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School of Engineering

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DEAN'S MESSAGE

Today's pedagogical studies tout the value of involving engineering students in research as a means to boost retention rates, stir curiosity, drive a hunger for learning, and add a sense of relevance to help answer the age-old question: "Why do I have to learn *this*?"

Recently we've asked some of our newest alumni about their time at SCU, continuing our quest to explore possibilities for current students in STEM experiences and opportunities. Time and again they've urged us to engage students early and often with hands-on, collaborative research and project-based learning.

Involving students in collaborative, hands-on research has long been a hallmark of a Santa Clara engineering education, attested to this month as we celebrate our 46th annual Senior Design Conference. You'll see a few capstone projects featured in these pages. You'll also find stories about graduate student and faculty research—as well as one about a 1985 alumnus and structural engineer who "went to bat" for his client in an innovative way that saved wildlife and helped local farmers.

We take pride in all the projects being done by our undergraduates, graduates, alumni, and faculty. We also look forward to creating new and diverse means of fostering research opportunities in the future. In the meantime, please enjoy this edition of *Engineering News*.

Godfrey Mungal
Dean
School of Engineering

Collaboration Makes It Happen

A catchy (some might say brain-infiltrating) Sesame Street song celebrates the joys of collaborative effort: "Cooperation … makes it happen; cooperation … working together!" And perhaps it's only natural to recall this song when seeing what bioengineers Joseph Neumeyer and Jake Prince and web design and engineering seniors Amy Miller and Blair Koeneman have cooperated to create.

The interdisciplinary team of four has developed a tool called MUMS to help expectant mothers in remote areas access vital health screening. Silvia Figueira, Frugal Innovation Hub director and associate professor of computer engineering, matched the students up and advised Miller and Koeneman, while bioengineering Assistant Professor Unyoung (Ashley) Kim advised Neumeyer and Prince.

MUMS, or Mobile Urinalysis for Maternal Screening, brings the standardized analysis of urine test strips normally performed in urban medical facilities out to where women actually live, helping them identify bacterial infection, gestational diabetes indicators, and other biological markers indicating risk and the need for further medical attention. "Many women around the world have limited access to screening measures," said Prince. "They need to know when they should pursue medical care for issues that are easily addressed if caught early. We wanted to provide a healthcare tool that works in parallel with data access developments. Medical personnel are using tablets," he said, "so we created an efficient process that leverages technology to enable more consistent care throughout a pregnancy and over a patient's lifetime."

Here's how it works: The field medical worker's tablet is clipped to the top of a housing unit, into which a patient's test strip is slid. A photo of the strip is taken, and colorimetric analysis is performed using a mobile app, which also interfaces with a database that stores historical patient information. "Nowadays, it's almost impossible to have a project that doesn't include some type of computer engineering aspect; without the interface for the iPad portal, the device would not be functional," said Neumeyer.

Photo: Joanne Lee

From left: Joe Neumeyer, Jake Prince, Amy Miller, Blair Koeneman

Contributing to improved healthcare has been very rewarding for the web design engineers, who see opportunities for the project to expand. Koeneman said, "NGOs or other health agencies could use geotagging to mine and understand health trends stemming from these test results. Also, the test doesn't just have to be for pregnant women; it's particularly useful for them, but the system could be used for other tests."

Having the experience of working across disciplines was especially appealing for all the teammates. In fact, they expanded their network even further by enlisting the help of three non-engineer members of the Engineering World Health (EWH) student organization. Miller said EWH "assisted with identifying the target market and performed background research on how to implement. Their input helped guide our design." She added, "It's been really interesting working on an interdisciplinary project. Every time we get together as a team and start talking things through, the project just jumps ahead so much faster than when we're working on our own."

Sounds like cooperation really does make it happen!

A Technological MARVel

Imagine you're a marine field researcher traveling to Canada's Northwest Territories to perform subsurface bathymetric research on ponds and small lakes that appear in the warmer months within the Arctic Circle. You fly in by helicopter, with your equipment making the trip in an open basket affixed to the outside of the chopper. You're dropped off about a mile from your destination, and face the daunting reality of having to hike in with all your gear.

Photo: Heidi Williams

From left, Drew Azevedo, Ben Hopner, Sam Bertram, and Greg Del Vecchio test MARV's navigation control.

Seniors Drew Azevedo, Sam Bertram, Ben Hopner (mechanical engineering) and Gregorio Del Vecchio (electrical engineering) have spent the past eight months addressing that very scenario as they designed MARV—Marine Autonomous Research Vessel, a rugged, transportable research platform that can be outfitted with a variety of sensors for data acquisition.

"We were approached by two marine researchers who currently travel with an inflatable boat and outboard motor that they use to collect data manually," Del Vecchio said. "One of the scientists has funding from the University of Alaska, Fairbanks, and he is paying the Robotics Systems Lab (RSL) to design a better system. Their current method is highly involved for the scientists conducting the research, who have a difficult time being as precise as a computer-programmed robotic vessel could be. They asked us to make life easier: Make a craft suitable for transport that helps them gather more reliable data."

Denizens of the RSL, the team knew that a compact, autonomous craft could be programmed to cover a large area, collecting information from numerous predefined locations. They took inspiration from the Lab's proven SWATH (small waterplane area twin hull) boat, the product of a decade of development work by dozens of undergraduate and graduate students, a craft regularly deployed on science missions in Lake Tahoe and the Monterey Bay. One small problem: The SWATH weighs 800 pounds.

Hopner said: "We wanted that capability but compact and user-friendly, so we prototyped a micro version of SWATH. After many iterations, we ended up with a radio-controlled hull consisting of two pontoons manufactured from 5052 aluminum. These pontoons are connected by a bridge made from 8020 structural aluminum framing that holds a water-resistant Pelican case for storing the brains of the operation."

The team used every tool at their disposal to design and build their prototype. In state-of-the-art lab facilities—mechanical engineering's Machine Shop and SCU Maker Lab with its rapid prototyping equipment, laser cutters, and 3D printers—they fabricated most of the components. They sought input from their advisor, RSL director and mechanical engineering professor Christopher Kitts. And of course, being millennials, they also tapped into YouTube. "We watched an episode from 'How It's Made' about pontoon boats that was really helpful," said Hopner.

With two to three researchers sharing the load, the team was given an upper weight limit of 110 pounds. Sounds doable—except that a chirp sonar sensor used for studying subterranean soil compositions or finding fault lines can weigh upwards of 30 pounds. Ultimately, the craft they built, which is easily dismantled and reassembled, weighs about 50 pounds before the batteries and sensors are added.

Next, MARV needed to be programmed. "Intel is also supporting our project," said Azevedo. "We wrote software to run a couple of their Edison processors and we bought an off-the-shelf autopilot that we're using for navigation. It's commonly used for drones, but we're adapting it to work on a boat, and it fits our purposes very well."

Bertram noted: "We designed everything to be modular and easily replaceable or modifiable. Using components that are readily available and that can be replaced in a day or two is optimal for field researchers in remote areas. When the scientists install their sensors and pre-program their mission, they will be able to collect reliable data from a platform that is easy to carry to remote areas."

"They asked us to make life easier," he added. "MARV does that."

WIN, WIN, WIN!

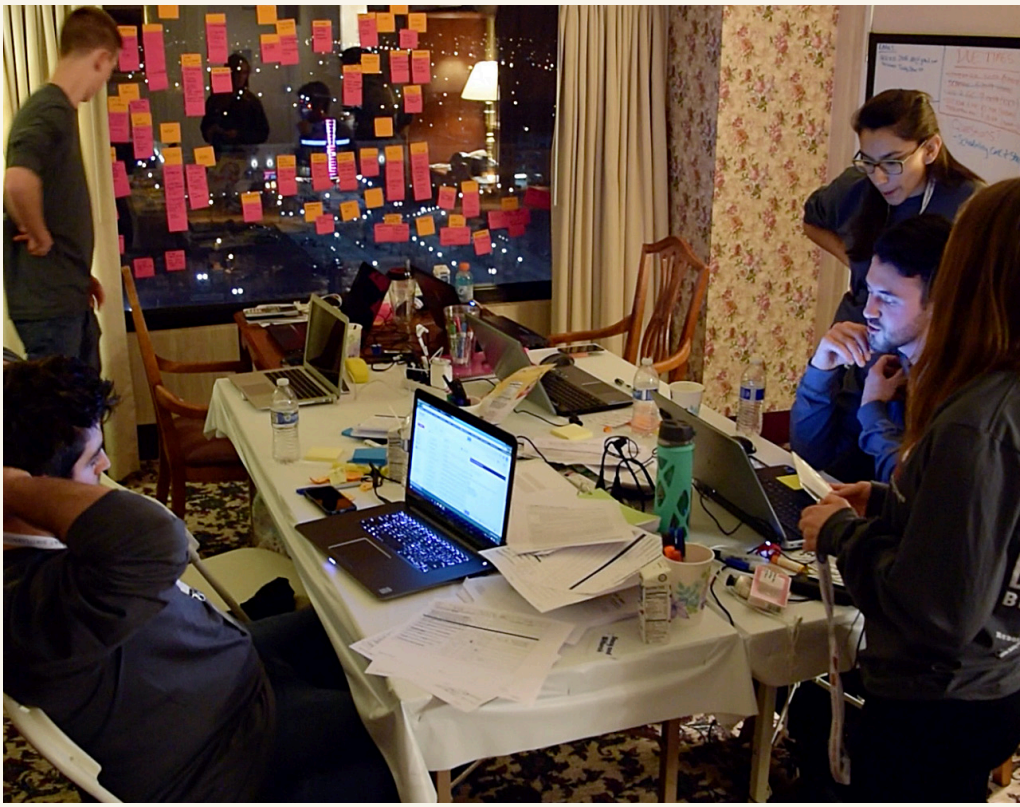
Recently, 21 SCU civil engineering students and their coach, Assistant Professor Hisham Said, joined an intense battle—the Associated Schools of Construction (ASC) Student Construction Competitions—transforming their hotel room into a makeshift project meeting room like you might find in a construction trailer. Over two days, they mobilized to compete in three contests: Design Build, Determining Project Risk (DPR), and Mixed-Use Projects.

The students put their analytical and problem-solving skills put to the test, focusing their attention on customer requirements, scheduling, cost estimates, and the myriad details that go into a construction project. Most intense was the DPR contest. Students were first tasked with identifying risks, negotiating contracts, assigning subcontractors, and so on. Then they had to respond to a number of scenarios: archeological relics found onsite, subcontractors suddenly out of business, materials unavailable…

Hectic hardly begins to describe the atmosphere. More than 1,300 students from 20-plus West Coast and mountain region universities feverishly attacked the problems presented from construction companies' actual portfolios, then submitted their proposals and presented their solutions to a panel of industry judges.

"Following the presentations, recruiters often stand right outside the doors, giving out their business cards or handing out offers," Said reported, "so it's a win, win, win. Students get to put their skills to work on real-life projects, schools market their programs, and employers see potential hires in action." This year SCU's team also brought home three wins—second place in the DPR competition, a first place finish by senior Ari Govan in the Alternates Competition (where individuals from different schools are teamed up), and Outstanding Student Achievement Award in the Mixed-Use category by senior Matt Millsaps.

Solid preparation contributed to SCU's success. For months the team held prep sessions with mentors from Devcon Construction, BNBT Builders, Blach Construction, Rudolph and Sletten, Cupertino Electric, SC Builders, and XRS Consulting. "We're very fortunate to have such strong support for an event that is a great proving ground for our students," Said added.



Civil engineering students turned their hotel room into a contest command center.

"After competing for the past two years, I know it has made an impact on my educational development," said Govan, who will be working for Blach Construction as a project engineer post-graduation. "It is an excellent way to gain experience and exposure to the construction industry as a student."

DPR team member Joey Novara agrees: "Participating in the ASC Competition as a sophomore was a great experience that gave me insight into the construction industry. I made a lot of new, lifelong friends in Santa Clara's civil engineering department. Placing second in the Determining Project Risk contest is one of many great college memories. I am looking forward to working with the team again next year."

LIGHTING THE WAY IN RURAL BENIN

They wanted to do something significant. They wanted to use what they have learned for something that mattered. So electrical engineering seniors Jacob Leatherberry and Nicolas Metais sought help with ideas from the late Jim Reites, S.J., associate professor of religious studies and engineering, who died on April 15 of this year.

Photo: James Reites, S.J.

Nico Metais and Jacob Leatherberry install the first light bulbs in Alafiarou.

Reites had facilitated a number of energy-related student projects in Africa, and it just so happened that a fellow Jesuit from Benin, Fr. Constant M.K. Bossou, currently pursuing his master's degree in computer engineering at SCU, knew of a perfect opportunity. But it would require support from more than a dozen others in Benin: Fr. Boussou's college classmates now in the Benin Electric Department, Jesuits in Cotonou, Brothers from a nearby Pastoral Center, Sisters of Charity Novitiate in Alafiarou, and village leaders. All together under the advisement of Reites and electrical engineering professor Tim Healy, Leatherberry and Metais brought electricity to Alafiarou in rural northeastern Benin. Their senior design solar microgrid project now lights the night and charges cell phones for 133 villagers.

There were some stumbling blocks. The students promised a system that could generate, store, and distribute electricity for 10 houses. What they didn't realize: In Benin, the term "house" equates to "family" … and those families are big—commonly 50 individuals at least. The deliverable was revised to 13 buildings. But which 13? On the ground, Leatherberry and Metais had decisions to make. "We spent an entire day out of the five we were there deciding where the system would go and what families would get lights. The village is split fifty-fifty between Muslims and Christians, and they get along really well, so we had to pick a mix to avoid risking any conflict," said Leatherberry.

Over the next few days, they didn't get much sleep. They would work on the installation all day then go back to their lodgings and continue perfecting the design until midnight or three in the morning. All was running smoothly until they went to boot up the system on the night before they were to leave the country. Flipped switch. Bright, flickering lights. Then … nothing.

"Shattered" is how Metais describes their reaction. "We were exhausted, but we were running around checking everything we could think of. Finally we decided to go home and think about it and do some more research."

Before they left, Metais said, a villager told them, "You guys are going to come back tomorrow, and if God wants it, it will work."

The next morning the pair discovered that the 24-volt light bulbs they had bought were actually only 12-volt. "Basically, we cooked a bunch of bulbs," Metais explained, "but we had a lot of spares. So we reconfigured our system to run on 12 volts, and it worked great." On that day, at least, engineering on-the-fly ended in a feeling of relief. "It was 16 hours of pandemonium," he said, "and we were so afraid of letting them down, but it all worked out."

Providing electricity was one thing, but keeping the system running and growing was another of the team's goals, so they implemented a sound economic plan. The electricity is not free; it costs about 50 cents per bulb per month. A small portion of the proceeds are used to employ Parfait, an electrician and Brother from the neighboring Pastoral Center, who collects payment, monitors and maintains the system, and has the key to divert power away from those not paying their bills. "Before we left, we told the villagers that if they didn't take hold of it, the project could decline. If a family can't afford to pay their bill, the community should get involved and help them pay. It's important to keep money coming in so expansion can continue," said Metais. Leatherberry added, "We impressed on them that the money is their money; it's not anyone else's, and this is just the beginning of something much greater. We way over-spec'd the system to enable expansion."

Just weeks after the Broncos returned home, Fr. Reites received good news from Alafiarou: "A meeting was held under the mango tree to discuss expansion. Two buildings near the initial installation will receive 13 more bulbs. Parfait will purchase the equipment and installation will begin. A team of three officials has already been established to ensure no one sleeps with the lights on. The people are very happy."

The SCU team is very happy, too. "We designed this open-source project as a proof-of-concept so it could be replicated in other villages, or expanded by future SCU senior design teams. This is just the genesis of the project; we hope it goes much further than we can anticipate," said Leatherberry.

Ed. note: For more on Fr. Reites' death, which coincided with our press time, please visit scu.edu/engineering/reites

Don't Fear the Smart Grid

During her sabbatical last quarter, JoAnne Holliday, associate professor of computer science and engineering, stepped out of the classroom where she teaches courses on information security, wireless and mobile networks, and distributed computing, and stepped into the world of smart grid and industrial control systems (ICS) security. "When I started looking into this," she said, "I was a little dismayed because it is so complex. I come from the IT realm and am used to thinking about computer security. But this is an entirely different category."

Before the smart grid came about, Holliday said, electrical system vulnerabilities were mostly due to weather—a tree falling or instability in the grid from natural causes—or vandalism to a piece of equipment. Generally, the disruption was isolated to a particular area, power was rerouted, and the problem was solved. But with the advent of the smart grid comes a vast array of concerns.

"The smart grid connects the staid world of public utilities to the wild and diverse world of the Internet," Holliday said. "Systems operators need to know how to match the generation of power with its usage. It's a real balancing act; if more power is produced than is being consumed, you get electrical instabilities, circuits get out of whack, and the imbalance must be corrected within a few milliseconds or you have real problems."

Monitoring equipment handles these issues to avoid brownouts and blackouts, she explained, but it must react quickly. On the Internet a two-second delay while a user downloads a webpage results in no harm, but in a more complicated system like the smart grid vulnerabilities arise. "Especially in computer systems," Holliday said, "the more bells and whistles, the more things can go wrong. Add to that complexity the possibility of intentional foul play and you can have real problems."

An industry this new lacks standards. "In IT over Internet, we're used to assuring all systems are patched with the latest software updates," she said. "In the ICS industry so many levels and versions of software are interconnected, and the lifecycle for software versions is often measured in years—ten years is not unusual! Sometimes utility operators are more afraid of the antivirus software than the virus itself. What if the antivirus software blocks a message that slows or stops the system? In the IT world, we say 'just reboot your system.' In the ICS world, this might interrupt vital operations, and that is assuming the system is not in some out-of-the-way, unmanned substation that requires travel to reboot or even just to press the enter key," she said.

But before you get too worried, Holliday notes, "The good news is that this industry is used to being regulated.

Photo: Joanne Lee

They are used to government oversight. Currently NERC, the North American Electric Reliability Corporation, is developing industry reliability and risk management standards for planning and operating the power grids that cover the U.S. and Canada—standards that can be implemented by FERC, the Federal Energy Regulatory Commission.

"We have to remember that the Internet was like this 15 years ago," she continued. "It took many years of annoying viruses before we developed firewalls and antivirus software and ways to ensure that software is updated. Today whole categories of software handle our computer security issues. The electric grid is in the same spot.

"Right now the industry is very trusting and a little naïve," she smiled. "We might be inconvenienced by brownouts or blackouts before it gets its act together. But change is in the works."

A Different Kind of Lab

Timothy Healy, professor of electrical engineering, had a vision for a different kind of research laboratory. One that is focused on addressing the world's energy challenges. One where a select group of highly motivated student scholars engages with tools for learning—formal instruction, yes, but also mentors from the world outside academia, field trips, and talks by industry leaders. A lab where students direct their research themselves, identifying and solving problems on their own. A place to serve as a living, evolving experiment in how to best encourage student research, curiosity, and love of learning.

Dr. Healy's brainchild is the Latimer Energy Lab, and since 2012 (through an endowment from an anonymous donor), both students and the Lab have benefited from its director's thirst for excellence and drive for ever-improving pedagogy. "I wanted the Lab to be an incubator for new teaching methods," Healy said. "Each summer we experiment with different approaches. Since the beginning, students have worked in small groups on a specific problem. More recently we've put larger teams of scholars to work on components of one 'super project' or on several synergistic projects. Current research points to the value of providing students the opportunity to problem-solve collaboratively, mirroring the way they will function when they start their careers."

Assisting Healy is mentor and adjunct professor Greg P. Smestad '83, founder of Sol Ideas Technology Development, and expert in the field of optoelectronics and materials used for solar energy conversion. "For one of the first projects," explains Healy, "Greg donated equipment and mentored Peter Stephens '14 (mechanical engineering) and Daniel Shull '14 (bioengineering) as they researched and modeled the power output of a Solyndra photovoltaic panel compared with a typical flat PV module, confirmed theory through experimentation, and presented their work at two conferences."

Visiting scholar from Brazil Jacqueline Barbosa and Kirby Linvill '15 (computer science and engineering) measured current-voltage characteristics of solar panels. Linvill wrote an Arduino code that reduced the cost from $6,000 to under $100, making solar measurements affordable for developing countries.

One of last summer's projects, an improved cookstove that uses the fire's heat to generate electricity for ventilation and water pasteurization, was recently implemented successfully by Christopher Clark '17 (mechanical engineering) in Tanzania and Malawi.

Smestad said, "The Latimer Lab is unique in the cross-pollinations it allows. A bridge is formed between a mechanical engineering student and the physics department, between an electrical engineering student and one in chemistry, and between engineering and environmental science majors. Dr. Healy opens the Lab up to other disciplines and encourages collaboration. He's always trying new experiments for the Lab; he's always exploring."

Alumni of the Lab have gone on to graduate study and careers at Apple, Lockheed Martin, Teradata, and utility companies. The future looks brighter still. "It is my hope that the Latimer Energy Lab can serve as a springboard toward a major new lab in the STEM complex now under development," said Healy.

Photo: Greg Smestad '83

Tim Healy with students in the Latimer Energy Lab.

GOING TO BAT FOR BATS

Photo: Wildlife Research Associates

Bats are right at home in their new, carefully designed habitat.

In the comic book world, Batman is a fictional superhero who roams the streets after dark to protect the citizenry. But the Caped Crusader's accomplishments pale in comparison to the real-world ecological superhero that courses through the sky each night, battling bugs, promoting pollination, and fertilizing fields and forests—the humble bat. Bats munching on mosquitoes can help us enjoy the outdoors, but their value extends far beyond the palliative. The world's only flying mammals are vital to our food supply, our economy, and our planet's natural ecosystems.

So when Cornerstone Structural Engineering Group, headed by President Todd Goolkasian, SE, B.S. '85 (civil engineering) was contracted by California's Tulare County to design a state-of-the art bridge replacement project, the company went to bat for the furry flyers with a design that not only included bat habitats, it also won the firm a prestigious National Engineering Excellence Award from the American Council of Engineering Companies.

Leading to the redesign were concerns over the stability of the original 1948 structure spanning the Kings River on Avenue 416 in the City of Dinuba. Goolkasian explained that in the 1940s and '50s "bridge expansion joints were typically designed into the structure to allow the bridge to shrink and expand under ordinary temperature changes. As it turned out these expansion joints provided just the right gap for bats to roost in comfortably. Now, with our more stringent seismic design codes, fewer expansion joints are used as they make the bridge more vulnerable to collapse during an earthquake. So today's structural engineers design bridges to be continuous over much longer span lengths, as we did for this 740-foot-long bridge. But eliminating these joints created the unintended effect of 'evicting' their long-term tenants!"

To obtain the necessary regulatory agency permits for the project, Goolkasian's team had to fulfill the California Department of Fish and Game's requirement to provide a biological habitat that is at least as good as what previously existed. The firm could have installed "bat houses" around the bridge—small wooden boxes on poles—but instead they decided to think outside the box and sought the advice of noted Chiroptera expert Greg Tatarian.

"Working with Mr. Tatarian," Goolkasian said, "Cornerstone developed a design that included the types of nooks and crannies studies had shown to be favored by bats for their day and night roosting—the types of crevices that the vintage concrete girder bridge with its multiple expansion joints had naturally provided. Since the smooth underside of the cast-in-place, post-tensioned, concrete box girder replacement bridge did not lend itself well to bat habitat, we incorporated several new elements into the underside of the bridge: concrete boxes were installed between columns for day roost, and spaces behind precast 'winged' bridge elements and other depressions were integrated to serve as night roost habitat."

Preserving bat habitat wasn't simply a design requirement to be checked off; its successful implementation is critical for California's Central Valley farmers. Tulare County leads the nation in agricultural production—$8.1 billion in 2014—and nearly half those earnings are generated from fruit and nut commodities. Bats annually save the farmers in this region millions of dollars by consuming prodigious amounts of harmful insects, protecting the crops and thereby reducing the amount of pesticides entering the ecosystem. Protecting the bat habitat is crucial to the region's wellbeing. Luckily, our bug-loving friends have found cozy digs in their new home.

In Tatarian's first post-construction monitoring survey, he noted that the design and implementation "has been successful, even in the first bat reproductive season since completion of the bridge." Population of four species of bats has increased from 1,200 to more than 4,000—and a new species, *E. fuscus* (big brown bat), has now taken up residence. Cliff swallows are also finding safe haven in the bridge's integrated crevices.

"While the need to provide bat habitat on bridge replacement projects was not a new requirement," said Goolkasian, "the 'old-school' solution would have been to provide a cheap, stand-alone environment—bat boxes. Knowing that my client (the County of Tulare) wanted a solution that would not require any maintenance or future expense caused us to rethink how we might incorporate the bat habitat more permanently into the replacement bridge design. In the end, we were able to come up with a much more robust concrete solution that fulfilled our ethical responsibility to ensure that the replacement bat habitat would be functional for the entire design lifetime of the replacement bridge."

Seeing the thousands of bats tucked comfortably into the bridge's carefully crafted spaces, and judging by the company's national recognition for the project, it would appear they are batting a thousand.

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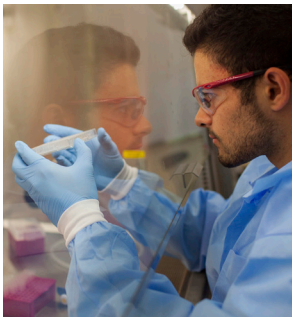

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AFFORDABLE HOUSING PUZZLE SOLVED BY SENIOR DESIGNERS

From left, Molly Bencomo, Megan August, and Ashley Waite on a site visit.

It's no secret that land in California is expensive. Or that buying a home here is out of reach for many. So Habitat for Humanity, known for helping families achieve homeownership, has gotten creative by expanding on its model of building single-family homes. Construction will begin in Fremont, California, this fall on a new three-story, multiple-family complex comprised of 30 two- three- and four-bedroom units. Plans were underway to replicate that structure in neighboring Walnut Creek. But a snag popped up. Differing city building codes required a redesign.

Habitat found help at SCU when civil engineering seniors Megan August, Molly Bencomo, and Ashley Waite took up the challenge as their senior design project, advised by civil engineering lecturer Tonya Nilsson, aka Dr. T.

The redesign presented a number of challenges. "In Fremont, the building height limit is 33 feet," said Waite. "So they had about a foot between floors for structural members. Walnut Creek's maximum is 29 feet, so the whole building had to shrink." The team performed load and cost analyses, eventually determining that TJI joists were the best option. "They cost more but since they span longer, fewer beams are required. Cost was especially important since Habitat is a nonprofit," said Bencomo. August added, "We also kept in the back of our minds the fact that volunteers will be helping with the construction." The TJI joists they selected are lighter and easier to install than traditional framing.

Another issue: "Working with AutoCAD designs for all three floors, we saw that not all the walls lined up. Columns need to go straight down, so adjustments had to be made," said Waite. "Dr. T said that choosing all the beams and members would be like putting a jigsaw puzzle together, and it was!" said August.

A site visit added another wrinkle. "Knowing how the complex would be situated in relation to the train line running right though the area raised concerns about how close construction equipment could get to the rails and made us think about noise insulation," said Bencomo.

"It's been a lot of work, but we love what we're doing," said August. "All three of us plan to go into structural engineering after graduation, and we were looking for a senior project that would have a big impact beyond campus. We're really lucky Habitat offered us this opportunity."

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