engineering news
School of Engineering
FALL 19
SANTA CLARA UNIVERSITY

Dean's Message

It's interesting that while fall is the time of the year when nature begins to cool off in preparation for the dormancy of winter, in the life of an academic institution things are just heating up.

That is certainly the case for the School of Engineering at SCU this year. Having begun my tenure here as Dean this past August, I am excited by the enormous potential I see in our students, faculty, and staff. Add to that the pace at which our new STEM complex, the Sobrato Campus for Discovery and Innovation, is taking shape in the middle of campus and though the temperature is dropping, there is definitely a spring-like feeling of growth and renewal on campus.

As I get to know my colleagues in the School and across campus, I am heartened by the creativity, compassion, collaborative spirit, and aspiration I encounter. Over the next few months, we will be rolling up our sleeves, reviewing the School's organizational structure, forming elected Faculty and Staff Councils, and codifying and filing school policies and procedures.

This fall SCU was ranked among the top 15 percent of universities worldwide. We are a national university and we strive to be a leader in engineering academic excellence in and out of the classroom and through our research. I am honored to be Dean of the School of Engineering at Santa Clara University and I look forward to working with this tremendous community of scholars to advance *Engineering with a Mission.*

Elaine P. Scott, Ph.D.
Dean
School of Engineering

Going Deep

Enabling a group of autonomous aerial and ground robots to work together to explore perceptually degraded, unstructured and GPS-denied environments is what gets electrical engineering Ph.D. candidate Kamak Ebadi out of bed every morning. His groundbreaking research—a collaborative simultaneous localization and mapping (SLAM) algorithm for multi-robot exploration of exactly those types of environments—has taken him to great heights and is now plunging him to great depths. Initially developed for exploring Mars with a first-of-its-kind helicopter and rover team, his work is now being used in harsh and challenging environments 900 feet below the Earth's surface.

As a doctoral research fellow at NASA Jet Propulsion Laboratory, Kamak was selected to join NASA JPL's CoSTAR (COllaborative SubTerranean Autonomous Robots) team for the prestigious DARPA Subterranean Challenge. Previous DARPA challenges led to breakthroughs for the internet, autonomous cars, and drones.

Team CoSTAR is made up of 60 technologists, researchers and engineers from 4 institutions—NASA JPL, Caltech, MIT, and KAIST (formerly the Korea Advanced Institute of Science and Technology) who are developing autonomous, collaborative subterranean robots for competition in DARPA's 3-year, multi-contest challenge. Only 20 members of each team may actually compete in the on-site challenges, and Kamak made the cut.

The first contest, held in August, was the Tunnel Circuit competition, held in Pittsburgh's formerly operational coal mining tunnels. For this competition, CoSTAR created a fleet of drones and wheeled and tracked robots that worked together using cutting-edge autonomy solutions to independently explore and map the warren of complex and challenging underground pathways and locate a variety of objects. Backpacks, cell phones and survivors (mannequins) were hidden throughout the course to replicate a real search and rescue scenario.

Photo courtesy of Kamak Ebadi

Kamak's collaborative SLAM solution, developed in partnership with JPL and MIT, helped the CoSTAR team win 2nd Place in the competition! Kamak is the lead author on a paper describing the breaking results of this solution submitted to the IEEE International Conference on Robotics and Automation (ICRA 2020), one of the largest and most prestigious robotics conferences in the world.

While using futuristic robots to find hidden treasure may seem like fun and games, DARPA created the challenge with the very serious purpose of advancing technology for defense and first responders operating in challenging underground environments. Finding solutions to the problems of troublesome access, GPS-denied, unpredictable terrain, limited visibility, and poor communication offers immediate benefit to disaster relief agencies, but also opens the possibility of addressing rising urban populations by building down, rather than up.

Today the competition focuses on applications here on Earth, but this research provides unparalleled scientific opportunities and lays the groundwork for future robotic exploration of caves and lava tubes on the moon, Mars, and beyond that could one day provide a safe habitat for future human space missions.

More: https://subt.jpl.nasa.gov/
https://www.subtchallenge.com/

Next Level IoT

It's just a tiny space—not much larger than a custodial closet really—situated off a busy corridor, near the School of Engineering's spacious, bustling student collaboration area. You might walk by it a dozen times a day and not ever think to peek in. But inside this room packed with imposing server stacks and desks covered with laptops, blinking electronic components, and test equipment, student researchers from undergraduates through Ph.D. level are working to advance networking and embedded systems for a myriad of applications. This is the SCU Internet of Things Research Lab (SIOTLAB), founded in 2017 and directed by Behnam Dezfouli, assistant professor of computer science and engineering.

Photo: Heidi Williams

Simon Liu '20 at work in the SCU Internet of Things Laboratory

"The low cost, low energy consumption, and small size of processing, memory, and wireless communication platforms have enabled applications from medical, to industrial, to smart home and connected vehicles, making IoT a very important area of research for academia and industry," Dezfouli said.

Research in the lab focuses on the four main components of building an IoT system: wireless communication, edge and fog computing, sensing, and security.

Here, one team addresses the efficiency of a home IoT system that needs to "sleep" in order to prolong battery life, but also must be hyper-vigilant to do its job and respond to user requests. They look into how the IoT devices in the home are affected by the use of other wireless devices, such as tablets or cell phones. Dezfouli noted that current WiFi access points do not differentiate between regular user traffic and the data of IoT devices. By building a testbed in the lab, researchers observed that the energy efficiency and reliability of communication between IoT devices and access points is significantly affected by other wireless use. To address this, the team is designing a new software stack for WiFi access points and IoT devices to intelligently schedule the transmission of data packets using novel queueing and machine learning techniques.

Given the rise of home mesh networks, they also are designing and developing a multi-access point system that intelligently controls the connection of each IoT device, depending on its location and communication requirements. "When a medical device is sensing, processing, and transmitting potentially life-saving data via a wireless link, it is important to ensure the communication and mobility of regular user traffic are not affecting the data collection capabilities of the mission-critical sensor," Dezfouli said.

Another area of research in the lab is what is known as edge to fog computing. Dezfouli explained, "Traditionally, the data sensed by IoT systems are sent to cloud platforms for processing and making decisions and actions. There are two problems with this model. First, there will soon be 50 billion IoT devices connected to the Internet, which generates a massive amount of data and traffic over internet structures—potentially more than what the current internet infrastructure and cloud platforms can process. The second problem is delay. Assume a robot used for gait rehabilitation in a house in Nashville is communicating with a cloud platform in Oregon. A long communication delay between the two entities is not acceptable for real-time, delay-intolerant systems. So, to address these problems we need to push processing closer to the edge."

His team of researchers is working on developing a fully software-based system that can be run on commodity hardware to enable the allocation of edge and fog resources to IoT devices requiring real-time monitoring and processing. "When necessary," he continued, "the system can communicate with the cloud to make the required notifications, but this approach prevents an overabundance of data from being transmitted through the 'fog'—the area between the edge and the cloud."

Working in the SIOTLAB is a good platform for SCU students to work with state-of-the-art technologies, Dezfouli said. "This cutting-edge experience enables them to easily get a position in industry. A number of our student researchers have gone on to work at Apple, Google and Cisco, and some are pursuing their graduate studies at Harvard and UCLA. We have had great support from industry through equipment donations from Avnet, Intel, Xilinx, Ruckus Networks, ST Microelectronics, Cypress, and Broadcom, too."

Dezfouli is excited about the potential of the lab. A flood monitoring system his team designed in collaboration with the City of San Jose has been deployed for a year now. Sensors installed on Coyote Creek monitor debris and keep track of rising water, reporting findings to the local utility. And there is so much more, he said. "We are also working on deterministic software-based packet switching, virtualization and coordination of processing tasks, software development technologies to enable AI on embedded systems, configurable device drivers, and distributed control systems. There is a lot going on in this small space!"

A MAGNETIC RESEARCH FIELD

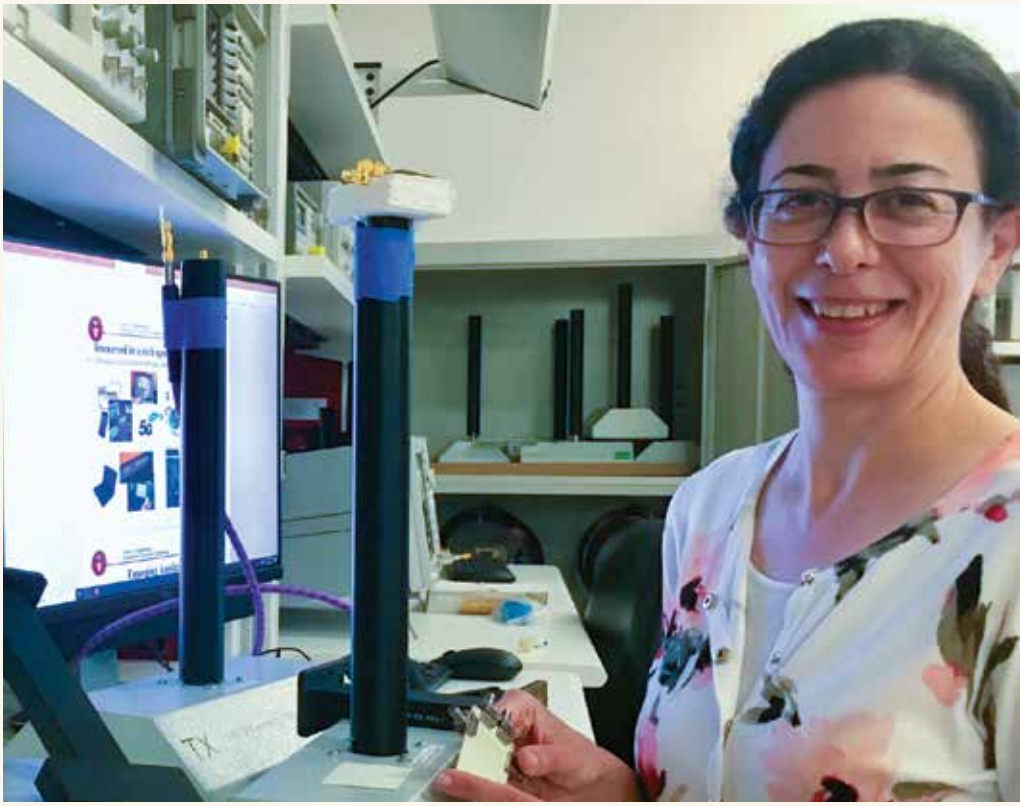
As a youngster, Ramesh Abhari, electrical and computer engineering department lecturer, found the field of electromagnetics magnetic. Drawn to the subject by its very mystery, she loved the deep thought process it took to make sense of it all and she knew she could figure it out. Now, with numerous patents granted or in the works, and with more than 100 journal and conference publications and 7 best student paper awards to her credit, she is even more passionate about putting her knowledge and creativity to work on what she considers "one of the main pillars of modern engineering."

"I love designing something that no one has thought about. I love teaching and doing research, and I make every effort to bring out the best in my students," she said in a tone more of wonder and excitement than of boastfulness.

The advent of 5G, IoT, artificial intelligence, and autonomous vehicles carries with it tremendous challenges. Engineers strive to advance technologies that enable the wireless connectivity needed to bring users into the modern age. "Antennas provide the wireless communication in our devices," Abhari said. "In your 5G cell phone, there may be more than 20 antenna operating bands to enable different functions. But what happens in this miniaturized, crowded space is the same thing that happens in a room full of people all talking at the same time—noise and interference can prevent effective communication."

In Abhari's lab, researchers focus on enabling miniaturization while reducing noise and interference in applications that span from millimeter-wave antenna arrays to microwave hyperthermia. They also develop methods to manipulate the substrate upon which a system is built so it is operational at a lower frequency at a smaller size. "There are more than one trillion transistors and kilometers of interconnects on a 20cm wafer scale semiconductor chip that was recently developed for AI and deep learning computing. In this packed environment unintentional antennas can occur that cause cross-talk and interference. Data centers have the same problem, but at a different scale," she explained.

Photo: Heidi Williams



Macro-engineering the substrate and power distribution network of high speed circuits is a specialty of Abhari's. Her groundbreaking research in this area uses metamaterials to reduce noise generated from interconnects inside a board. Similar to the padding used by sound engineers to line the walls of their recording studios, metamaterials are employed and boards are engineered to absorb noise. "Through isolation enhancement techniques, we can filter, trap, and absorb the unwanted energy to create the perfect interconnect," she said. Recently, her Ph.D. student Ali Khoshniat won 1st Place in the Student Hardware Design Contest at the IEEE International Symposium on Electromagnetic Compatibility, Signal, and Power Integrity Conference in New Orleans for his work on measurement of radiated electromagnetic noise from high-speed circuits and use of metamaterials for noise mitigation.

Abhari is excited about the results generated in her lab and about the prospects for her students. "This is a hot topic and our students are in high demand. They are learning the fundamentals of electromagnetics and gaining experience in innovative design—applying the same concepts, but using different strategies as demanded for diverse applications and environments," she said.

The field that first attracted her attention as a youth continues to inspire the enthusiastic researcher to this day. "In a way," she said, "with these advancements in wireless connectivity we are redefining our environment and ourselves. The sort of connectivity we have with our phones, wearable devices, and smart implants is another level of enhancing our senses. Remember the cyborgs from science fiction movies? We are almost there. Wireless connectivity is creating a smart skin for the Earth that acts as our extra sense."

DE NOVO FELLOWSHIP SPARKS DIVERSITY IN UNDERGRADUATE RESEARCH

Photo: Heidi Williams

To encourage traditionally underrepresented students to become involved in research, the School of Engineering and the College of Arts and Sciences put out a call to undergraduates last spring: apply for a De Novo Fellowship; get paid for up to 10 weeks of full-time research with a faculty mentor; travel and present your work at an academic conference.

Five engineering students were selected for the prestigious fellowship and throughout the summer, Amritpal Singh '20, an electrical engineering major minoring in computer science and engineering as well as mathematics, could be found in the lab, working alongside his mentor Kurt Schab, assistant professor of electrical and computer engineering, to advance the theory of evaluating the performance of small antenna systems designed into electronic circuitry.

Their research tracks distortion to compare the efficiency of LTI (linear, time-invariant) and non-LTI antennas, addressing a challenge that circuit designers have faced in selecting their best option. Singh explained that linearity and time variance data make a system easy to analyze, so designers of new antenna systems often simply accept the performance bounds associated with LTI systems to assess efficiency. But assuming LTI bounds may not be optimal; using the bounds of a non-LTI antenna could produce a better outcome. "Comparing LTI to non-LTI has been difficult, though," Singh said, "so we are figuring out a way to compare the two." Using LTspice computer software to simulate their circuit, they send an on-off key signal; a different part of the circuit checks what is being sent, and measures distortion. "We're using another software program to tell the simulation tool to initiate the test, so we can run multiple tests sequentially," Singh said.

"Stepping away from non-LTI antennas is a huge conceptual leap for the electromagnetics community," said Professor Schab. "This work with Amritpal is a critical step in establishing a new common language for antenna designers and system engineers to specify and analyze this new class of devices. Having Amritpal and Brad [Brad Shirley is a 2019 Kuehler Grant recipient] in the lab this summer has been a real joy. Summer research experiences like this support faculty research and give undergraduates an amazing opportunity to gain experience and technical depth past what they normally see in the classroom."

Talking with him about this research opportunity, Singh's enthusiasm is contagious. "It's been great—really enjoyable! Since we're working in the same lab, if I get stuck on something, I ask for help and Dr. Schab is right there. I'm getting to use all of my major and minor expertise, and on the side I'm reading about variational calculus and linear algebra and just learning a lot, in general." Lest you think he is all business, know that this researcher, IEEE student chapter treasurer, and math tutor, is also a huge fan of *Survivor*.

But of all his interests and activities, the De Novo Fellowship does seem to be having a strong impact on him. As he heads into his senior year, Singh is thinking more and more about the future. "I've known for a while that I want to go to grad school, but now I'm wondering if I should skip the master's degree and go for a Ph.D. Going from high school to pursuing a doctorate in such a short time seems like such a leap," he said, with a look of amazement on his face, "but now it looks like a real possibility."

scu.edu/engineering/de-novo
scu.edu/engineering/kuehler

A Major Exploration

Bioengineering senior Shani Williams is focused on getting all she can out of her time at Santa Clara University, even when school is not in session. She spent the summer as part of Assistant Professor Emre Araci's research team, developing a "wearable sensor for physical activity tracking"—an ultrathin microfluidic sensor that can be placed on the skin to measure how the tissue reacts in connection with a particular movement. Shani was paid to work on the project for 10 weeks as a De Novo Fellow—a program designed to encourage underrepresented students in engineering and the sciences to take on a research challenge.

"I wanted to explore my interest in microfluidics and work on an actual medical device. I was drawn to this major because in my view, bioengineering most closely connects products to improving people's lives and provides a greater opportunity to create products that can help people. The device I am working on can be used for sports medicine and rehabilitation after injuries or a stroke," she said. Dr. Araci points out the device will also be helpful in diagnosing movement disorders, such as Parkinson's Disease. "The relationship between movement and context is an important requirement for diagnosis," he said.

Shani began her research by running tests to measure the device's sensitivity and directional specificity to strain. Next, she moved on to prototyping thinner and thinner devices to better conform to the skin and increase sensitivity to movement, testing on skin to see how each iteration reacts to movement.

"This research project has allowed me to become acclimated to how efficient research should be conducted to give good results. I've had to identify problems within the experiment; find and use the right resources; and I've gotten better at reading literature to help solve problems. Now I know you can't just jump over the steps, it takes time to go through the process to get good results. Another thing I've really enjoyed about the experience is that it is very collaborative," she continued. "Dr. Araci provides guidance on how to set up the experiments and the whole team of undergraduate and graduate researchers gets together every Friday to present data from our experiments and have a discussion on how to improve our work. I've learned a lot by listening to everyone."

With the fall quarter starting up, Shani is picking up on some of her other activities—she's active in the student chapter of the National Society of Black Engineers, works as a lab technician for the organic chemistry department, and is a team member and safety officer of the Women's Rugby Club. She will also start working on her senior design project.

"I want to take advantage of as many opportunities as I can to learn about other fields of bioengineering. This summer I learned about wearable microfluidics; for senior design I will be focusing on using machine learning to make sure radiation treatments are segmented to the proper organs to reduce further cancer," she said. Whatever she takes on, Shani gives it her all. "My grandmother has this saying she always shares," she continued, "'If a task is once begun, never leave it till it's done. Be the labor great or small, do it well or not at all.' That stays with me. That's my motto."

Photo: Nicole Morales

Getting a Grip

Facing an ongoing farm labor shortage that leaves tons of crops unharvested each year, giants in agriculture are banking on automation as an answer to this costly problem. A number of companies are closing in on a strawberry picker that can identify ripe fruit, grip tenderly enough to pluck the berry from its stem without damage, and operate during the cool nighttime hours when bruising is less likely. Millions of dollars are being poured into developing a device to pick this one particular crop.

A solution for one crop is nice, but Santa Clara's Robotics Systems Laboratory (RSL) is looking to expand on the use and marketability of such a tool by designing a robotic arm end-effector—the claw-like part that interacts with the plant—that is adaptable for a number of different crops, say strawberries, tomatoes, and grapes.

This is a new project for the RSL, so lab director Christopher Kitts tasked civil engineering junior and De Novo Research Fellow Mai Sinada with getting it off to a good start. "I spent five weeks acquiring preliminary knowledge and building a database on the topic of soft robotics and agriculture—determining what products are commercially available, studying designs, learning about specific applications, and researching the market," she said. Next, she created a tradeoff analysis, market and design analysis, and wrote a conclusion before diving into prototyping a variation of a currently available end-effector. (The RSL maintains detailed wiki pages for each project so work can progress seamlessly as students graduate or move on to other pursuits.)

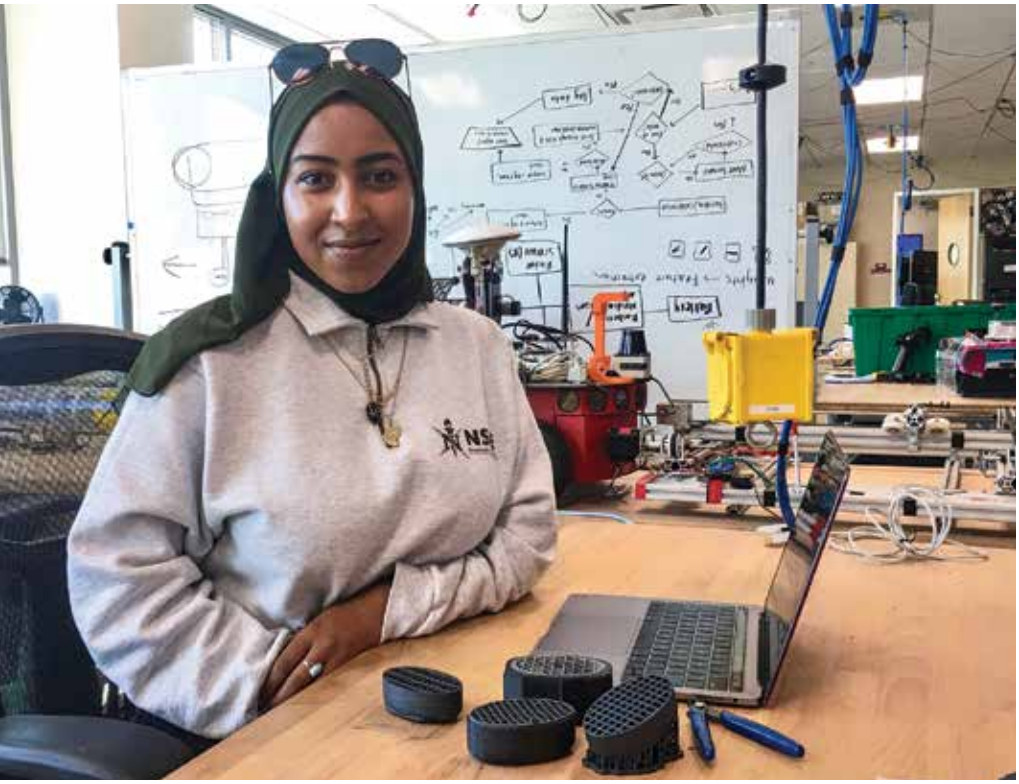


Photo Courtesy of Mai Sinada

Following up on her thorough research, Sinada began the fun work of designing and testing new form inserts for the device. Using both rigid and flexible materials, she continued to iterate for the next five weeks, changing the spacings in the gripper, and shaping the form inserts to be more adaptive to their respective use.

"I used Solidworks [3D CAD software] to come up with designs and printed them out using the 3D printers in the Maker Lab," she said. Sinada was already Maker Lab trained; as a first-year representative for SCU's student chapter of the National Society of Black Engineers, she had organized a lab training event for all NSBE general members.

"The De Novo Fellowship has been great and the atmosphere in the RSL is very welcoming," she said. "I was looking for an opportunity on campus instead of starting with a co-op or external internship. I wanted to learn how to look at problems from an academic standpoint. This experience gave me early exposure to project management and deadlines that will help me with my senior design project next year, and when I move into my real-world career I will bring a researcher's work ethic with me. I love being able to make something and using my hands when doing it. I need to touch and hold and move something in order to learn, and engineering encapsulates that. 'Engineering with a Mission' is what drew me to Santa Clara and building something that impacts someone's life is a challenge that makes this field so rewarding. I'm so happy I've had the opportunity to work on this project that may someday impact how farmers harvest their crops."

8 QUESTIONS FOR RATHI MURTHY, SVP/CTO OF GAP INC.

Rathi Murthy received her master's degree in computer engineering from Santa Clara University in 1995. Since then, she has held senior positions at American Express, eBay, Yahoo!, and WebMD, among others, and is currently Senior Vice President and Chief Technology Officer at Gap Inc., where she thrives on "removing friction and avoiding the status quo" while helping the company "get faster, cheaper, better." Here, she answers a few questions about SCU, diversity in the workplace, mentoring, and more.

What drew you to SCU?

I started my graduate studies while I was working full-time and had a one-month old at home. Three things drew me to Santa Clara: it was one of the few colleges that offered early bird or evening classes to accommodate studying while raising a family. I also felt SCU was rich in bringing in industry experts as professors in the graduate program—people who were working in Silicon Valley industry. It's a strong program that brings in real life experiences.

How has your graduate education, and particularly your SCU graduate education, helped you?

The foundation it provided was very strong; it was solid. We had to take 45 units of work with lots of math, data structures, networking. The requirements for the grad program made me very solid in basic engineering principles that have taken me all the way through in my career. SCU played a key role in making sure I was strong in the fundamentals.

What does a "typical" day on the job look like for you?

It's never typical! I'm a slave to my calendar and have no idea what's in store from one day to the next, but I am mostly either discussing strategy with leaders on initiatives for the company, or working with the whole organization to make sure our teams are aligned, inspired and know what to do. I also participate in various business operations reviews to understand what's happening across the company to make it faster and more efficient. I also set aside time to stay abreast of what's happening outside our company and sharing what we're doing at Gap Inc. with others. I am also passionate about contributing to a stress-free corporate America and I teach yoga and meditation on weekends; that's how I get my energy recharged!

What are the best things about being SVP/CTO and what are the most challenging?

Best: I've found my spot; this is not work for me because I love working with people. I have built a brand for myself as someone who removes friction and avoids the status quo while helping people build their skills and make the company better. Most challenging: Transformation is always difficult; it's like pulling teeth to get people to go with you, to get them inspired. But taking them on that journey is exciting and rewarding. Technology is evolving every day; the competition is not waiting. Speed and adaptability are critical and a company has to be nimble. Getting out there and helping the company is what gets me up every morning.

Any comments about diversity in the workplace that you would like to share?

This is one of our strengths at Gap Inc. We have over 70 percent women in the organization with women leaders across the stack. The culture began with our founders, a husband and wife team who each contributed equal funds to start the company. This put men and women on an equal footing from the start and equal opportunity was ingrained across the company. At Gap Inc., we make sure people can be themselves and we embrace all cultures and behaviors; this is at the core of the company and I love working in that environment.

Mentoring seems to be an essential part of your DNA; how did that come about?

As I was building my career, I was always looking for mentors. It was ingrained in me to seek out and maintain good relationships with people in and out of my company who could provide guidance and advice. I'm a good learner, in general, but I never thought I had much to offer. When I became Senior Director of Engineering at Yahoo! I was asked to speak about my journey at a women's event. I initially responded that I didn't know what I could offer. My VP sat me down and said that kind of thinking was selfish—that we all learn from each other, and women need to hear from other women. That woke me up! I realized it was true and that I needed to give back and make myself available as a mentor. Whether I feel I am an expert or not, I need to share. I am grateful

Photo courtesy of Rathi Murthy

to all those people and situations that got me to where I am today and taught me to believe in myself and Dream Big! We are a small group of women leaders in technology and it's important for us to support each other and encourage many others in their journey.

What's next for you?

Right now, I'm at a stage where my kids are older, I'm continuing to work in a challenging role, and I still have a lot of energy and time on my hands. I'd like to join company or nonprofit boards and serve that way. I also dream of devoting more time to mentoring other women executives.

Please finish this statement: It's a good day when...

It's a good day when I feel I've changed or impacted another person's life in a positive way. There are days when somebody calls and tells me my advice changed the way they looked at their job and it helped them push forward. That's a good day.

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The Jesuit University in Silicon Valley

Photo: Jim Gensheimer

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REMEMBERING MARK ASCHHEIM

The School of Engineering lost a dear colleague and friend last June, when Mark Aschheim, Peter Canisius, S.J. Professor in Civil, Environmental, and Sustainable Engineering, passed away after a two-year struggle with cancer. Department Chair Edwin Maurer shared the following remembrance of Mark at a memorial gathering in October.

Mark Aschheim was a gift to Santa Clara University. When he arrived in 2003 he brought with him the highest level of technical competence, a commitment to advancing sustainable technologies while modeling them in his own life, and a passion for the education of our students to serve their communities and the world. This alignment of institutional mission and Mark's professional and personal commitment was reflected in everything he accomplished at SCU. This includes prolific academic research into structural performance under seismic conditions, public service as a core member of the California Straw Building Association as they drafted revisions to the International Residential Code, and as a devoted teacher promoting pedagogical advances, student research, and leading the practical implementation of bamboo structural members in SCU's Solar Decathlon projects.

It is easy to be in awe of the many accomplishments Mark achieved, though it is at least as telling how understated he was about them. He stood firmly where his values placed him, in humble service to others. SCU strives to educate people of competence, conscience, and compassion. In Mark we received all three generously.

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