DEPARTMENT OF
Mechanical Engineering
UNIVERSITY OF WISCONSIN–MADISON

WINTER 2016
www.engr.wisc.edu/me

Harnessing 3D printers to enhance engineering education

Starting fall 2015, students in ME 314: *Manufacturing Fundamentals* have significantly more hands-on learning opportunities, thanks to extensive lab equipment upgrades and a new instructional model.

The course covers many aspects of the manufacturing process and, through labs, students apply what they've learned on topics like CNC, control algorithms, motion control, automation with programmable logic controllers (PLCs, which are industrial computers used to automate machines on a factory floor), metrology and engineering economics. But growing enrollment and a limited quantity of each piece of equipment cut down on the time students had to actually use the equipment.

Faced with this challenge, the department saw an opportunity to integrate additive manufacturing into the core undergraduate curriculum while also greatly increasing students' hands-on time in labs.

"We completely reworked all the lab activities so they're based on one plant—a 3D printing platform," says Erick Oberstar, a mechanical engineering associate faculty associate who led the substantial effort to transform the course. "We're still covering all the same topics; we're just having students apply them using an additive manufacturing process instead of a subtractive process."

The department purchased new fused deposition modeling 3D printers for every lab workbench and then customized each desktop printer by installing automation hardware with touch panel interfaces and input/output electronics that were all donated by B&R Industrial Automation Corp.

Oberstar says all this industrial hardware is coupled to the 3D printer's functionality. For example, when students do the PLC programming lab, the code they write for the PLC actually controls the 3D printer, which then prints the specified part.

Grainger Professor of Sustainable Energy and ME Chair Jaal Ghandhi says these upgrades give students valuable experience using real-world automation equipment. *(Continued p. 6)*

Pictured** (from left)**: Jaal Ghandhi, COE Dean Ian Robertson, Erick Oberstar, B&R President Marc Ostertag, B&R Southern Wisconsin Manager Steve Boelte, B&R Regional Manager Patrick McDermott, and Associate Lecturer Michael Decicco with one of the lab's 3D printers customized with B&R Automation equipment.

Jaal Ghandhi

The close of 2015 provides a good time to reflect on the changes that we have seen in the mechanical engineering department this past year. The faculty ranks have significantly changed. As I wrote last spring, Professors Neil Duffie, Sandy Klein and Rolf Reitz have retired. However, this fall we were joined by four new faculty members: Peter Adamczyk, Corrinne Henak, Alejandro Roldán-Alzate and Sangkee Min. Assistant Professors Adamczyk, Henak and Roldan-Alzate—as you will read about in this newsletter—represent a significant push by the department into the field of biomechanics. We're excited to see how these new faculty members, and those in the department already working in this area, will impact the general field of human health through improved understanding of the 'human' machine. Min, an expert in advanced manufacturing, is one of the first new hires in the Grainger Institute for Engineering, which was made possible by a $25 million commitment to the college from The Grainger Foundation of Lake Forest, Illinois.

We continue to see a strong demand for engineering among incoming under-graduate students, and our department has grown in response to that demand. In fact, in the 2014-2015 academic year, we granted 211 BSME degrees, which exceeds the previous high (over the past 10 years) by more than 30! The college has implemented a new direct-admission policy with a published required grade-point average that students must meet in order to stay in the department after their first year. Not only does this direct admission allow us to plan for the number of undergraduate students we will have in our department, it enables the students to connect immediately with their peers and with advisors here who can help keep them on track.

The pace of technological change has not slackened, and it truly is a great time to be a mechanical engineer. ON, WISCONSIN!

Jaal Al

Jaal Ghandhi, Chair
ghandhi@engr.wisc.edu
(608) 263-1684

Chancellor Rebecca Blank, COE Dean Ian Robinson, and Bucky at the Grainger announcement.

Major commitment to elevate UW-Madison undergraduate engineering education

In September 2015, The Grainger Foundation of Lake Forest, Illinois, announced a $22 million commitment to establish the Grainger Fund for Undergraduate Education, which will provide College of Engineering undergraduate students an unparalleled environment that will position them for success, not only academically, but in their future careers. The Grainger Foundation commitment comes on the heels of a $25 million commitment that founded the research-focused Grainger Institute for Engineering in the college in June 2014.

This new commitment will help launch initiatives that allow the college to educate an increasingly diverse population of undergraduate students and to enable a growing number of students to achieve their goal of becoming an engineer.

Among those initiatives are a peer-to-peer learning and tutoring center that focuses on student success and a level academic playing field for students from a wide range of back-grounds; state-of-the-art classrooms conducive to collaborative learning that solidifies students' deep understanding of the material; and a design innovation makers-pace that will be a hub for creativity, enabling students to roll up their sleeves, explore new ideas, tinker, build and experiment, and in the process, broaden their understanding of the entire cycle of product development.

"This commitment will have a trans-formational impact on the success of our undergraduates," says Dean Ian Robertson. "Opportunities for our students to work in transdisciplinary teams, to express their creativity and to expand their entrepreneurial skills have become an essential component in the engineering experience. We are changing the world by changing the way we deliver an undergraduate education."

Souped-up software reduces guesswork, tedium in computer-aided engineering

A team of UW-Madison engineers recently released a new computer-aided engineering software program, and its users are already calling it a "gift from heaven."

Associate Professor Krishnan Suresh *(pictured)* led a team that spent four years developing the software, which assists in optimizing the design of parts for just about anything—from bicycles and airplanes to bridges and furniture.

The software is intended to help designers quickly identify component shapes—known as topologies—that maintain their structural integrity while using the least amount of material possible. Less material means components are both cheaper to produce and weigh less, major goals of most design engineers across applications. "Design optimization lies at the heart of modern engineering," Suresh says. "It is critical in reducing cost, reducing material, reducing weight and increasing quality, and is a driving force behind innovation."

The free software is available as a plug-in for the popular computer-aided design program SolidWorks and as a cloud-based program accessible over the web. The SolidWorks plug-in, called ParetoWorks, has been available since 2013, and is used by more than 50 universities around the world as well as several industrial corporations. The web-based version, released in 2015 at cloudtopopt.com, already counts more than 500 users, with two or three new users each day, Suresh says."We've been getting a lot of positive feedback," Suresh says.

According to Suresh, the software is popular because it not only takes the guesswork out of creating ideal component topologies—a feature already available on other commercial software tools—but does so at incredibly fast speeds. The software needs only seconds to identify an optimized shape for a component, which Suresh says is far and away faster than other available software, all of which is beyond most human capabilities. "Design optimization can be very tricky, and difficult for humans to carry out manually," Suresh says.

Even an exceptionally talented human engineer cannot intuitively come up with some of the material-saving topologies that a robust computer program is able to identify."We believe our tools are more robust, have wider applicability and are significantly faster than competing software and human design," Suresh says.

The innovative software was largely funded by the National Science Foundation, and more recently by Sandia National Laboratories and the software company Autodesk.

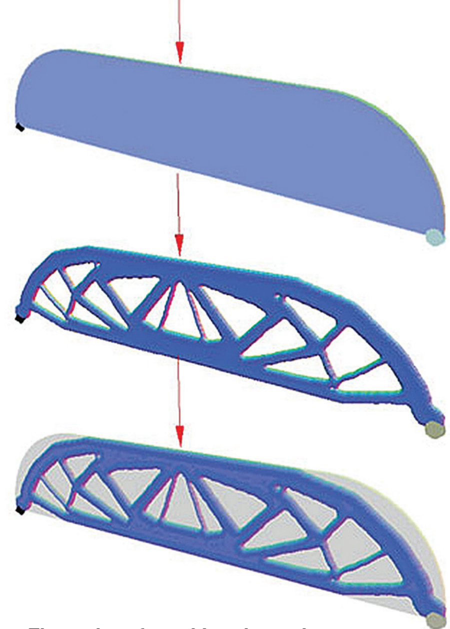
Suresh says the next goal is commercialization. His team is partnered with Jon Eckhardt, a professor in the Wisconsin School of Business and the executive director of the Weinert Center for Entrepreneurship at UW-Madison, and their goal is to create a spinoff company.

Suresh says the possibilities for commercialization are bright, as designers in all sorts of fields could benefit from the software. For instance, designers in the 3D printing industry are quickly adopting the software because it helps reduce expensive printing materials.

Suresh has worked with companies such as Madison-based Design Concepts to continuously improve the product. "They helped flush out a lot of problems with the software in its early stages," Suresh says.

Now, the software is sufficiently robust and user-friendly to take to the masses—a major milestone in the world of design optimization.

"To the best of our knowledge, this is the first implementation of a full-fledged 3D cloud-based design optimization," Suresh says. "It's an accomplishment that even large corporations are struggling to match."



The series of graphics above show a hypothetical structural problem: the component must hold up under the stress of an applied force, represented by the arrows. The top image represents the component before optimization, while the following images show the component optimized by Krishnan Suresh's software.

ALUMNI NEWS

Alumnus Pulvino receives college Distinguished Achievement Award

Todd Pulvino is a recognized leader in finance whose distinguished career includes success in academia and business.

As a co-founder and principal at the investment firm CNH Partners, an affiliate of AQR Capital, Pulvino has championed the use of creative, technical approaches to identify and enhance investment opportunities. He co-founded CNH's arbitrage investment business and has served as a lead manager of arbitrage strategies since 2001. Currently, more than $7 billion is invested in arbitrage strategies across CNH and AQR funds.

After earning his UW-Madison bachelor's degree in mechanical engineering in 1984, Pulvino began his career as a project engineer at The Aerospace Corporation. After six years at The Aerospace Corporation—during which he also earned a master's degree in mechanical engineering from the California Institute of Technology—Pulvino went on to pursue graduate studies at Harvard University, where he earned a master's degree and a PhD in business economics.

After completing his PhD in 1996, he joined Northwestern University's Kellogg School of Management as an assistant professor of finance, focusing his research on the risks and returns in event-driven arbitrage, the practice of buying and selling similar assets simultaneously, for a profit. While at the Kellogg School, he received two Journal of Finance Smith Breeden prizes for his research, received the L.G. Lavengood Outstanding Professor of the Year Award in 1999, and rose to the rank of tenured associate professor of finance in 2003. Prior to earning tenure, he was also a consultant at two fund-of-fund firms, Collins Associates and Grosvenor Capital Management, and spent a year as a visiting professor at Harvard Business School. Pulvino left his associate professor position at Northwestern to focus on CNH Partners in 2004.

Although his career progressed from engineering to the world of finance, Pulvino says his UW-Madison engineering education gave him a strong foundation for building a dynamic career. "One of the things that I like about engineering is how analysis informs design," he says. "Analytical techniques, and more generally the analytical thought process, that I learned in classes like Professor Emeritus Wayne Milestone's design analysis class, helped me in engineering and continue to help me in the finance world."

Pulvino is a member of the UW-Madison mechanical engineering industrial advisory board. He lives in Sarasota, Florida, with his wife, Katie. They have three children, Christa (26), Nick (24) and Natalie (19).

NEW FACULTY

PETER ADAMCZYK

Making strides toward advanced protheses

Walking seems simple: Just place one foot in front of the other. However, each individual step involves hundreds of coordinated muscle contractions, subconscious calculations, and articulated motions up and down the entire body.

Assistant Professor Peter Adamczyk, who earned his PhD in mechanical engineering from the University of Michigan, studies the biomechanics of walking. In his research, he quantifies and characterizes the complex symphony of impulses and adjustments underlying every single step.

Adamczyk puts that data to work in designing interventions to help people avoid falls and in advanced designs of prosthetic devices that mimic the performance of missing limbs.

In the past he has experimented with shape-changing prostheses, and designs that change their stiffness in response to different activities. Adamczyk anticipates developing software for robotic prostheses —educating the brains inside robotic feet to better mimic the motions of walking.

READ MORE:

go.wisc.edu/more-adamczyk

CORINNE HENAK

Exploring perplexing properties of cartilage

Layers of cartilage line the interfaces between bones at every joint within the human body. As people age or experience injury, their cartilage wears down, sometimes leading to incurable osteoarthritis. This condition causes extreme discomfort and decreased mobility—and the lifetime risk of knee osteoarthritis is approximately one in two.

Yet, researchers don't fully understand what causes those diseases, what the natural progression of those diseases is, or how to intervene effectively.

From a mechanical perspective, Assistant Professor Corinne Henak hopes to understand the uncanny physical properties of cartilage in an effort to improve human health outcomes for orthopedic disease.

Henak, who earned her PhD at the University of Utah and engaged in post-doctoral research at Cornell University, also intends to learn how mechanobiology, the response of cells to mechanical signals, affects disease progression.

READ MORE:

go.wisc.edu/more-henak

SANGKEE MIN

Manufacturing the future of innovative design

Manufacturing paradigms that have sought to increase output and efficiency while reducing cost have squelched creativity and manufacturing competitiveness. Assistant Professor Sangkee Min doesn't merely want to push the envelope of possibility for manufacturing; rather, he hopes to redefine the envelope entirely, ushering in a new era of truly innovative designs.

Min, who earned his PhD from the University of California at Berkeley and has international experience in both academia and industry, envisions a future where designers—unencumbered by manufacturing constraints—have ultimate freedom to produce their most avant-garde ideas.

He hopes to create a network of innovation from a huge knowledge base, including specialists in photolithography, metal cutting, injection molding, etching, additive manufacturing and advanced manufacturing in order to produce truly innovative designs that customers want to buy.

READ MORE:

go.wisc.edu/more-min

ALEJANDRO ROLDÁN-ALZATE

Applying theoretical fluid dynamics to improving surgical outcomes

One of the key challenges in planning a surgery is accurately predicting how the intended modification will alter blood flow within the affected organ. Diverting fluid along a new path, such as in an artificial bypass, will create unforeseen regions of pressure and turbulence within the organ's interior pipes. To minimize potential harm to patients, surgeons need to know in advance how their plan will perturb flow through the body's plumbing.

Assistant Professor Alejandro Roldán-Alzate, who earned his PhD in mechanical engineering from UW-Madison and spent five years as a radiology researcher, uses a combination of computer simulations, flow measurements in artificial model organs, and physiological data to investigate liquid motion in living bodies. He hopes this fluid-dynamics-based approach to surgical planning will improve treatment options and contribute to more positive outcomes for patients facing everything from heart surgery to liver transplants.

READ MORE:

go.wisc.edu/more-roldan-alzate


B&R Automation's Steve Boelte, Patrick McDermott and Marc Ostertag tour the Mechatronics Lab with COE Dean Ian Robertson.

Harnessing 3D printers to enhance engineering education *(Continued from p.1)*

"The electronic hardware and interfaces from B&R Automation are state-of-the-art, production-floor electronics, so students are getting a pretty unique educational experience," Ghandhi says. "And since we've distributed this equipment onto every lab bench, students are now hands-on with this technology for the whole lab period."

Marc Ostertag, president of B&R Automation, says he's very impressed with how the department integrated the automation equipment with the 3D printers. The innovative setup allows students to interact with the hardware and gain a deeper understanding of how industrial automation works in the real world, he says.

"We've made this technology a lot more accessible, and that's a huge deal."

—Erick Oberstar

Ostertag says this kind of hands-on learning experience makes students especially attractive to employers. "We hire a lot of engineers straight out of college, so we benefit a lot from this partnership as well," Ostertag says. "Students who come through this lab will have a better education in real-life engineering challenges and know how to use automation equipment, and that's a huge benefit for us as we look to hire engineering graduates. So it's really important for us to be involved with and support top universities like UW-Madison."

Beyond learning industrial automation tools, Oberstar says the changes to the labs will also help prepare students to work with additive manufacturing processes that they will encounter in their engineering careers."With these labs, we're teaching students the fundamental process that's happening with additive manufacturing, and this new equipment allows us to really get down into the nitty-gritty details of what's going on inside these machines, which helps facilitate students' understanding of the entire process," Oberstar says.

Since ME 314 is a required course for mechanical engineering undergraduates, Oberstar says every student will now get a lot more exposure to 3D printing technology.

"There was some exposure for certain students who sought out the 3D printers around campus for their senior design projects, but now we just opened it up for all mechanical engineering students," he says. "We've made this technology a lot more accessible, and that's a huge deal."

The educational innovations weren't limited to the labs. Oberstar and his teaching assistants also changed the course's format from a lecture-based course to a "flipped" course model that replaces formal classroom lectures with active learning experiences. Students now watch online videos that cover the lecture material on their own time, and then show up for class ready to discuss, ask questions and work through problems with the professor and fellow students. "This will improve the contact time that students have with the instructor and increase interactions," Oberstar says.

While the new flipped course paradigm started in fall 2015, some students got the opportunity to complete labs using the new equipment in spring. "There was nothing less than pure excitement from everybody involved with the new labs. The students really loved it," Oberstar says.

In fact, the excitement extends beyond students. Oberstar says he has given alumni tours of the lab, and when they learn about the new lab setup, there has been a common response. "A lot of them say, 'Can I come back and take this class?' And these are professional mechanical engineers working out in industry who think this stuff is so exciting that they want to come back," he says. "We have so much cool stuff in this lab, for engineers it's like being a kid in a candy store."

Ramon Roche-Maldonado encourages minority students to study engineering

Solid training in a science, technology, engineering, or math (STEM) discipline opens doors to boundless opportunities. However, some minority students cannot picture the possibility of going to college, let alone pursuing career in science or engineering. Mechanical engineering undergrad Ramon Roche-Maldonado hopes to break down barriers, and open children's eyes to a future in STEM.

Roche-Maldonado has promoted science education to underserved communities since setting foot on campus four years ago. Within his first weeks in Madison, he made a beeline for the Society for Hispanic Professional Engineers (SHPE), eager to lend a helping hand. "I knew exactly what I wanted to do. I wanted to do outreach," he says.

Six years ago, students from SHPE visited his high school and nurtured him through the application process to UW-Madison. "They helped me get to where I am," he says. "I wanted to help other students and continue the cycle."

Throughout his four years at UW-Madison, he has worked tirelessly to promote science education among underrepresented students. "I want to motivate kids not just to go to college, but to pursue a STEM career in college," says Roche-Maldonado.

He sees STEM education as a path to a brighter future, with long lasting effects for entire communities. Despite obstacles faced by minority students, he stays positive. "I know that long-term it's going to be better—that these students are going to make something of themselves and impact society in a positive manner," he says.

In order to introduce high schoolers to engineering, Roche-Maldonado, in collaboration with the UW-Madison student chapters of the National Society of Black Engineers and the Society for Women Engineers, spearheaded a monthly event called the Pre Collegiate Initiative. At the Saturday meetings, students from Madison secondary schools come to campus to learn about each engineering discipline from researchers and industry representatives.

"The program helps introduce students to engineering and also make them feel more comfortable at the university. Even though these kids have lived in Madison their entire lives, many had never set foot on campus," he says.

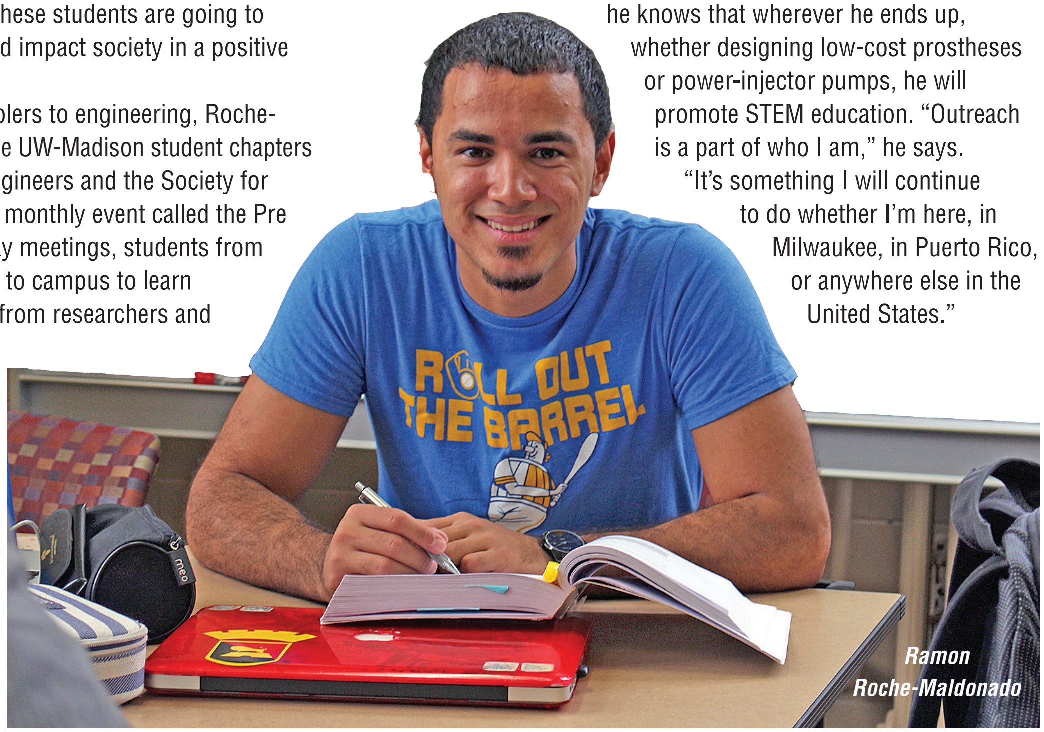
He credits his own passion for engineering to his high school science teacher, who taught classes through the Project Lead the Way program, a national hands-on STEM-instruction initiative. He remains close to his former teacher, returning often to his former school in Milwaukee to encourage students to pursue science.

As a first-generation college student born in Puerto Rico, Roche-Maldonado has personal experience with the obstacles to higher education faced by many minority students. "Initially when I came to campus, freshman year, I felt very much alone," he says.

Additionally, having worked to help his family pay the bills since high school, he felt guilty for leaving his family and not being able to contribute while supporting himself throughout his studies. "Most people don't have to worry about their family struggling," he says. "I send money to my family. I go back to Milwaukee. But sometimes I don't have the weekend to study because I have to go back to Milwaukee and make sure bills are paid."

Organizations such as SHPE, and the LEED Scholars program offered through the college Diversity Affairs Office, helped Roche-Maldonado find a sense of community on campus, and connected him with students facing similar struggles. Support from connections he made in these groups helped him keep up with his rigorous mechanical engineering coursework, while also pursuing multiple internships with Chrysler and Rockwell Automation.

After graduation in 2016, Roche-Maldonado is unsure exactly where his trajectory will take him. However, he knows that wherever he ends up, whether designing low-cost prostheses or power-injector pumps, he will promote STEM education. "Outreach is a part of who I am," he says. "It's something I will continue to do whether I'm here, in Milwaukee, in Puerto Rico, or anywhere else in the United States."



Ramon Roche-Maldonado

Professor Emeritus William Feiereisen

William J. "Bill" Feiereisen, a former professor of mechanical engineering, passed away on May 9, 2015, at the

age of 93 after a year-long battle with cancer. After graduating from UW-Madison in 1942 with a degree in mechanical engineering, he entered the U.S. Navy and World War II as an electronics technician servicing radar technology. He later returned to Madison and joined the mechanical engineering faculty at UW-Madison. Feiereisen rose to the rank of full professor and worked at the university until his retirement in 1994.

READ MORE: go.wisc.edu/feiereisen

College of Engineering
UNIVERSITY OF WISCONSIN–MADISON

Department of Mechanical Engineering
1513 University Ave.
Madison, WI 53706

3D-printed parts could be hot new technology for keeping power plants cool

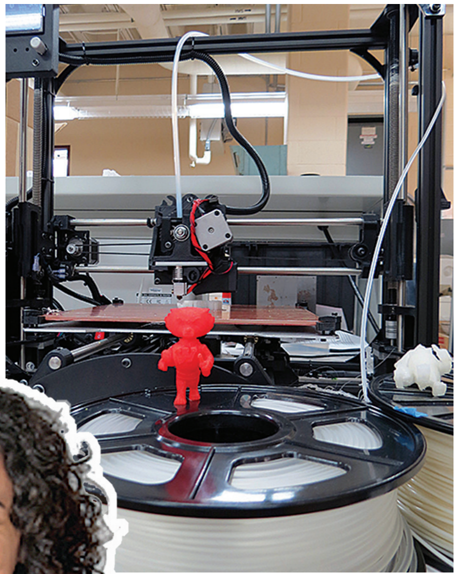
Cooling systems in power plants require heat exchangers to carry low-grade energy away from the inner-workings of the electrical generation machinery—and improvements to heat exchanger technology aim to increase energy efficiency.

Assistant Professor Natalie Rudolph *(pictured)* thinks the answer to some of those improvements begins with 3D-printed parts. Optimizing the geometry of a heat exchanger is one way to increase its efficiency. However, the optimum shape for heat transfer may not be feasible for conventional manufacturing.

This is where 3D printing comes in. It allows designers to create a spectrum of shapes unencumbered by traditional manufacturing restrictions. "3D printing allows us to think a little bit differently," says Rudolph, an expert in polymer engineering and 3D printing who joined the mechanical engineering faculty in fall 2014. "The current generation needs to relearn what is doable with fewer manufacturing restrictions than conventional processes."

In collaboration with colleagues in the College of Engineering, Rudolph is working on producing a prototype heat exchanger using a 3D printing technique called fused deposition modeling. This project is supported by funding from the U.S. Department of Energy ARPA-E program.

Rudolph is excited about the prospect of this project to improve energy efficiency and reduce water consumption in the U.S. Currently, the water used to cool power plants represents the single largest use of fresh water in the country. Technology for air-cooling power plants is currently expensive and less efficient than water cooling. This project has the potential to effect a change, enabling both improvements in efficiency as well as dramatic reduction in fresh water consumption. **READ MORE: go.wisc.edu/rudolph-cool-3d**



A miniature model of Bucky stands atop a spool of the input material from which it was produced, while one of the 3D printers in the UW-Madison Advanced Manufacturing Lab operates in the background.