



Penn Engineering



LEVERAGING
NETWORK
SCIENCE





Ghost Minitaur

Ghost Minitaur is the creation of postdoctoral researcher Avik De (ESE'17) and Ph.D. student Gavin Kenneally (MEAM'17), both members of Kod*lab, the laboratory of Daniel E. Koditschek, Alfred Fitler Moore Professor in Electrical and Systems Engineering.

The duo founded Ghost Robotics in 2015 and created Ghost Minitaur, a low-cost, gearless robot that displays impressive speed, precision and animal-like agility and responsiveness. The robot can climb up stairs and fences, crouch to fit under crawl spaces, balance on two legs, jump over obstacles, and navigate rocky, sandy or debris-filled environments. It has a range of applications, such as security, search and rescue, asset and infrastructure inspection, exploration, field survey, medical support, warfare and hazardous environment operation.

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“THE WHOLE ECOSYSTEM AVAILABLE
TO YOU AT PENN ENGINEERING
AND THE INTERDISCIPLINARY
EXPOSURE TO WHARTON PREPARE
YOU FOR THE REAL WORLD OF
ENTREPRENEURSHIP.”

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VIJAY KUMAR
Nemirovsky Family Dean

Access to Knowledge

Now more than ever, it is the responsibility of top academic institutions to be providers of educational excellence for our matriculants, and to be open sources of knowledge for surrounding communities.

In March, Penn hosted a Teach-In. Spearheaded by Faculty Senate Chair Santosh Venkatesh, professor in Electrical and Systems Engineering (ESE), the event sparked discussion about knowledge production in the modern academy at a time when trust in such institutions feels tenuous.

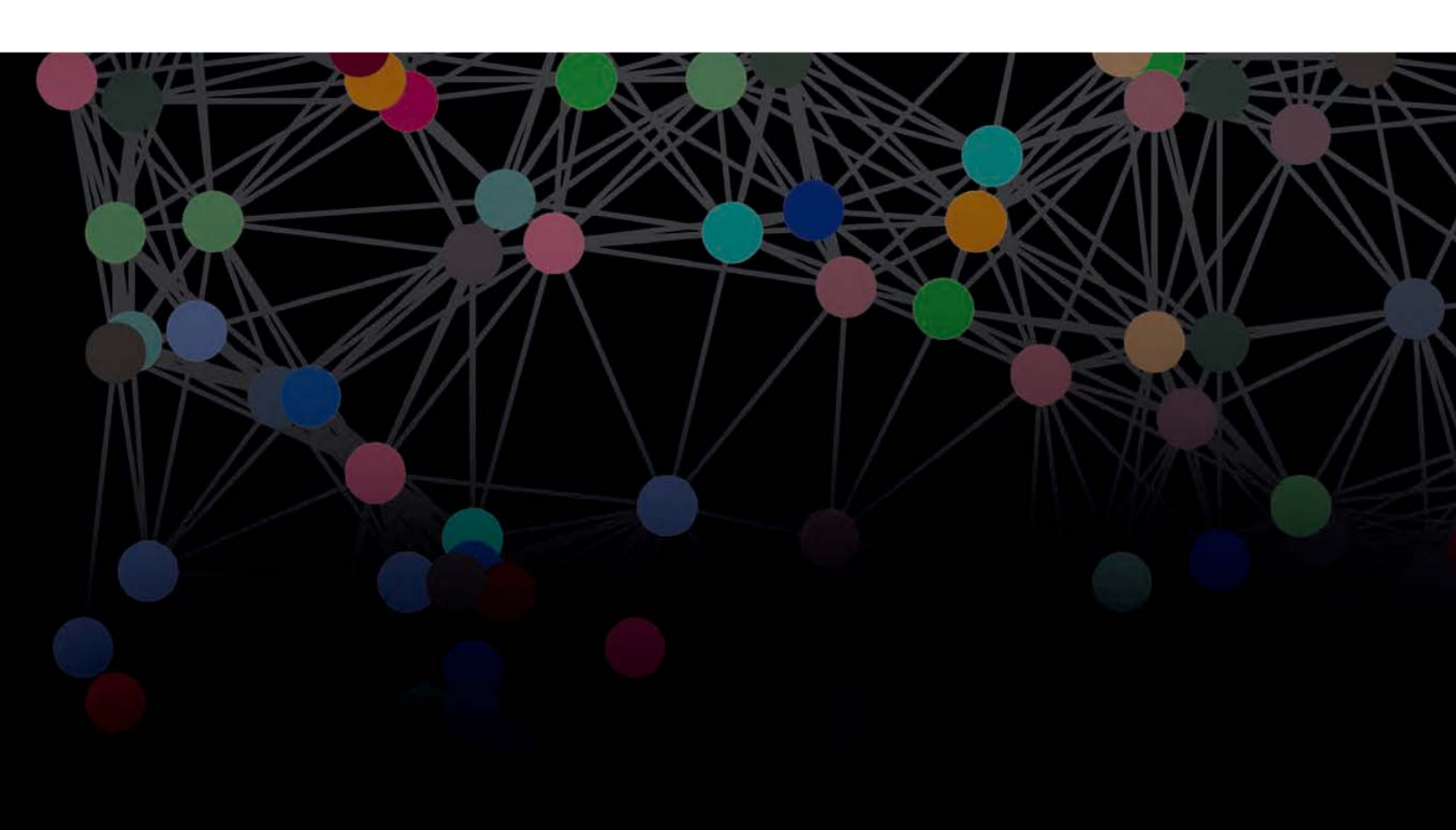
One series of talks revolved around “The Future of Technology,” with Penn Engineering faculty experts convening two important panels: “Engineering Human Health” and “AI and Society.” They featured Bioengineering’s Jennifer Phillips-Cremins, David Meaney and David Issadore; Chemical and Biomolecular Engineering’s Kathleen Stebe; Computer and Information Science’s Susan Davidson, Michael Kearns and Aaron Roth; and ESE’s Rakesh Vohra. Another talk, “Lies, Pixels, and Video Fakes,” led by Norman Badler of Computer and Information Science, outlined how technological advances are making computer graphics increasingly indistinguishable from reality.

Members of the community at large had the opportunity to hear about cutting-edge developments in these critical areas. Perhaps more importantly, they had the opportunity to join the discussion.

Our engineering students took part in a forum on the purpose of a Penn education, robot parades and an “AR Scavenger Hunt,” where participants hunted for virtual objects in real-world spaces.

In my 30 years at Penn, I have witnessed changes at Penn Engineering and watched macro-educational and research trends evolve. I am more convinced than ever that technology is the driving force behind research advances and access to education at Penn and other universities. But what we must not forget is that many still lack opportunities to gain knowledge in the presence of expertise and mentorship.

Events like the Teach-In at Penn can and should be avenues to advance relationships with local communities in order to combat this inequality. Penn Engineering and its peers are uniquely positioned to meet this challenge. 🇺🇸



Alejandro Ribeiro

EXPANDING APPLICATIONS OF NETWORK SCIENCE

The real power behind a network, says Alejandro Ribeiro, isn't its component parts. It's the myriad ways they connect with one another. The social bonds we share with others. The flow of information that makes the internet possible. Even the tiny electrical impulses that appear between neurons in the brain, letting us think, feel, taste, touch and interact with the rest of world.

As an associate professor in the Department of Electrical and Systems Engineering, Ribeiro uses complex mathematical frameworks to understand how networks behave. Instead of looking at individual points in that network, he examines what's going on between those points. "It's really about the connections each point shares with others. If a single data point is a city on a map, we're looking at the highways that run between each of those cities," says Ribeiro.

SHAKESPEARE'S WORK?

The plays of William Shakespeare are just one area where Ribeiro's work is proving useful. Although 500-year-old literature may seem an unlikely place for mathematical analysis, the field could help settle one of the thorniest mysteries surrounding the works—whether or not Shakespeare actually wrote all of them.

The Bard's Henry IV plays have been particularly suspect, but until now, there hasn't been a rock-solid way to confirm their authorship. Ribeiro's work is changing that. The process involves an emerging technique called "Graph Signal Processing," or GSP, which he has pioneered over the past several years. Along with colleagues at MIT and De Montfort University in the U.K., he created what he calls a "word adjacency network" for each of the plays, taking stock of words that appear in all of them. Rather than focusing on descriptive words that



determine a play's content, however, he used GSP to analyze the relationship between words like "the," "and," "a" and "to," scrutinizing the connective tissue of each work.

RIBEIRO WAS ABLE TO SHOW THAT MOST OF THE BARD'S WORKS CORRESPONDED WITH HIS USUAL STYLE, BUT A FEW OUTLIERS DIDN'T.

"It's not just about the number of times each word appeared, it's about the order. Sometimes there's a difference in those relationships," he says. In some plays, for example, the word "they" appears more often in a sentence sometime after the word "a" is written; in others, it might come after the word "the" appears. By looking at those relationships, Ribeiro

says, it's possible to create a fingerprint for an author's style, and by extension, their identity.

Through his analysis, Ribeiro was able to show that most of The Bard's works corresponded with his usual style, but a few outliers didn't. Parts of Henry VI, for instance, were strongly associated with word patterns used by Christopher Marlowe, one of Shakespeare's contemporaries, meaning that the play could have been a collaboration.

ROBOTIC SWARMS

The complex relationships Ribeiro is teasing out of Shakespeare's plays might also be applicable to a completely different field: swarm robotics. In the future, groups of tiny robots may be able to communicate and work with one another, like a colony of ants, to meet a shared objective such as delivering packages or inspecting a bridge.



There's just one problem: All of those drones need to "talk" to one another to cooperate, and existing cell phone networks aren't reliable enough to handle that traffic. Instead, the drones will need to create an ad-hoc wireless network between them, letting each robot relay messages through its peers in a giant game of telephone.

THE POWER BEHIND A NETWORK ISN'T ITS COMPONENT PARTS; IT'S THE MYRIAD WAYS THEY CONNECT WITH ONE ANOTHER.

That can make collective decision-making a challenge. In a network like this, connections between individual robots would constantly change. Ribeiro is working on ways to let the drones analyze their network and determine on their own what a good wireless connection looks like.

"Two drones near each other with a strong signal would have a way to say, 'This is a good link,' and go from there. You want the ability to connect to

other robots to be something that can be learned autonomously by the entire network," he says.

Thanks to a grant from Intel, Ribeiro has an autonomous swarm network up and running with 10 drones, and hopes to expand that number in the future.

HIGHWAYS IN THE BRAIN

In addition to large robotic swarms, Ribeiro wants to turn his attention to an even more complex network: the billions of connections between neurons in the human brain. He's collaborating with Danielle Basset, Eduardo D. Glandt Faculty Fellow and Associate Professor in Bioengineering, to analyze and describe that web of cells mathematically using the GSP technique.

Bassett and Ribeiro's study looked at "cognitive flexibility," or the speed at which people can shift their focus between tasks. Over the past century, Bassett says, neuroscientists have discovered major "highways" of connected cells that carry huge amounts of neuronal activity around the brain. But in some people, that activity flows more efficiently than in others.



The Ribeiro group discusses filtering in graphs. From left: Luana Ruiz, Alejandro Ribeiro, Harshat Kumar, Kate Tolstaya and Mark Eisen.

Using an MRI machine, the two researchers were able to see brain activity in the study's participants as they worked through a series of visual tests. Brain signals in subjects who switched tasks easily tended to stick to well-traveled cellular highways, making a beeline for their targets; in participants with "inflexible" brains, the pair found that many of those impulses went "off road," taking a circuitous path.

"Right now, we do not have good theory for how and why some people have more cognitive flexibility than others. These GSP tools provide new insights that might help us to develop such a theory," Bassett notes.

MENTORING INNOVATORS

Ribeiro is adamant that he wouldn't be applying his skills to such varied fields if it weren't for his students. "Ph.D. candidates are the most valuable asset that a university has. I couldn't do all that work on my own," he says.

That sentiment also extends to undergraduates. In Ribeiro's view, even a neophyte has the potential to

tackle real-world problems, and to make a lasting contribution to their field—if they put in the work.

"I am not going to hold your hand, ever. We're going to walk to the top of a cliff together, and I'm going to toss you down. You won't die, but you'll suffer, and I'll throw you a rope to climb back up if you need it," he says, laughing. "You can be sure not all students like that approach, but most do."

It's a philosophy that seems to have paid off. In 2012, Ribeiro won the S. Reid Warren, Jr., Award, which is presented annually by Penn Engineering undergraduate students in recognition of outstanding mentorship. In 2017, he won the University of Pennsylvania's highest teaching award, the Lindback Award for Distinguished Teaching.

"I'm not doing this because I find it entertaining. I'm doing this because if you allow me to push you, I can show you things that are like magic," he says. "I'm going to help you climb a very steep mountain of information. And even if you don't make it to the top, that's okay. You've still learned more than if you're just climbing in the foothills." ▾

By David Levin

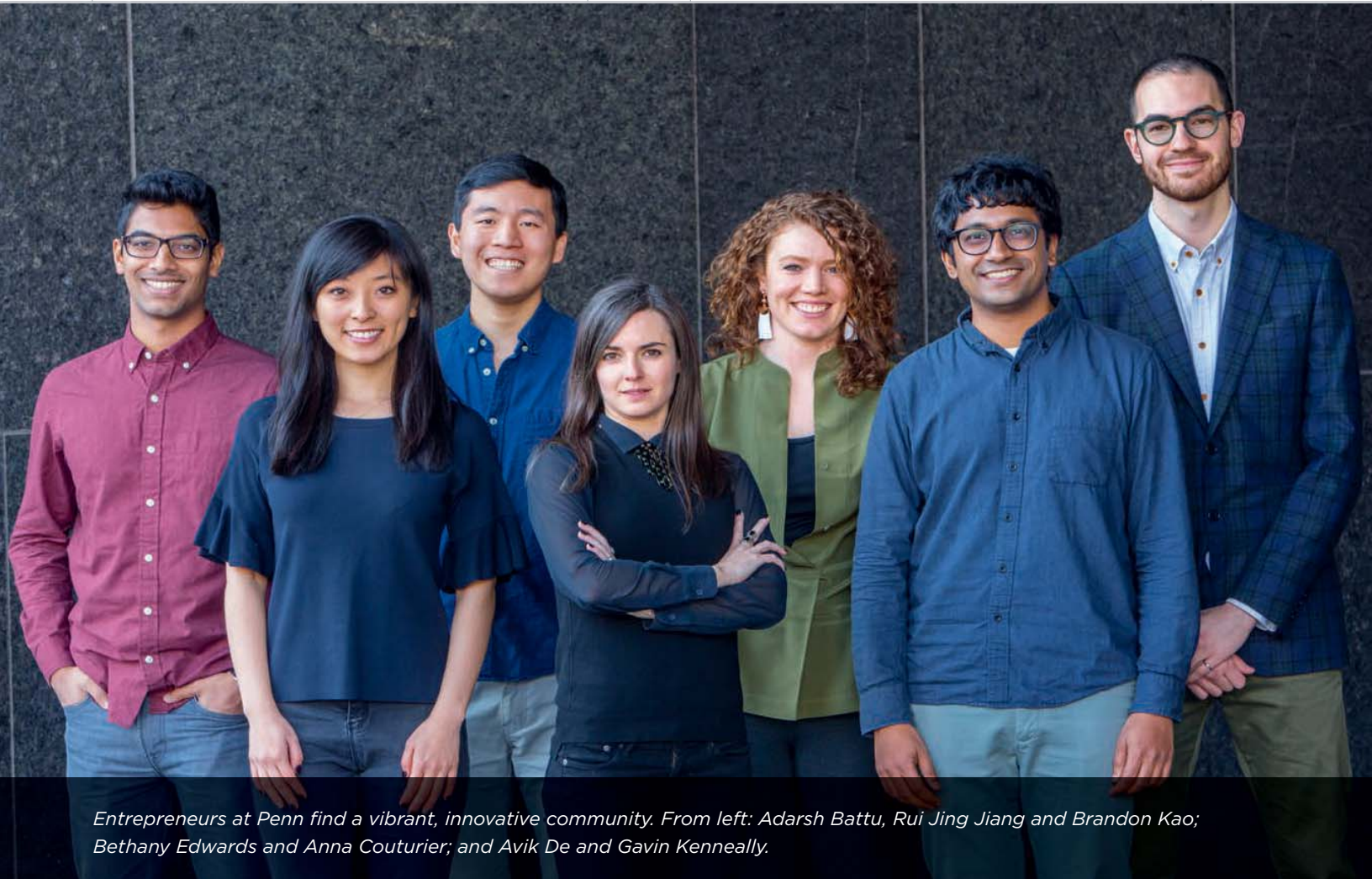
Engineering Enterprise

A THREE-PACK OF STARTUPS

Penn Engineers get an early advantage in the startup game. Coursework, competitions, funding and other resources offered by the University infuse students with the interdisciplinary education, experience and support needed to envision and implement impactful solutions to a wide range of global problems. Meanwhile, encouragement and insights from talented faculty and driven peers inspire

budding entrepreneurs to further hone their technologies and successfully commercialize their products, turning their dreams into reality.

Three nascent businesses launched by current students and recent graduates embody the spirit of innovation that abounds on campus and draws motivated students to Penn in the first place.



Entrepreneurs at Penn find a vibrant, innovative community. From left: Adarsh Battu, Rui Jing Jiang and Brandon Kao; Bethany Edwards and Anna Couturier; and Avik De and Gavin Kenneally.



Ghost Minitaur is an ultrafast, ground-based autonomous robot that moves with animal-like agility and responsiveness.

REVOLUTIONIZING ROBOTS

Developing new ways for ground-based robots to interact with the environment and perform useful tasks is the main goal in Kod*lab, the laboratory of Daniel E. Koditschek, Alfred Fitler Moore Professor in Electrical and Systems Engineering and a world authority on bio-inspired robotics. As Kod*lab members, postdoctoral researcher Avik De (ESE'17) and doctoral student Gavin Kenneally (MEAM'17) wanted to push the envelope by designing robots that could feel the world and move like animals. "While bipedal and quadrupedal robots may be theoretically superior to wheels and tracks, the complexity and costs associated with deploying commercial solutions has been a major roadblock," says De.

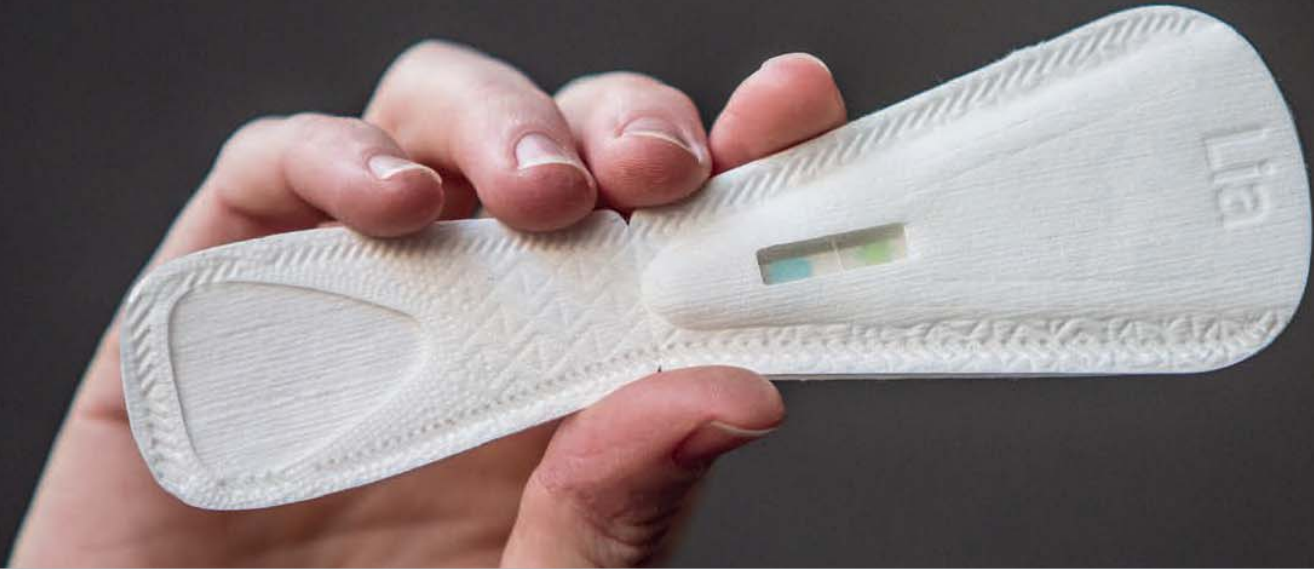
In overcoming these challenges, De and Kenneally have developed ultrafast and highly responsive autonomous legged robots that offer superior operability in unstructured environments compared with wheeled and tracked devices. The duo founded Ghost Robotics in late 2015, with Koditschek's encouragement and support from PCI Ventures, a division of the Penn Center for Innovation. "Many years of work on direct-drive quadrupedal robot designs and locomotion led to the launch of Ghost Robotics," Kenneally says.

In late 2016, the company unveiled the Ghost Minitaur, a low-cost, gearless robot that displays

impressive speed, precision and animal-like agility and responsiveness. The small four-legged robot can climb up stairs and fences, crouch to fit under crawl spaces, balance on two legs, jump over obstacles, and navigate rocky, sandy or debris-filled environments. A core design principle for the robot is reduced mechanical complexity, resulting in better durability and lower cost compared to other unmanned ground vehicles.

The Minitaur can be used for a range of applications, such as security, search and rescue, asset and infrastructure inspection, exploration, field survey, medical support, warfare and hazardous environment operation. Key customers include Google, DeepMind, U.S. Army Research Labs, Princeton, Penn, Carnegie Mellon University and the University of Washington. Currently, the company is preparing to deploy pilot versions of the GR Vision 60, a mid-sized foldable tele-op and autonomous all-terrain ground drone with six hours of projected mixed-use endurance.

In February, Ghost Robotics showcased its latest vehicles, including the GR Vision 60, to an expert panel assembled by the Association for Unmanned Vehicle Systems International (AUVSI). Amidst stiff competition, the company won AUVSI's Innovation Challenge. "This has been a long journey, and we see many applications for the platform and underlying technology ahead," De says.



Lia was designed to be the first discreet, flushable and biodegradable pregnancy test, bringing the platform into the modern era.

PROTECTING PRIVACY

One of the most emotional moments of a woman’s life is finding out whether she is pregnant. But all too often, the stress associated with taking a pregnancy test is compounded by the fact that it can end up in the trash where it could be seen by others. Moreover, currently available pregnancy tests add two million pounds of plastic and digital waste to U.S. landfills every year. Finding a solution to this two-pronged problem became a passion for Anna Couturier (IPD’14) and Bethany Edwards (IPD’14) when they were students in Penn’s master’s program in Integrated Product Design.

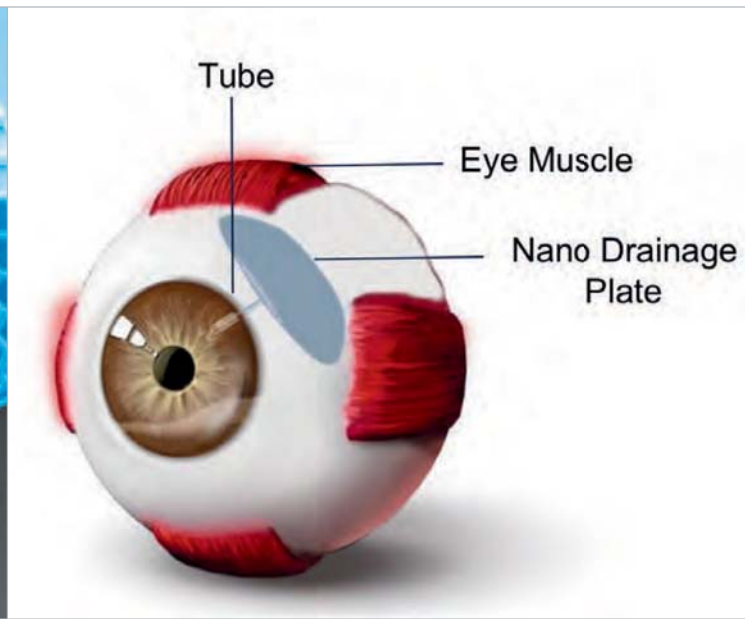
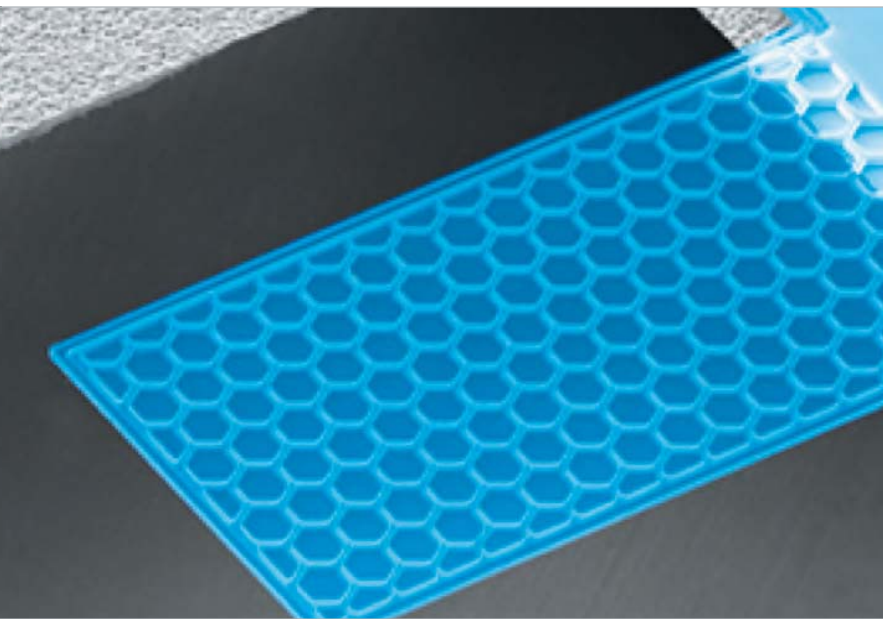
“We became interested in designing temporary products to be completely biodegradable, in order to match their life cycles,” Couturier says. “We also noticed that there had not been any innovation to the form factor in pregnancy tests since they were first introduced. Another goal was to deliver a pregnancy test that would impact the way individuals view pregnancy testing and offer a more private experience for women.”

To address these challenges, the duo founded Lia Diagnostics in late 2014, along with Sarah Rottenberg, adjunct assistant professor in the School of Design and the executive director of the Integrated Product Design program. In just 1.5 years, the team developed the first and only flushable, biodegradable pregnancy test.

Painstaking research on innovative water-dispersible materials and tireless prototype testing led to the development of a revolutionary coating that allows Lia to repel water long enough for a woman to take the test, then break down easily when flushed. The easy-to-use, environmentally friendly test, which is made of the same natural plant fibers as most toilet paper, is proven to be more than 99 percent accurate.

Last December, Lia won the €42,000 prize at TechCrunch’s Startup Battlefield at Disrupt Berlin 2017. On the same day, the company announced that its pregnancy test had been cleared by the U.S. Food and Drug Administration for over-the-counter use. Lia will launch its pregnancy test in mid-2018 and will continue to develop and commercialize water-dispersible, biodegradable diagnostic kits and products that are better for the user and the environment, with the goal of modernizing and humanizing reproductive health and wellness products.

“Lia is the only discreet pregnancy test alternative with zero synthetic materials, such as plastic, glass fibers, and nitrocellulose elements, which are found in nearly all single-use diagnostics that are available on the market today,” Couturier says. “By creating a product that is more sustainable and that considers the emotions associated with pregnancy testing, we are supporting all women while working to support a healthier planet.”



VisiPlate is an ultrathin ocular implant that reduces pressure within the eye by draining excess fluid through a tube onto a drainage plate, where it can be reabsorbed.

NANOSCALE SOLUTIONS

Glaucoma is the second-leading cause of blindness globally and is becoming increasingly prevalent as the world's population ages. There is no cure for glaucoma, and currently available treatments such as eye drops and surgical interventions have either limited compliance or high rates of failure.

A long-term solution to this problem may come in the form of strong, flexible, ultrathin alumina nanoscale plates developed in the lab of Igor Bargatin, Class of 1965 Term Assistant Professor in Mechanical Engineering and Applied Mechanics. Despite being the thinnest plates that can be picked up and manipulated by hand, they can spring back to their original shape after being bent and twisted. These plates were selected for implementation in the 2016-2017 Y-Prize competition, a contest in which student teams propose innovative commercial applications for technology invented by Penn Engineering researchers.

The winner of the competition, VisiPlate, leveraged the technology to create an implant that reduces pressure within the eye by draining excess fluid through a tube and onto a curved drainage plate, which is thinner, stronger and more reliable than existing lines of defense. Diffusing the shunted fluid over a wide area allows that fluid to be reabsorbed at a manageable rate, preventing blindness caused by open-angle glaucoma. Moreover, the 100-nanometer-thick drainage

plates can be easily implanted in the front of the eye, making surgery faster, less invasive and risky, and more cost-effective.

VisiPlate is the brainchild of Brandon Kao (MSE'18), Rui Jing Jiang (W'18) and Adarsh Battu (W'18). As Penn students, the trio became interested in competing for the Y-Prize and envisioned a new way of fighting blindness. The team worked with ophthalmologists Richard Stone and Eydie Miller-Ellis at the Perelman School of Medicine, as well as Bargatin's team and Jeffrey Babin, associate practice professor and associate director of the Engineering Entrepreneurship Program.

With the ample resources at Penn and funding from the nonprofit organization VentureWell, the students have developed prototypes, refined their business plan, completed a pilot preclinical study to verify VisiPlate's biocompatibility, and filed a provisional patent application. Last year, the team co-founded a medical devices startup called Avisi Technologies, whose mission is to leverage cutting-edge technology to create impactful solutions for global health problems. "We envision creating a world where glaucoma is no longer a formidable and debilitating disease," Kao says. "VisiPlate's success thus far has been made possible by the wide range of support from the community we found at Penn." ▾

By Janelle Weaver

Game Changer

A PENN ENGINEER JOINS THE PHILADELPHIA PHILLIES

When Alex Nakahara (MEAM'10) was asked recently if he is ever able to mention his job title without someone excitedly responding with "Moneyball!" he smiled broadly and answered, "Pretty much no." Nakahara was quick to add, however, that he often uses the analogy to better explain what he does for a living.

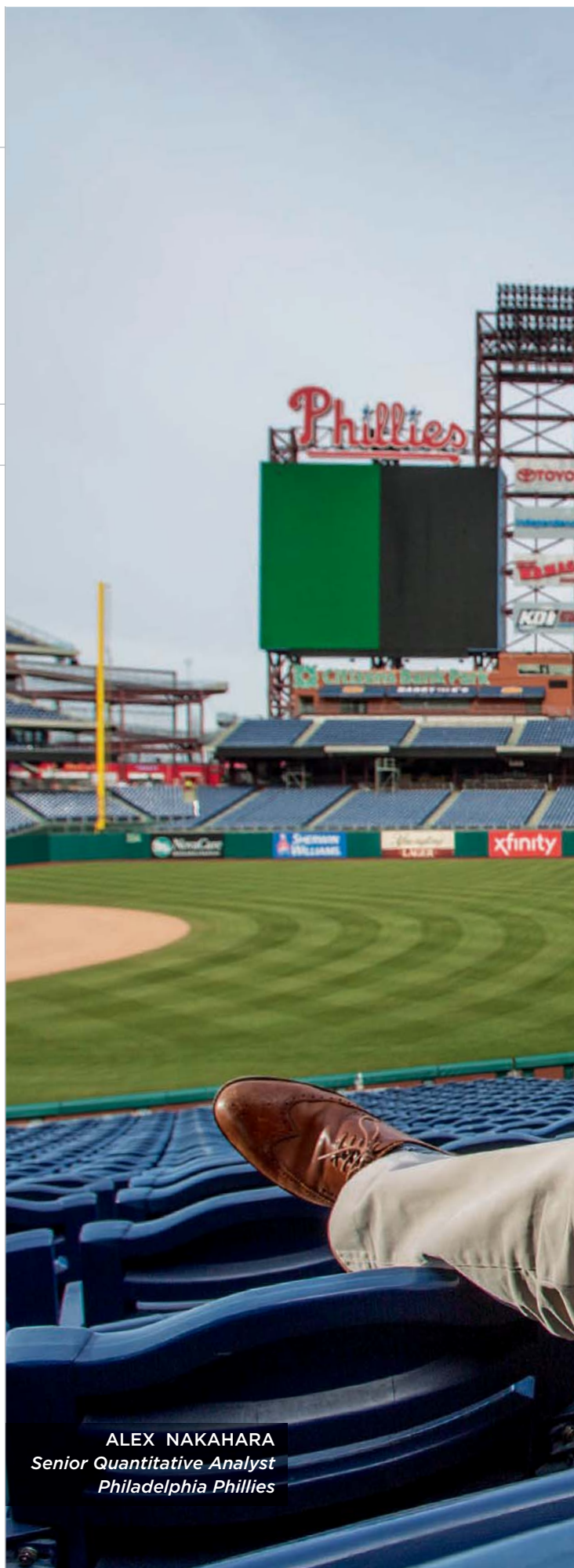
Nakahara is a senior quantitative analyst for the Philadelphia Phillies, and the reference is, of course, to Michael Lewis' 2003 book, *Moneyball: The Art of Winning an Unfair Game*, and its 2011 award-winning film adaptation starring Brad Pitt and Jonah Hill. Recounting the story of Billy Beane, the real-life former general manager of the Oakland Athletics, the book and the film introduced to popular culture the data science specialty of baseball analytics, or sabermetrics.

NAKAHARA'S ANALYSIS IS CENTERED ON PLAYER PERFORMANCE IN BATTING, PITCHING, FIELDING AND THE TACTICS OF IN-GAME ACTIVITY.

Nakahara is, in fact, a sabermetrician, the term being derived from SABR, the acronym for the Society of American Baseball Research. As an article posted last year on the Phillies' website amicably put it, he is one of "a bunch of smart people without baseball backgrounds" being hired by the team.

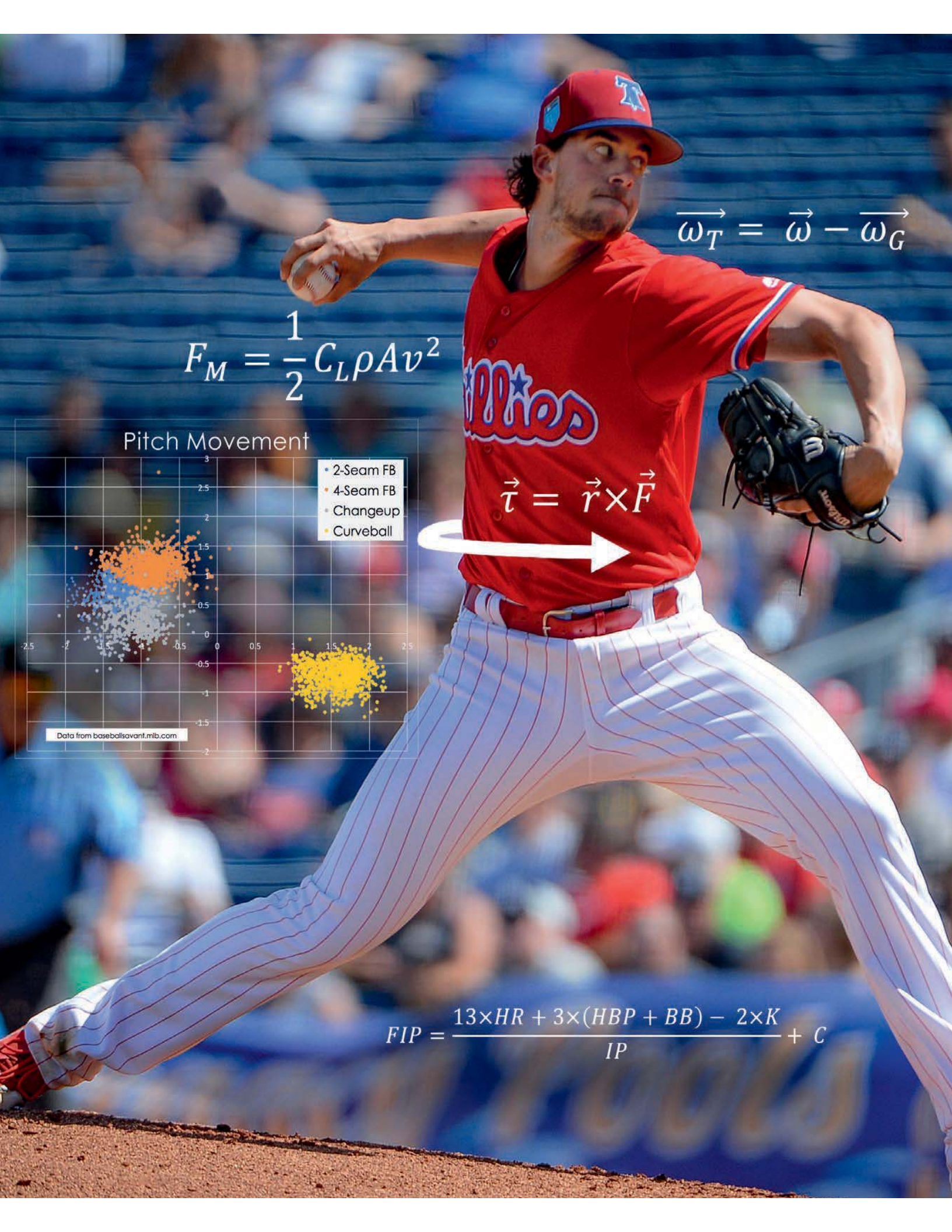
AN INNATE CURIOSITY

More precisely, Nakahara is one of nine analysts and software engineers whose research is centered on player performance in batting, pitching, fielding and the tactics of in-game activity. His group's work is changing the way decisions are made in the Phillies' front office. Their predictive findings can ultimately influence hires, trades and the scouting and training of players.



ALEX NAKAHARA
Senior Quantitative Analyst
Philadelphia Phillies

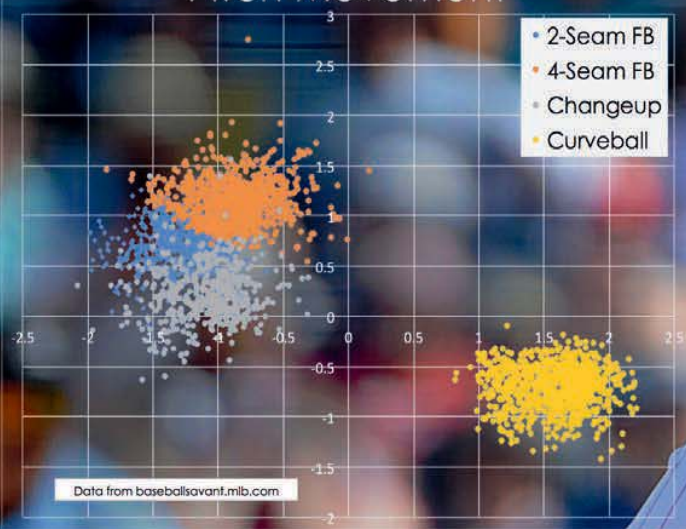




$$\vec{\omega}_T = \vec{\omega} - \vec{\omega}_G$$

$$F_M = \frac{1}{2} C_L \rho A v^2$$

Pitch Movement



$$\vec{\tau} = \vec{r} \times \vec{F}$$



$$FIP = \frac{13 \times HR + 3 \times (HBP + BB) - 2 \times K}{IP} + C$$

The principles behind sabermetrics and baseball physics reveal how an engineer can uniquely engage in America's national pastime.

And while it is true that the word “baseball” appeared nowhere on Nakahara’s resume, his undergraduate degree from Penn in Mechanical Engineering and Applied Mechanics, master’s in Aeronautics and Astronautics from MIT, and five years as a systems engineer at Northrop Grumman made Nakahara a perfect Phillies fit. He brings to the table the mindset of an engineer: critical thinking, the ability to find problems and then solve them, and an innate curiosity about how things and systems work.

Phillies leadership considers having some analysts lacking baseball experience to be an advantage: They are able to interpret with unbiased eyes what Nakahara describes as “oceans” of game and player performance data available to all teams in equal measure. By way of digital photographic and radar technology now embedded in every Major League Baseball field, analysts can access runners’ base-to-base speed, pitch velocity and the landing location of every ball batted. Additionally, individual teams can make use of other sources, including scouting notes and players’ medical histories.

Nakahara is fairly new to the Phillies, and he admits to now and again looking around his office at Citizens Bank Park to make sure his dream job, coveted by so many newly graduated data scientists, statisticians and mathematicians, is indeed real. Visually, he can actually take in the entire office; the work area is configured on the open model so popular with tech companies these days. This design seems to work well for Nakahara’s boss, Andy Galdi, a former YouTube quantitative analyst at Google. The cubicle-free space, featuring clusters of desks and multi-user computer monitors, has proven to promote collaboration and inspire shared creative energy.

A COMMON GOAL

Along with its players, coaches and scouts, the Phillies team includes specialists of other stripes:

physical therapists, nutritionists, conditioning experts and mental skills trainers. A video department can supply in-play clips and images that can be used by analysts to complement their numbers. With a common goal to gain a competitive advantage for the Phillies, all are welcome to bring their ideas and questions to the analytics “think tank.” Likewise, the analytics team often goes out to the other groups to learn more about their areas.

SABERMETRICIANS ARE ABLE TO INTERPRET WHAT NAKAHARA DESCRIBES AS “OCEANS” OF GAME AND PLAYER PERFORMANCE DATA.

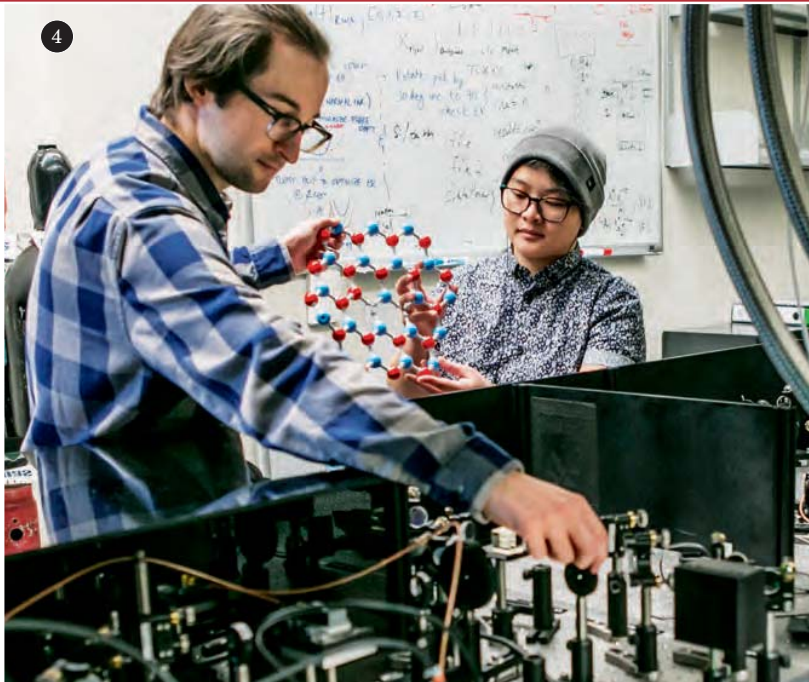
Nakahara’s collaborative professionalism aligns well with what he describes as the Phillies’ family-like work environment and inclusive team culture. He is delighted with the high-spirited perks of the job, like having the team mascot, the Philly Phanatic, appear at his wedding and being invited to get on board the Philadelphia Eagles’ *Road to Victory* bus for a front office photo op. His group had a presence at spring training in Clearwater, Florida, and members of the analytics team make visits to the minor leagues along with the scouts.

Data analysts see and think about the game of baseball in new and different ways and, accordingly, are able to formulate innovative ways in which to play it. They also are able to analyze and validate conventional baseball wisdom, showing that the old ways are often right. The reality that sabermetrics can improve efficiency and accuracy across the board has now permeated the ethos of Major League Baseball, and Nakahara is personally committed to building diverse working relationships based on trust throughout the Phillies’ headquarters. 🍷

By Patricia Hutchings



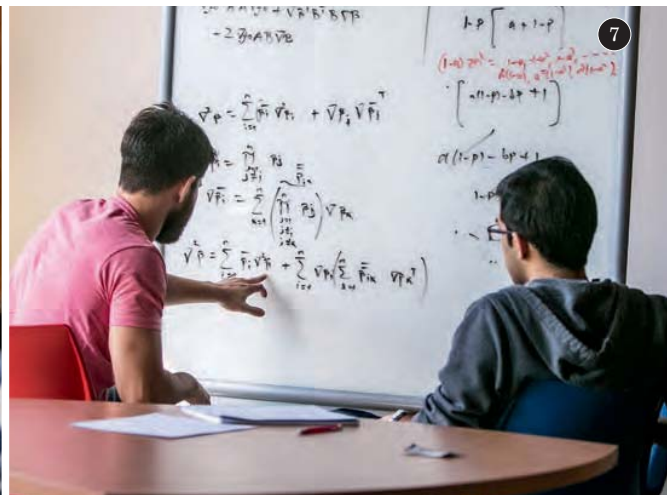
On Our Camera Roll



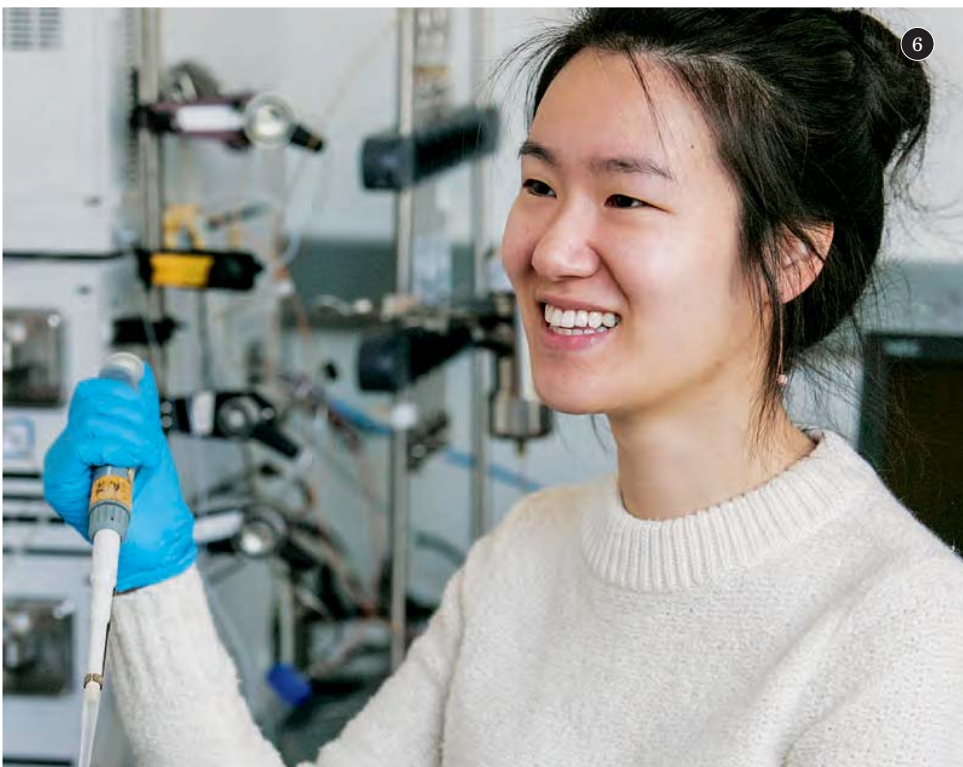
1. From model-car housings to light fixtures, fabricating mockups is made easy in the Rapid Prototyping Lab, home to a fleet of 3D printers and laser cutters. **2.** Students in CIS 530, Computer Linguistics, focus on an interactive lecture in the Forman Active Learning Classroom. **3.** MEAM junior Allison Grey mills chess pieces in the Precision Machining Laboratory for her project in Integrated Product Design. **4.** Graduate students David Hopper and Tzu-Yung Huang prepare experiments in the Quantum Engineering Lab.



5



7



6



8

5. In Towne 211, a study space filled with activity, students collaborate on problem sets. **6.** Jina Ko, BE doctoral student in the Issadore lab, injects samples into a diagnostic platform. **7.** Discussing a proof, doctoral students Santiago Paternain and Harshat Kumar aim to show the stability of their proposed system dynamics. **8.** An early spring morning finds students striding past the venerable Towne Building.

Hack4Impact

A GLOBAL CODING FORCE FOR GOOD

There's a multiplier effect when Penn students combine their programming capabilities and commitment to social justice in order to help nonprofits further their mission.

"We have a vision for how we want social impact to be a focus for technology," says Katie Jiang (CIS'20), co-director of Hack4Impact, a student-led club founded at Penn in 2014 that, together with partner chapters around the country, has helped nearly 40 nonprofits in Philadelphia and beyond. "We want to engage more students at Penn and at other universities in social impact to empower nonprofits with programming solutions that will help them grow, become more efficient and achieve their goals."

Participants in Hack4Impact, a creative and dedicated cadre of 30 Penn students, spend 5 to 15 unpaid hours weekly developing web-based applications that help nonprofits access, share and

analyze complicated, changing data sets. Choosing from dozens of nonprofit applications, they select five coding projects each semester, prioritizing opportunities to create broadly useful, replicable programs for nonprofits whose missions they are passionate about advancing.

"HACK4IMPACT HAS SOLIDIFIED MY CONVICTION THAT I WANT TO WORK WHERE I CAN USE MY SKILLS TO BENEFIT OTHERS."

"My Hack4Impact experience has been really special and one of the best parts of my time at Penn," says Jiang. "It has expanded my mindset beyond the technical work of being a software engineer to thinking and caring more about



Pictured from left: Abhinav Suri, Katie Jiang, Jasmine Lee, Santiago Buenahora and Stephanie Shi.

real-world problems, and how to support the nonprofits that are working to address root causes. We'll see where that takes me in life." In addition to furthering participants' programming, product development, leadership and peer mentoring skills, their Hack4Impact experiences reflect how students draw upon Penn resources to engage civically.

HAPPY DANCE

During a recent video call with Sally Matsuishi, executive director of Next Generation Scholars of San Rafael, California, Jiang led a demo of the program her team developed to help the nonprofit support low-income high school students through each step of the college application process. "We could see her do a happy dance," says Jiang. "Her excitement was contagious. It's so fulfilling, so fun for me to see the impact."

Abhinav Suri (B'19, CIS'19), Hack4Impact co-director, led another potentially game-changing project for Madaktari Africa, a nonprofit in Tanzania. To address the scarcity of medical specialists in this sub-Saharan nation, Madaktari Africa recruits U.S. medical specialist volunteers who train Tanzania's more generalist medical teams, building in-country capacity for urgently needed specialty care such as neurosurgeries for auto accident victims and cardiac telehealth screening in remote areas.

After a surge in volunteer sign-ups last summer, Madaktari Africa's computer system became so overloaded that the nonprofit halted new registrations. Suri, a pre-med student, contacted the nonprofit at the start of Penn's fall 2017 semester and offered Hack4Impact's assistance in developing an efficient volunteer management program, slated to launch in 2018. "We have high hopes this will support a meaningful experience for volunteers while facilitating real change on the ground," says



Reading Terminal Market is a diverse marketplace in the heart of Philadelphia, with cuisines and products from an array of cultures and countries. However, new merchants in this market often had a difficult time getting the best prices for materials from suppliers because they lacked contacts. Hack4Impact's solution was to create an online marketplace for suppliers and merchants to buy and sell products. The team helped 89 merchants and dozens of suppliers migrate over to the new web application, amounting to thousands of items in the online marketplace with many transactions happening on a weekly basis.



Maarten Hoek, Madaktari Africa's managing director.

Another recent project for the ACLU of Pennsylvania gave Stephanie Shi an opportunity to apply knowledge gained in NETS 212, Scalable and Cloud Computing. Shi, a sophomore in the Jerome Fisher Program in Management & Technology (M&T), built scalability into the program that her team developed to help the ACLU efficiently review public records to proactively identify issues and trends that merit on-the-ground investigations. "These analytic tools will make it easier for us to do our work and to identify troubling trends in the judicial system," says Andrew Christy, ACLU attorney and Independence Foundation Fellow.

Dhruv Maheshwari (M&T'15) co-founded Hack4Impact in 2014 with Ali Altaf (CIS'15). "This was the perfect intersection of my business and computer science academic work with the social impact and nonprofit experiences I had as a Penn Civic Scholar," says Maheshwari. "It was the

culmination and proof that I had learned something at Penn, that there is a meaningful way to tie these disciplines together."

TANGIBLE BENEFIT

Because Hack4Impact cultivates a close-knit, potentially life- and career-changing community on campus, the club caps membership at 30 students who are selected not just for their computer coding capabilities but also for their commitment to social impact. "We can teach anyone how to program and how to do the specific things that make projects successful from a technical standpoint. But we can't teach anyone the passion for benefiting one's own community," says Suri.

Hack4Impact also pushes for greater diversity. "We actively work to recruit and serve as a supportive community for underrepresented minorities in computer science and take care to address biases society has about people of color and women in



STEM,” says Shi. “These are some of the most brilliant, hardworking and down-to-earth people I know. They motivate me to become a better person, and Hack4Impact has solidified my conviction that I want to work in areas where I can use my skills to benefit others in tangible ways.”

HACK4IMPACT SELECTS FIVE CODING PROJECTS EACH SEMESTER, PRIORITIZING OPPORTUNITIES TO CREATE BROADLY USEFUL, REPLICABLE PROGRAMS FOR NONPROFITS.

Students regularly debate whether to maintain the membership cap. Their concern is that these benefits may not scale with more participants, lessening their impact. Hack4Impact is instead growing by opening seven new chapters at other universities, including

Georgia Tech, the University of Michigan and the University of Illinois at Urbana-Champaign. Unlike many coding clubs, Hack4Impact is unique in offering a trifecta of volunteer-ready projects for nonprofits, startup mentoring and support, and connections to a growing national network of purpose-driven coders.

Over the next five years, Hack4Impact’s alumni board aims to launch an annual summer conference, create paid fellowships to develop high-potential projects and establish new chapters at tech companies. “Five to ten years from now, our vision is that we’ll become a community of 1,000 alumni who will be change-makers and are passionate about social impact,” says Maheshwari. “It’s exciting to see our initial idea take root and inspire more students.”

By Jessica Stein Diamond

Material Breakthroughs

BRINGING INNOVATION TO MARKET

Arjun Srinivas (M&T'07) discovered his love of engineering and materials science when he first learned that periods of human history, like the Stone Age, Bronze Age and Iron Age, were defined by the materials used at the time. "When you think about our development as a species, it can be traced to eras of discovery and revolutionary innovation, which all begin with new materials. If we look at where we are today, some people call it the Information Age, but we are arguably living in the Silicon and Plastics Age," he says.

The company Srinivas founded, Innova Dynamics, which developed nanotechnology-enabled electronic materials for touch displays, is very much a product of the current age.

PIONEERING VISION

The concept for Innova originated during Srinivas' time as a student in the Jerome Fisher Program in Management & Technology (M&T) at Penn, specifically during his engineering Senior Design project. "At the time, there was a lot of discovery and innovation in nanotechnology, and I was drawn to that field," he says. "For my engineering degree, I majored in Materials Science and Engineering with a specialization in Nanotechnology, and at Wharton, I focused in Finance."

For his project, Srinivas partnered with three of his fellow M&T'07 classmates: Alex Mittal, Cal Peng

and Priyanka Agarwal. Mittal had just returned from a volunteer experience with Engineers Without Borders in Honduras and had seen firsthand the challenges of bringing clean water to remote villages. Together, the team developed their idea and the approach of embedding silver nanoparticles into PVC piping to purify water and prevent contamination. The exact design was, in a sense, serendipitous.

"SOME PEOPLE CALL THIS THE INFORMATION AGE, BUT WE ARE ARGUABLY LIVING IN THE SILICON AND PLASTICS AGE."

"We knew that simply coating or plating the pipes with silver was too expensive, and we realized that using nanoparticles would drastically reduce the cost," Srinivas says. "Had we been in industry or looked to the way Dow Chemical would have approached the problem, we would have mixed the nanoparticles into a paint and then painted them onto the pipe. But our inexperience with the way things were done was an advantage, and spurred us to try to embed the silver particles directly into the pipe, which turned out to be a novel idea."

As the students developed a prototype, they realized that their invented process could apply



Photo credit: Travis Scheff & Mary Kwan

ARJUN SRINIVAS (M&T'07)

not only to PVC pipes, but to any number of plastic surfaces and products, resulting in antimicrobial keyboards, doorknobs, telephones and light switches. Furthermore, they realized their process was not just limited to antimicrobial silver nanoparticles, as it could be used with myriad other functional nanoparticles, such as carbon nanotubes and silver nanowires.

"It was then that we realized we had invented a real platform technology," he says. "By the end of the

project, we were filing a provisional patent, which led to the founding of Innova Dynamics in 2007."

Srinivas, Mittal and Peng stayed on for an extra semester at Penn and entered the Wharton Business Plan Competition, where they won second prize, the People's Choice Award and the Gloeckner Award, landing them \$30,000 in seed money and capital—what Srinivas calls the "rocket booster" that transformed their idea into a viable company. They also received a grant from the Weiss Tech House Innovation Fund.

CAMPUS TO CORPORATION

While many of their other classmates followed job offers into consulting and investment banking, Srinivas and Mittal stuck with the Innova vision and applied their M&T training to balance the competing concerns of business and innovation. “The whole ecosystem available to you at Penn Engineering and the interdisciplinary exposure to Wharton prepare you for the real world of entrepreneurship, both in the practical education and the confidence to start your own company,” he says.

During a particularly challenging economic period, the team managed to raise funding, completing their first round in September 2008, the same week of the stock market crash. Initially, Innova remained focused on antimicrobial products, developing the platform technology for consumer applications. Soon, Innova’s antimicrobial keyboards and telephones were being used in nursing homes and hospitals across the country.

“IT WAS A WONDERFUL AND GRATIFYING EXPERIENCE TO BE THERE FROM DAY ONE, TAKING AN IDEA WE CAME UP WITH AT PENN TO BUILD A COMPANY.”

But as the company set out to expand, it came up against some of the challenges of working in the antimicrobial space and being regulated by the EPA. “At that point, we pivoted to the electronics market, using the same approach to embed silver nanowires to be conductive and yet completely invisible, effectively enabling the user to print invisible circuits,” he says.

Here, too, was an opportunity: With the advent of mobile devices and the expanding use of touch-screens in consumer electronics and beyond, the touch sensor market was growing exponentially, but the existing technology was expensive to manufacture and process. Innova’s proprietary Innlay inks and screen-printable paste could eliminate the use of indium tin oxide and photolithography, making the screens flexible and more affordable to produce. Innova partnered with leading global companies such as BASF, PPG Industries, Dai Nippon Printing Co. and TPK Holding Co. in order to quickly take the product to market.

“It was a wonderful and gratifying experience to be there from day one, taking an idea we came up with at Penn to build a company, launch a product, and form partnerships around the world,” says Srinivas. After spending nine years growing the company to 38 people across the U.S., Japan and Taiwan, Srinivas sold the company in 2016 to TPK.

Now, Srinivas dedicates his time to advising and consulting with other startups in areas such as wearable sensors, artificial intelligence-enabled materials development, advanced textiles and nanotechnology-based automotive coatings. GraphWear, one of the companies he advises, was co-founded by his onetime intern and Penn graduate Saurabh Radhakrishnan (GEng’15). “It’s an amazing story,” says Srinivas. “After his internship at Innova, he went back to get his master’s degree at Penn Engineering because he saw how it had prepared me for entrepreneurship. Now he is the founder of his own company.”

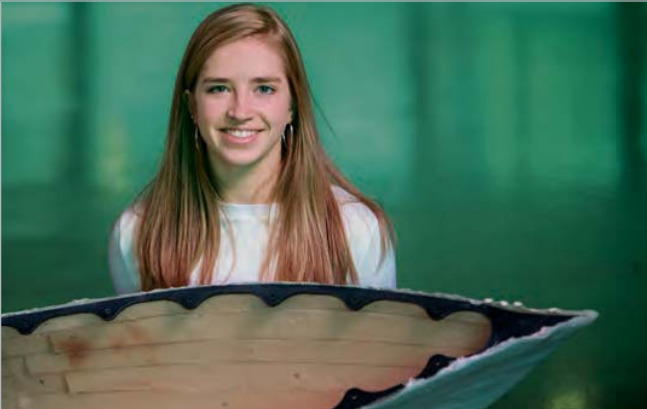
Srinivas says he’ll get back to creating something new of his own when the time is right. “Starting a company takes the right team, with the right idea, at the right time. In the meantime, I look forward to seeing what technologies and opportunities the future will bring.”

By Elisa Ludwig

Senior Design Preview

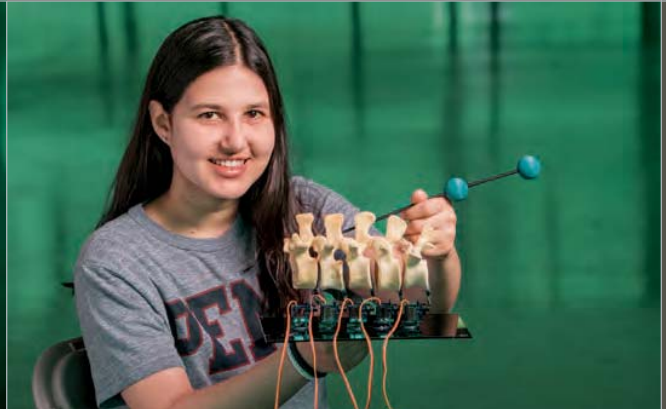
Senior Design is the capstone project, the culmination of what students have learned during their years at Penn Engineering. In addition to courses in the fall and the spring, students form teams, secure advisors and spend countless hours developing a project designed to solve a real-world problem using engineering solutions.

Below is a small sampling of in-progress projects from this year's graduating class. Check with us in May to see the results of the School-wide competition.



ARCHIPELAGO is an autonomous boat that provides safe and reliable transport of medical supplies to those in need, addressing problems with expensive and unreliable distribution networks in outlying islands in many regions.

Team: Nadia Kreciglowa, Anurag Makineni, Thomas Mulroy, Shreetej Reddy, George Sun and Brian Zhang



SPINEGUIDE is a training device that guides pedicle screw insertion during spine surgery. It utilizes software and a wand tool powered by an Xbox Kinect, allowing for live updates of insertion trajectory to avoid neurovascular complications.

Team: Jessica Rose, Michael Roth, Gurjeet Singh and Nicholas Vigilante



FOOT'S EASE is a smart shoe and activity tracker that lifts the foot with a motorized cable in response to sensors on the bottom of the shoe, increasing mobility, providing real-time data feedback and detecting falls in patients.

Team: Cody Clouser, Kelly Larkin, Julia Lin and Ece Sahin



EAGLEEYE removes the risk of in-air collisions of autonomous drones by implementing an infrastructure-to-vehicle (I2V) centralized air traffic control module, allowing for efficiencies in food and package delivery as well as agricultural and industrial applications.

Team: Jack Kearney, Max Li, Sahithya Prakash and Will Tam



Lukasz Bugaj

*Assistant Professor
Bioengineering*

Ph.D. in Bioengineering;
University of California, Berkeley; and
University of California, San Francisco



Alex Hughes

*Assistant Professor
Bioengineering*

Ph.D. in Bioengineering;
University of California, Berkeley



Deep Jariwala

*Assistant Professor
Electrical and Systems Engineering*

Ph.D. in Materials Science and Engineering;
Northwestern University



Bomyi Lim

*Assistant Professor
Chemical and Biomolecular Engineering*

Ph.D. in Chemical and Biological Engineering;
Princeton University



Michael Mitchell

*Skirkanich Assistant Professor of Innovation
Bioengineering*

Ph.D. in Biomedical Engineering;
Cornell University



George Ilhwan Park

*Assistant Professor
Mechanical Engineering and Applied Mechanics*

Ph.D. in Mechanical Engineering;
Stanford University



Paris Perdikaris

*Assistant Professor
Mechanical Engineering and Applied Mechanics*

Ph.D. in Applied Mathematics;
Brown University



Aaswath Raman

*Assistant Professor
Electrical and Systems Engineering*

Ph.D. in Applied Physics;
Stanford University

HONORS & AWARDS

Mark Allen, *Alfred Fidler Moore Professor in Electrical and Systems Engineering and Scientific Director of the Krishna P. Singh Center for Nanotechnology*, was named Fellow of the National Academy of Inventors, a professional distinction accorded to academic inventors.

Paulo E. Arratia, *Professor in Mechanical Engineering and Applied Mechanics*, was a recipient of a 2018 Lindback Award for Distinguished Teaching. The Lindback Awards were established in 1961 with the help of the Christian R. and Mary F. Lindback Foundation. They are the most prestigious teaching awards given by the University of Pennsylvania.

Jason Burdick, *Professor in Bioengineering*, was selected as the 2017-2018 recipient of the George H. Heilmeier Faculty Award for Excellence in Research for “pioneering contributions to designing and developing polymers for applications in stem cell biology and regenerative medicine.” This award honors a Penn Engineering faculty member whose work is scientifically meritorious and has high technological impact and visibility.

Jennifer Phillips-Cremins, *Assistant Professor in Bioengineering*, was elected a 2018 Kavli Fellow of the National Academy of Sciences. The Kavli program honors young scientists who are considered leaders in their fields and have made significant contributions to science.

Nader Engheta, *H. Nedwill Ramsey Professor in Electrical and Systems Engineering*, was a recipient of the 2018 IEEE Nanotechnology Council Pioneer Award in Nanotechnology for “his transformative contributions to the nanoscience and nanotechnology of photonic metamaterials and for the development of optical nanocircuits.” Engheta was also elected Fellow of the International Union of Radio Science.

Raymond Gorte, *Russell Pearce and Elizabeth Crimian Heuer Professor in Chemical and Biomolecular Engineering*, was elected to the National Academy of Engineering (NAE) for “fundamental contributions and their applications to heterogeneous catalysts and solid state electrochemical devices.” Election to the NAE is among the highest professional distinctions accorded an engineer.



Mark Allen



Paulo Arratia



Jason Burdick



Jennifer Phillips-Cremins



Nader Engheta



Raymond Gorte



Insup Lee



Daniel Hammer



Cynthia Sung



Celia Reina



Stephan Zdancewic



Karen Winey

Daniel A. Hammer, *Alfred G. and Meta A. Ennis Professor in Bioengineering*, was a recipient of the Provost's Distinguished Ph.D. Teaching and Mentoring Award. This award is presented by the University of Pennsylvania to standing faculty members for their distinguished teaching and mentoring of doctoral students.

Insup Lee, *Cecilia Fidler Moore Professor in Computer and Information Science*, was named Fellow of the Association for Computing Machinery (ACM) for "theoretical and practical contributions to compositional real-time scheduling and runtime verification." The ACM supports the professional growth of its members by providing opportunities for life-long learning, career development and professional networking.

Celia Reina, *William K. Gemmill Term Assistant Professor in Mechanical Engineering and Applied Mechanics*, was selected to receive the Eshelby Mechanics Award for Young Faculty. This award is given annually to emerging junior faculty who exemplify the creative use and development of mechanics.

Cynthia Sung, *Gabel Family Term Assistant Professor in Mechanical Engineering and Applied Mechanics*, was a recipient of a 2017 *Popular Mechanics* Breakthrough Award, which celebrates a short list of "world-changing" innovations each year.

Karen Winey, *TowerBrook Foundation Faculty Fellow and Professor in Materials Science and Engineering*, was selected to receive the Trustees Council of Penn Women 6th Annual Advising Award. This award recognizes undergraduate advisors who provide outstanding assistance and advice to their advisee students and who have made a significant impact on the academic experience of these students.

Stephan Zdancewic, *Professor in Computer and Information Science*, was named a recipient of a 2018 Lindback Award for Distinguished Teaching. The Lindback Awards were established in 1961 with the help of the Christian R. and Mary F. Lindback Foundation. They are the most prestigious teaching awards given by the University of Pennsylvania.

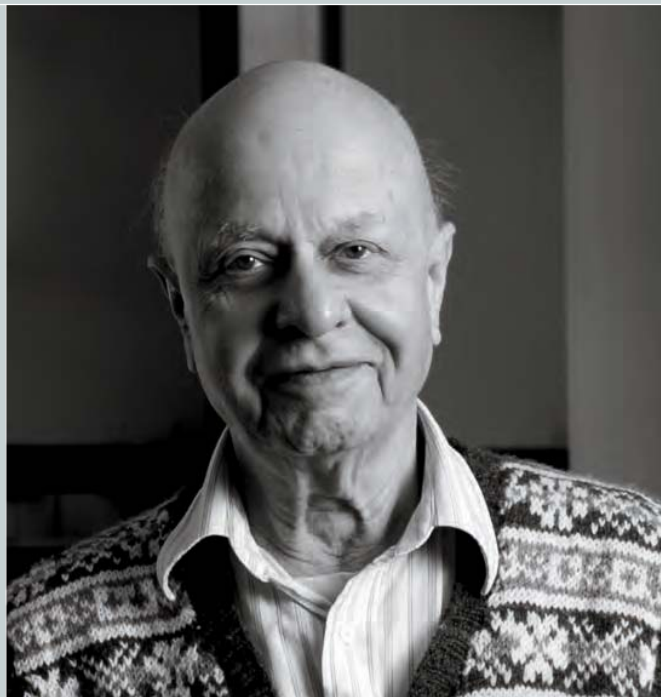
Aravind Krishna Joshi, *Henry Salvatori Professor Emeritus of Computer and Cognitive Sciences at the University of Pennsylvania*, died on December 31, 2017. He was 88 years old.

Dr. Joshi earned a Bachelor of Engineering degree from Pune University in India in 1950, a master's degree from Penn in 1958 and a Ph.D. from Penn in 1960. As a graduate student, Dr. Joshi was on the team led by Zellig S. Harris and Henry Hiz that created the first natural language parser in 1959.

Dr. Joshi was appointed as assistant professor in Electrical Engineering in 1961 and received a secondary appointment in the Department of Linguistics in 1964. He became an associate professor in Electrical Engineering in 1967 and was promoted to the rank of professor in 1972. He became emeritus in 2012.

His research focused on the intersection of computer science and linguistics. In his early work, Dr. Joshi developed much of the mathematics of linguistics called "tree-adjointing grammars," which have aided the analysis of human languages and led to developments in artificial intelligence and biological computation. He later worked with Lila P. Gleitman of the Psychology department on interdisciplinary research projects at the nexus of psychology, linguistics and computer science, and contributed to the growth of a new academic discipline now known as cognitive science. In 1983, Dr. Joshi became the Henry Salvatori Professor of Computer and Cognitive Sciences. In 1990, along with Dr. Gleitman, he started Penn's Institute for Research in Cognitive Science.

In 2001, the Aravind K. Joshi Term Assistant Professorship in Computer and Information Science was endowed with a gift from Silicon Valley entrepreneur and Penn alumnus Jerry Kaplan (CIS'79).



Dr. Joshi was the recipient of many honors and awards, including the Benjamin Franklin Medal in Computer and Cognitive Science from the Franklin Institute; the Cognitive Science Society's David Rumelhart Prize for Contributions to the Theoretical Foundations of Human Cognition in 2003; the Association for Computational Linguistics (ACL) Lifetime Achievement Award in 2002; and the International Joint Conference on Artificial Intelligence (IJCAI) Award for Research Excellence in 1997. He also served as ACL president in 1975.

He is survived by his wife Susan (Heyner); daughters Shyamala and Meera; and grandchildren Marco and Ava.

Contributions in his memory should be directed to The Aravind K. Joshi Professorship Fund. Checks can be mailed to Penn Engineering, Office of Development and Alumni Relations, 123 Towne Building, 220 South 33rd Street, Philadelphia, PA 19104-6391.



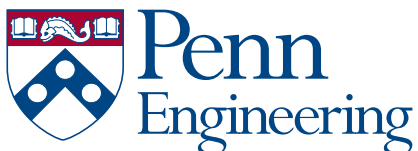
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Fred Warren

Investing in the Promise of Innovation



When you first meet venture capitalist Fred Warren (ME'60, WG'61), two things become immediately apparent: He excels in the art of good conversation, and his inquisitiveness about the world underpins his passion for Penn Engineering and in discovering the next great innovation. "I have an unrequited curiosity about most things. I enjoy learning and having deep conversations with smart people, particularly about technology," he says.

Warren has devoted more than 30 years to the oversight of both the University (as a member of the Board of Trustees) and Penn Engineering (as an Overseer). He and his wife Robin are also founding donors of the Warren Center for Network and Data Sciences (warrencenter.upenn.edu), Penn Engineering's incubator of forward-thinking, collaborative research that is shaping how network science improves many aspects of life.

How does your education meld with being a venture capitalist?

My Penn Engineering education enabled me to understand the aspects and importance of innovation, while my Wharton MBA gave me the ability to understand markets and the economic upside of technology. Those skills have served me well in venture capital investing.

What inspired you to establish the Warren Center?

The impetus to be the founding donor and continued supporter of the Warren Center is the energy Michael Kearns, National Center Professor of Management & Technology in Computer and Information Science, brings to the table. I was so impressed with his NETS engineering program for undergraduates that I asked him what else he wanted to do in this area. When he answered that he wanted to build a graduate center, I said, "Let's do it."

What fascinates you about the research underway at the Warren Center?

It's where some of the most compelling research in machine learning is being done—and being done better than anywhere else.

How could this research impact venture capitalism?

As a venture capitalist, I'm concerned with privacy—who has access to what data. I'm also concerned with getting the most accurate information to make good investment decisions. But the massive amount of data that must be sifted through can hamper that process. Machine learning can help us better quantify the sensitivity of data to enhance a global data privacy framework, as well as achieve faster and more accurate analysis of complex data.

What underscores your commitment to Penn Engineering?

I am personally compelled to give back to Penn, which has contributed greatly to my success. I was honored to be part of the Board of Trustees and proud of our accomplishments. Now, as an Overseer, it's exciting to help secure the future of Penn Engineering in a world where technology and education are rapidly changing. 🇺🇸

By Amy Biemiller

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ROTHBERG CATALYZER MAKERTHON

An event powered by the Penn Center for Health, Devices and Technology, the Rothberg Catalyzer Makerthon asked students to form multidisciplinary teams to create hardware prototypes that address unsolved healthcare challenges. During the March 23-24 event, teams were encouraged to consider the functional, emotional and social needs of patients. The 2018 grand prize-winning team, BCI Epilepsy, built a virtual reality system to aid in testing for epilepsy in children.