and staff in his lab discuss wrestling matchups between Gritty, the Philadelphia Flyers mascot, and college mascots such as the Stanford Tree ("can't punch"), Syracuse's Otto the Orange ("also problematic") and finally the Penn Quaker. Nick Vigilante, research associate, concludes, "Gritty with his chaotic energy would win that one easily. Quakers don't fight."

3:00 p.m. Near the 1920s-era leather football helmet hanging on his wall, Meaney works on a paper about the predictive computational tool he's developed to help helmet manufacturers design and test new helmets.

Meaney, who played football in high school, will provide the computer program free to manufacturers to help them evaluate each new helmet design to see if it passes existing safety standards and to assess how it compares to the safety profiles of existing helmets.

4:00 p.m.

5:30 p.m.

4:00 p.m. The lights dim. Kanye West's *Good Life* booms; Meaney laughs at the mood shift. As the instructor, he leads stretches, warm-ups and high-intensity intervals, varying the pedaling pace and resistance to (clean) hip hop and electronic dance music.

As Cardi B's *I Like It* plays, Meaney says, "Okay, big climb. Get that pace up." Cardio- and music-inspired elation grows: everyone's wiping sweaty brows, gulping water and out of breath. After a cool-down, the lights flip on. Chatting students (mostly bioengineers) head out to begin the weekend.

5:30 p.m. Meaney catches the train home to Media, picking up pizza and salad en route. Even though he's a capable cook, he and his wife Lynn prefer to begin their weekend with conversation and a cocktail on their front porch, watching sunlight fade through the woods. After dinner, they watch an episode of *W1A*, a British comedy series, then turn in for the night at 10:20 p.m. Meaney concedes, "Sleep is important for cognitive activity. So my goal is to add 10 more minutes a night every three months."

Optimal Solutions

Nature-inspired Engineering

Sometimes the best solutions to engineering problems are hinted at by nature itself. Mucus secreted by snails allows them to securely stick to the rough surfaces of rocks or trees but detach when the conditions are right. Hammer-like structures on the mantis shrimp survive high-velocity impacts on the heavily mineralized biological structures of prey, including mollusk shells, crab exoskeletons and the skulls of small fish. In humans and other animals, the circulatory system effectively transports oxygen and nutrients throughout the body while removing waste products.

Inspired by the biological systems described above, scientists from Penn Engineering recently overcame major obstacles in their subfields by creating multifunctional robot blood that enables long-duration autonomy, reversible superglues and a 3D-printing method to construct exceptionally tough and damage-resistant composite materials.

SIMULATING CIRCULATORY SYSTEMS

Animals are composed of biological systems that have multiple functions, and the human circulatory system is a prime example of this multifunctionality. In addition to transporting oxygen and nutrients throughout the body, the circulatory system removes waste products, regulates internal temperature and cellular pH levels and assists in fighting off disease and infection. By contrast, modern robots still lack the multifunctional, interconnected systems found in living organisms and instead are typically composed of distinct power, actuation, sensory and control systems that are optimized for specific tasks, resulting in reduced efficiency and autonomy.

“A major deficiency in all robotic systems is that they cannot operate for very long autonomously,” says James Pikul, assistant professor in Mechanical Engineering and Applied Mechanics. “This is why most robots are tethered or connected to a power outlet. Despite the many recent advances in energy storage technologies, robots still only operate for up to an hour, while humans can operate for a week without food.”

> MODERN ROBOTS STILL LACK THE MULTIFUNCTIONAL, INTERCONNECTED SYSTEMS FOUND IN LIVING ORGANISMS.

Energy storage is one of the major barriers to achieving long-duration autonomy in robots. Added battery packs take up more volume and increase weight, requiring additional modifications to maintain overall performance. “In a typical engineered device, there are trade-offs between dexterity and endurance, so a robot can either last longer and have a bigger battery, or have a smaller battery but be able to perform more functions,” Pikul says.

But redox flow batteries (RFBs), which use liquid or semi-solid components, hold potential for addressing this problem through multifunctional energy storage. Pikul and his collaborators recently developed an RFB-inspired synthetic circulatory system embedded in an untethered, lionfish-like aquatic soft robot.

As reported in June in the journal *Nature*, this vascular system combines the functions of hydraulic force transmission, actuation and energy storage into a single integrated design that increases the energy density by a factor of four compared to the same fish powered with only lithium-ion batteries. As a result,

Serving as both a power source and the hydraulic fluid that moves the robot's fins, Pikul's "robotic blood" is multifunctional, just like the real thing. Underwater robots are especially constrained by size, weight and distance from humans who can charge their batteries, so efficiency is crucial.

the robot can use its tail fin to swim against a current at 1.56 body lengths per minute for up to 36 hours.

"The novelty of our technology is in the ability to make and use a multifunctional fluid that stores energy and provides other functions useful to robots," Pikul says. "This has never been demonstrated before."

According to the researchers, the use of electrochemical energy storage in hydraulic fluids could facilitate increased energy density, autonomy, efficiency and multifunctionality in future robot designs. Potential applications include search-and-rescue missions, ocean exploration on Earth, extraterrestrial reconnaissance missions or delicate environmental tasks such as sampling coral reefs.

"This technology can be used to improve the range and capabilities of any autonomous device that uses electricity and a fluid," Pikul says. "This can help make electric vehicles and heavy machinery more sustainable by allowing them to be further powered by electricity instead of fossil fuels, or allow robots that assist humans in hospitals or in workplaces to be more practical and able to operate longer. I am hoping that this technology makes these diverse engineered systems more useful and efficient for humans."

SNAIL-LIKE SUPERGLUE

When Gaoxiang Wu (MSE'16) was a doctoral student, he spent a lot of time working with a hydrogel called poly(2-hydroxyethyl methacrylate), or PHEMA, which is found in contact lenses and other biomedical devices. One day, Wu made various patterns with this gel on a glass slide and left it on the bench. When he returned, he had a hard time separating the dried gel from the slide, but after soaking the gel in water, it slid off easily.

"It was a curious finding," says Shu Yang, Wu's former doctoral advisor and professor in Materials Science and Engineering. "It got us wondering why and whether there is any biological system that might work in a similar way."

It turns out there is. Upon drying, mucus secreted by snails forms a stiff protective substance called an epiphragm, which allows them to temporarily but securely adhere to surfaces.

THESE REUSABLE ADHESIVES COULD BE USED FOR SURGERY, ROBOTICS, CAR AND FURNITURE ASSEMBLY, WALL CLIMBING, MANUFACTURING AND MORE.

In a study published in July in *Proceedings of the National Academy of Sciences (PNAS)*, Wu, Yang and their collaborators described a hydrogel-based reversible superglue inspired by snail epiphragm. The surface layer of the PHEMA gel readily conforms to flat or rough surfaces when wet and subsequently locks into this configuration as the gel dries. When rehydrated, the gel detaches from the surface.

"The key is that the gel should be very soft when wet, so it can squeeze and fill in all the micro- and nano-cavities on the surface it sticks to with a small amount of pressure," says Yang. "Since PHEMA gel doesn't shrink much, it doesn't pull away from those tiny cavities on the substrate. That's the reason it sticks so well."

The PHEMA hydrogel combines the benefits of liquid and dry adhesives in a single material, while overcoming their respective limitations. Achieving both super-strong adhesion and reversibility has been challenging, particularly for hydrogels, which typically do not adhere strongly to any material.

"Until our study, it was not clear whether one could design a material that works against arbitrary surfaces and yet delivers adhesive strength comparable to liquid adhesives," says Yang. "But our

Jason Christopher Jolly, one of Yang's students and co-authors, is attached to the gantry by a postage-stamp-sized square of their epiphragm-like adhesive gel. As with a hibernating snail, it would take a hammer and chisel to remove the adhesive when it's dry, but adding water relaxes the gel and its grip.

The nozzle of any 3D printer can extrude material in a precise shape, but Raney's work is enabling them to add microscopic shapes within those materials, like the spirals of chitin or cellulose that make crustacean shells and tree trunks extra tough.

adhesive is superior to liquid-based superglues for its reversibility and non-contaminating adhesion."

According to Yang, these reusable adhesives could be used for surgery, robotics, car and furniture assembly, wall climbing, manufacturing and more. But there are still a few kinks to work out. "Since no one wants a car that falls apart in the rain, we currently are searching for alternatives that will not require the use of water to loosen the gel's hold," Yang says.

TOUGH NATURAL COMPOSITES

Natural composites generally possess exceptional mechanical properties due to their heterogeneity and structural complexity across multiple spatial scales. For example, wood exhibits high stiffness, high damage tolerance and low density due to spatial variations in cellulose fiber alignment.

Complex fiber arrangements such as helices enhance the toughness of natural composites by disrupting the propagation of cracks during fracture. This mechanism is present in wood, bones, shells and hammer-like structures called dactyl clubs in stomatopods, a group of highly aggressive marine crustaceans. The dactyl clubs from the mantis shrimp can withstand thousands of highly energetic blows on heavily mineralized prey before being replaced during periodic molting events.

"Conventional manufacturing methods are not able to produce the elegant and complex micro-structural features observed in nature, which are critical for producing tough composites," says Jordan Raney, assistant professor in Mechanical Engineering and Applied Mechanics. "Part of what we do is create new materials and 3D printing

approaches that let us move toward increased control and nuance in the design and fabrication of bioinspired, fiber-reinforced composites."

"CONVENTIONAL MANUFACTURING METHODS ARE NOT ABLE TO PRODUCE THE ELEGANT AND COMPLEX MICRO-STRUCTURAL FEATURES OBSERVED IN NATURE," SAYS RANEY.

As reported last year in *PNAS*, Raney and his collaborators developed a rotational 3D printing method to construct carbon fiber-epoxy composites with precisely controlled helical fiber arrangements, resulting in superior combinations of stiffness, toughness and damage tolerance. The researchers were able to spatially control the orientation of short fibers in polymer matrices simply by varying the nozzle rotation speed and the print path.

According to the researchers, this approach can be applied to the broad array of materials that have been developed for extrusion-based 3D printing. "Because the fiber alignment is controlled almost exclusively by the shear field in the extrusion nozzle, the same approach works for a broad range of short fiber composites," Raney explained. For example, the group's recent work, published in *Advanced Materials Technologies,* uses these techniques to print all-natural short fiber composites composed of sticky rice and cotton fibers. "We control the fiber alignment in these natural composites using exactly the same approach that we used for carbon fiber composites."

By Janelle Weaver

On Our Camera Roll

1. The Quain Courtyard offers a pleasant outdoor study space. **2.** Friends share stories of fall break fun. **3.** Computer Science undergrad Kidist Wosenyeleh studies near the Colker Fountain. **4.** Sophomore Khalil Lewis enjoys an easy, traffic-free commute to class by bicycle. **5.** Prospective students and their families concentrate on the Penn tour guide in front of the Towne Building.

6. ESE senior Celine Lee studies outside of Skirkanich Hall, where new tables and chairs expand the building's footprint. **7.** The Singh Center for Nanotechnology boasts quiet meeting spaces for students with incredible views of the campus and Philadelphia. **8.** An undergraduate enjoys a snack and the unseasonably warm fall weather outside Hayden Hall. **9.** Master's student Chang Liu assembles her project for Introduction to Mechatronics. **10.** Walkers, cyclists and skateboarders flood Smith Walk in between classes.

Scramblin' with the Penn Band

In a 2017 video commemorating the Penn Band's 120th year at the University, Band Director Greer Cheeseman (C'77) momentarily considers an off-camera question he'd been asked about requirements for membership. "My only requirements," Cheeseman drolly replies, "are a good attitude and a pulse. Talent," he added, almost as an afterthought, "is optional."

Are Penn Engineering students and present band musicians Caitlin Frazee, Bernie Wang and Landon Butler offended by this irreverent and seemingly unfiltered remark? To the contrary! In their view, Cheeseman's deadpan assessment perfectly captures the spirit and nature of the organization. The Penn Band is, like most bands in the Ivy League, a "scramble" band, whose members delight in rowdiness and anti-regimentation. It is a marching band, in other words, that doesn't march.

HOWEVER HARDWORKING AND HIGH-ACHIEVING, THESE PENN ENGINEERING STUDENTS MAKE IT THEIR BUSINESS TO ENTERTAIN AND BE ENTERTAINED.

Under the aegis of the Department of Athletics, band members often perform over 100 times a year, heralding official processions, scattering across football fields both home and away, taking ownership of the Palestra and generally making themselves heard at notable campus events. And

they play music! Band fans, team sports spectators and alumni can count on hearing their old Penn song favorites along with some new and popular tunes. At halftime, a disembodied voice narrates a joke-like story that concludes with a choreographed on-field formation as its punchline.

READY FOR ANYTHING

The ebullient Caitlin Frazee (BE'22), flute section leader of the band, seems to personify the energy and enthusiasm of this large performing arts organization. She notes, in fact, that it is a defining quality of band culture for members to exhibit their Penn spirit—and to do it proudly. Face painting, Penn "tattoos" and the wearing of the red and blue are strongly encouraged. Frazee describes her primary responsibility as section leader of "tenish" flutes and piccolos as "being ready for anything." Rehearsals and game attendance take second place to members' academic responsibilities and accountability, so performances rely more on the "magic" of their fluctuating group than on any directive to "show up or else." Members are there because they want to be.

Playing the flute and taking part in band hijinks one day, adding her classically trained soprano to St. Mary's Church choir as a choral scholar the next, working as a researcher in the Yang Lab in the Department of Cancer Biology and attending classes keeps Frazee busily crisscrossing campus. While her humorously written Penn Band bio lists her favorite activity as napping, it is unlikely that this Bioengineering major could find enough time in her day for it. Carrying six credits, Frazee gives

high praise to what is known as Band Study. She says that gathering with bandmates in a concerted group effort to support one another academically has helped her sharpen her time management skills and keep current with her assignments. As with many of her peers, Frazee sees collaboration rather than competition as key to success.

SLIDING WITH THE LOW BRASS

Enrolled in Penn's dual-degree VIPER (Vagelos Integrated Program in Energy Research) curriculum and certified as a Kukkiwon 3rd Degree Black Belt, Bernie Wang (MSE/Ch'21) is not as intimidating as he sounds. Wang is the band's equipment manager, keeping detailed spreadsheet accounts of instrument inventory and lending. A trombonist since elementary school, Wang is another musician who defies the band's "talent optional" allowance. And while aware that the band has no mandatory attendance rule, Wang was present at nearly all of their gigs this past spring semester, even throughout the notoriously difficult MSE-plus-Chemistry sophomore spring.

As a newly minted Penn freshman, Wang couldn't wait to join the band, wondering when he could finally be a part of the fun and meet them. The decision was a wise one: The mental intensity required to handle two majors (Materials Science and Engineering and Chemistry) is counterbalanced by the spontaneity and creativity inherent in band performances. Wang also enjoys the social aspect of band life, both on Penn's campus and at away games. Through an Ivy League agreement, home team bands host the visiting ones, and band members socialize and enjoy a change of campus scenery.

DRUM ROLL, PLEASE

Who knew that an aspiring systems engineer from the Kansas City 'burbs would find himself at home in the organized chaos of the Penn Band? Meet Landon Butler (SSE'22), a drumline section leader. (Butler shares leadership responsibilities for the large 30-to-35-member section with Nicolas Corona (W'21).) Butler describes the importance of the band's inviting and friendly environment

as "immense," and appreciates the diversity of backgrounds and cultures he has found across the University.

THE PENN BAND IS, LIKE MOST BANDS IN THE IVY LEAGUE, A "SCRAMBLE" BAND, WHOSE MEMBERS DELIGHT IN ROWDINESS AND ANTI-REGIMENTATION.

As for his musical experience, Butler's mother's reluctance to pass up a good bargain resulted in her son beginning piano lessons in second grade ($5.00 per half hour!). Bargain or no bargain, he was not a fan of the piano and had switched to percussion by the fifth grade. He marched with a traditional marching band in high school, where his music became a serious commitment of time and dedication. Elected drum captain in his senior year, Butler still considers it one of his most "cherished" roles. At Penn, he not only plays the drums, but also reads music and composes drum cadences. Using free software called MuseScore, Butler has helped to write a few of the percussion parts for the band's pep songs.

Butler's fascination with scientific and technological problem solving developed in tandem with his musical abilities. After obsessing early on with the computer game Math Baseball, Butler later enrolled in Project Lead the Way, a national four-year STEM curriculum that he credits for solidifying his interest in engineering.

You can be sure that the next time the band launches into *Drink a Highball* at the end of the third quarter and, according to tradition, pieces of toast sail from the stands onto the football field, a Penn Engineer is somehow involved. However hardworking and high achieving, these Penn Engineering students make it their business to entertain and be entertained.

Cue the crash of cymbals

By Patricia Hutchings

During a Carol Night program at Tarkwa Breman Girls' School, Lin presents a gift sent from a WagiLabs program in YWCA Chicago. By exchanging messages and gifts, the WagiLabs programs build international empathy between children.

A Change of Plans

Designing a Post-grad Year

In the year they spent working for a nonprofit startup in rural Ghana, Class of 2018 alums Julia Lin, Kate Panzer and Erica Higa shared a catchphrase: It doesn't hurt to ask. "We had no network there, no expectations," Lin says. "So we asked for things and created our own connections."

The three became a team during their senior year when they applied for the 2018 Penn President's Engagement Prize. Panzer, a Bioengineering major with medical interests, connected with Higa through service-learning projects in Ghana and Rwanda. Higa studied Mechanical Engineering and Applied Mechanics (MEAM) with a minor in Energy and Sustainability and was a four-year varsity soccer player. Lin, also a MEAM major, began Penn's master's in Integrated Product Design during her senior year. She met Panzer while working at GEMS, a Penn Engineering camp for middle school girls.

CHANGING COURSE

By combining their interests with Panzer and Higa's service experiences, the three developed a proposal called Classroom to Community that would provide hands-on opportunities for STEM students in Rwanda. When their project did not win, the soon-to-be graduates quickly readapted. "We were disappointed, but we said, 'Let's get back together and figure out how this is going to work,'" Panzer says. The team decided to let their project go and support a pre-existing organization instead.

Shadrack Frimpong, a 2015 Penn graduate and Engagement Prize winner, had helped mentor the team through their proposal process. With his prize, Frimpong had founded Cocoa360—a girls' school and clinic supported by a community-run cocoa farm in Tarkwa Breman, Ghana. Because Cocoa360 aligned with the team's interests in health and STEM education, they met with Frimpong. "We asked,

At a Talent for Telecom show organized by Panzer and five local schools to advocate for networking in the Tarkwa Breman community, the team, along with Mavis Osei Banful, Assistant Headmistress of Tarkwa Breman Girls' School, poses for a group shot in traditional Northern Region smocks.

'What can we do for you?', and he said, 'Come to Ghana!'. We were there two months later," Higa says.

Tarkwa Breman is a village of three dirt roads nestled within farmland in western Ghana. Lin, Panzer and Higa shared a home with Cocoa360's headmistress and assistant headmistress and spent their free time strumming the guitar, playing with local kids or visiting families in the community. As the Digitization, Monitoring and Evaluation Fellow, Lin implemented systems to collect farm attendance and harvest data, communicated with donors and taught a WagiLabs "kidtrepreneurship" class at the school. Panzer, the Health Research Fellow, analyzed data from Cocoa360 and other clinics to report the ten most common diagnoses in an effort to gain more funding for treatments. As the Development Fellow, Higa supported many parts of Cocoa360's operation, including social media, fundraising and administration work.

FINDING THE RIGHT TOOLS

Penn had prepped them for the year in specific ways: Higa had an introduction to international development through her service-learning course, while Lin had lesson-planning experience from outreach with the Penn chapter of the Society of Women Engineers. Panzer's experiences in Ghana had given her an introduction to the country, but with no formal training and short notice, the three did not feel entirely prepared. They experienced the learning curve of a startup environment and

(Left) Panzer joined the Tarkwa Breman Girls' School parents in gathering and carrying cocoa at the Tarkwa Breman Community Farm to support Cocoa360's Farm for Impact model. (Right) Higa sat with a student during a mid-morning recess break, after supporting the teachers at the Hackett Family Kindergarten Block that morning.

unexpected cultural differences. "Even the concept of time is different," Panzer says. "It was hard just trying to get everyone in the same location at the same time for meetings."

Roadblocks became more manageable as they exercised the resourcefulness that had brought them to Ghana to begin with. Teamwork played a large role, a skill they credited to their engineering education.

"I was the coordinator, trying to remind our team why we were doing things," Higa says. "Kate was the enthusiasm, always ready to form partnerships, and Julia was all about big ideas and design."

The three even found time outside of work to record and perform *Akwaaba (You Are Welcome Here),* a song they had written with local kids in English and Twi, the regional language. Panzer organized a talent show between five different schools, spending hours walking between campuses to communicate because of minimal phone service. "I learned at Penn that engineering doesn't have to be about a device," Panzer says. "It's about being able to problem solve in general."

HUMAN-CENTERED DESIGN

One of the biggest keys to success at Cocoa360 was people. Though Penn Engineering teaches stakeholder involvement, the value of involving people in the creation process became more apparent in a small community. "You have to put yourself in people's shoes," Lin says. "If I wanted to design for the farm, I needed to be there at

Lin taught a weekly WagiLabs creativity class to students enrolled in Kindergarten Class 2.

4:00 a.m. to assist the farm manager." The three women realized that going out and making connections was just as valuable as working in the office, and these relationships led to deep friendships that made leaving Ghana bittersweet.

"PENN ENGINEERING GRADUATES HAVE ACCESS TO SO MANY RESOURCES. IT'S OUR RESPONSIBILITY TO USE THAT PRIVILEGE TO BETTER THE WORLD AROUND US," HIGA SAYS.

Each graduate plans to return in the next few years to see their friends in person. In the meantime, Higa is putting her passion for sustainability to work at Recology, a waste recovery company in her home state of California. She plans to stay involved in international development in the long run. Panzer, conducting research at the University of Michigan while applying to medical schools, is looking for programs that will let her return to Ghana for disability health research.

Back at Penn, Lin has been inspired by Cocoa360 to include a social component in her master's capstone project. "I have more perspective on how many resources Penn has," Lin says, "and am excited to try more things around campus." Higa agrees: The value of a Penn Engineering degree depends on what you make of it. "Even without the Prize, Penn Engineering graduates have access to so many resources," Higa says. "It's our responsibility to use that privilege to better the world around us."

By Lida Tunesi

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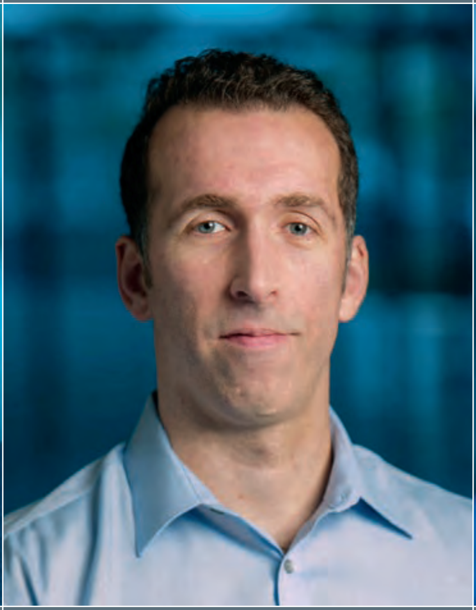
University of California, Los Angeles



Nikolai Matni

Assistant Professor
Electrical and Systems Engineering

Ph.D. in Control and Dynamical Systems

California Institute of Technology

Shirin Saeedi Bidokhti

Assistant Professor
Electrical and Systems Engineering

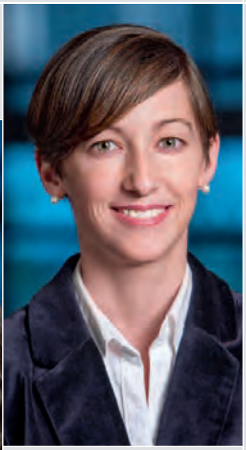
Ph.D. in Communication and Computer Sciences

Swiss Federal Institute of Technology

NEW LEADERSHIP

Cherie Kagan, *Stephen J. Angello Professor in Electrical and Systems Engineering,* has been named Associate Dean for Research at Penn Engineering. Dr. Kagan will focus on increasing support for research initiatives, strengthening ties with industry, championing faculty-friendly policies for research and innovation, and promoting interschool collaborations, especially in energy science and technology.

David F. Meaney, *Solomon R. Pollack Professor in Bioengineering,* has been named Senior Associate Dean at Penn Engineering. This new leadership position will have oversight responsibilities in space and infrastructure planning, facilities and research services, and will create and cultivate new interschool partnerships that will expand Penn Engineering's footprint on campus.



Danielle Bassett

Vanessa Chan

Russell Composto

Boon Thau Loo

Stephanie Weirich

Mark Yim

Danielle Bassett has been named the *J. Peter Skirkanich Professor of Bioengineering.* The J. Peter Skirkanich Professorship was established to honor the late J. Peter "Pete" Skirkanich, an alumnus, trustee and member of the School of Engineering and Applied Science Board of Overseers. His generous support for Penn Engineering paved the way for Skirkanich Hall.

Vanessa Chan has been named the *Jonathan and Linda Brassington Practice Professor* in the School of Engineering and Applied Science. Dr. Chan is a professor in the Department of Materials Science and Engineering. The Jonathan and Linda Brassington Practice Professorship was established to provide financial support to a practice faculty member in the School of Engineering and Applied Science.

Russell Composto has been named the *Howell Family Faculty Fellow* in the School of Engineering and Applied Science. Dr. Composto is a professor in the Department of Materials Science and Engineering. The Howell Family Faculty Fellowship was established to provide financial support to a faculty member in the School of Engineering and Applied Science.

Boon Thau Loo has been named the *RCA Professor of Artificial Intelligence* in the School of Engineering and Applied Science. Dr. Loo is a professor in the Department of Computer and Information Science. The RCA Professorship was established with the support of RCA, originally the Radio Corporation of America, which was one of the earliest and most successful consumer electronics companies.

Stephanie Weirich has been named the *ENIAC President's Distinguished Professor* in the School of Engineering and Applied Science. Dr. Weirich is a professor in the Department of Computer and Information Science. The ENIAC President's Distinguished Professorship was established in honor of the Electronic Numerical Integrator and Computer (ENIAC), the world's first general-purpose electronic computer.

Mark Yim has been named the *Asa Whitney Professor of Mechanical Engineering*. The Asa Whitney Professorship was established to honor Asa Whitney, benefactor of Penn's first endowed professorship, whose bequest established the Asa Whitney Professor of Dynamical Engineering in 1877.

HONORS & AWARDS

Igor Bargatin, *Class of 1965 Term Assistant Professor in Mechanical Engineering and Applied Mechanics,* has been selected to receive a 2019 National Science Foundation (NSF) CAREER Award. This honor is the NSF's most prestigious award and aims to support junior faculty members who embody the role of ideal teacher-scholars through the integration of education and research while supporting the mission of their organizations.

John Bassani, *Richard H. and S. L. Gabel Professor in Mechanical Engineering and Applied Mechanics,* has been awarded the 2019 Daniel C. Drucker Medal from the American Society of Mechanical Engineers (ASME). This award is conferred in recognition of distinguished contributions to the field of applied mechanics and mechanical engineering through research, teaching and service to the community over a substantial period of time.

Lee Bassett, *Assistant Professor in Electrical and Systems Engineering,* is a recipient of The Grainger Foundation Frontiers of Engineering Grant for Advancement of Interdisciplinary Research from the National Academy of Engineering (NAE). This program brings together outstanding early-career engineers from industry, academia and government to discuss pioneering technical work and leading-edge research in various engineering fields and industry sectors.

Dawn Bonnell, *Penn's Vice Provost for Research and Henry Robinson Towne Professor in Materials Science and Engineering,* has been honored as one of three 2019 Distinguished Life Members of the American Ceramic Society (ACerS), an organization that strives to advance the understanding of ceramics and other materials. The Distinguished Life Member award is the organization's highest honor.

Robert Carpick, *John Henry Towne Professor in Mechanical Engineering and Applied Mechanics,* has been selected as a Fellow of the American Society of Mechanical Engineers (ASME). ASME is a leading engineering organization that emphasizes multidisciplinary collaboration and skill development, and the Fellow distinction recognizes nominees for their significant engineering achievements.

Nader Engheta, *H. Nedwill Ramsey Professor in Electrical and Systems Engineering,* has been inducted into the Canadian Academy of Engineering (CAE) as an International Fellow. The CAE comprises many of Canada's most accomplished engineers. Engheta was among the five international fellows that were inducted this year.


Igor Bargatin


John Bassani


Lee Bassett


Dawn Bonnell


Robert Carpick


Nader Engheta

Hamed Hassani

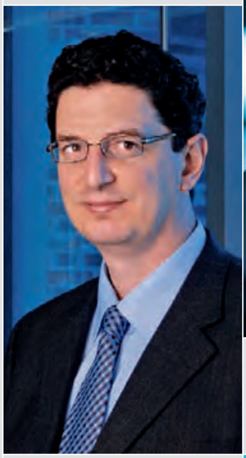
Hamed Hassani, *Assistant Professor in Electrical and Systems Engineering,* has been selected to receive a grant through the Air Force Office of Scientific Research's Young Investigator Research Program (YIP). The objective of this program is to foster creative basic research in science and engineering, enhance early career development of outstanding young investigators, and increase opportunities for the young investigators to recognize the Air Force mission and the related challenges in science and engineering.

Daeyeon Lee

Daeyeon Lee, *Professor in Chemical and Biomolecular Engineering,* has been selected by the U.S. Chapter of the Korean Institute of Chemical Engineers (KIChE) as the recipient of the 2019 James M. Lee Memorial Award. This award honors the late first president of the U.S. Chapter of KIChE by recognizing an outstanding Korean or Korean-American chemical engineer.

Michael Mitchell

Michael Mitchell, *Skirkanich Assistant Professor of Innovation in Bioengineering,* has received a Young Investigator Award from the Chinese Association for Biomaterials. This award recognizes individuals who have successfully demonstrated significant achievements in the field of biomaterials research.



George Pappas

George Pappas, *UPS Foundation Professor of Transportation and Chair of Electrical and Systems Engineering,* has been elected a Fellow of the International Federation of Automatic Control (IFAC). The IFAC is a scholarly society devoted to the theory and application of automatic control and systems engineering in diverse fields, including engineering, biological, social and economic systems.

Paris Perdikaris

Paris Perdikaris, *Assistant Professor in Mechanical Engineering and Applied Mechanics,* has been selected to receive a grant through the Air Force Office of Scientific Research's Young Investigator Research Program (YIP). The objective of this program is to foster creative basic research in science and engineering, enhance early career development of outstanding young investigators, and increase opportunities for the young investigators to recognize the Air Force mission and the related challenges in science and engineering.

Andrew Tsourkas

Andrew Tsourkas, *Professor in Bioengineering,* is a recipient of The Grainger Foundation Frontiers of Engineering Grant for Advancement of Interdisciplinary Research from the National Academy of Engineering (NAE). This program brings together outstanding early-career engineers from industry, academia and government to discuss pioneering technical work and leading-edge research in various engineering fields and industry sectors.

Jonathan Wilf

BUILDING COMMUNITY AND CONNECTIONS

Overseer Jonathan Wilf (ENG'06) speaks often about the importance of belonging to a community. Long before he met his wife at Penn and forged lifelong connections at the University, his grandparents put the philosophy into practice. Holocaust survivors who immigrated to America in 1950, they eventually settled in New Jersey and grew a successful business in real estate. Over time, his family sought a deeper connection to American society and found sports to be the answer.

"My family became huge sports fans," says Wilf. "Sports tied them to American culture, so when the opportunity to invest in the Minnesota Vikings came along, they decided it was time."

After graduating from Penn with a BAS in Computer Science, Wilf went on to earn a JD from Cardozo School of Law at Yeshiva University. He is co-owner and Executive Vice President, Strategic Planning and Business Initiatives of the Minnesota Vikings and a partner at WISE Ventures, an investment fund that recently purchased a franchise in Activision Blizzard's *Call of Duty* league.

Describe your roles with the Minnesota Vikings and WISE Ventures.
At the Vikings, we are inundated with opportunities to invest in emerging sports and entertainment technologies. My role has been to help field those opportunities and find those that fit with our goal of improving our football team and fan experience. A lot of what we do is in the sports, entertainment and technology sectors. Through WISE Ventures we are able to help innovative companies grow with guidance that we can offer from our many years of experience in these areas.

Do you foresee eSports becoming as popular as traditional sports?
I believe that eSports is the next evolution of sports and entertainment and that building community and connections between people is incredibly important. Even as things go online, fans can still be part of a close-knit group. They're talking with friends about the upcoming game or recapping the win or loss of their team. They feel part of something that's more than looking at their friends' photos and feeling left out; they're part of a culture that's more easily accessible and rewarding.

Which faculty member influenced you most at Penn?
I had a great relationship with Eduardo Glandt, who is just a wonderful human being. Whenever I needed help, he was always welcoming and would talk about how to deal with the stress of the academic workload. He's an inspiring person, and I really admire his passion for engineering, the School and Penn.

What are the rewards of being an Overseer?
Whether it's giving advice or helping other alumni and current students, either through financial aid, guidance or mentorship, I wanted to be part of this community. As an Overseer, I see what's going on at the School, the growth that's happening and the excitement that people have. It ties me into the Penn community; when I was asked to become an Overseer, my response was "absolutely."

By Ryan Hampton

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ON THE WATER

Barry Slaff is a busy guy. When he's not developing bioinformatics methods to understand how genetic information is processed in cells, the Computer and Information Science doctoral student can be found dragon boat racing.

Slaff, pictured below in a red cap, discovered the aquatic sport three years ago and began training on the Schuylkill River with a local racing team. This past August, he competed in the World Dragon Boat Racing Championships in Pattaya-Rayong, Thailand, for Olympic Team USA. Slaff says that while his training schedule is robust, he manages to find enough time in the day for research, racing and a good night's sleep in between.