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The University of Wisconsin-Madison will formally recognize 2012-13 as the Year of Innovation. As the engineering dean at a major research university, I recognize the importance of innovation in moving research discoveries into society to improve our quality of life and the economy.

Innovation is where great ideas and discoveries are put to work for the greater good. In the College of Engineering, we have been effective in this area, generating more than 100 patent disclosures and several licenses each year. We also are creating spinoff companies based on technologies invented by faculty, staff and students.

We asked some of our top innovators to relate their experiences in their own words. Our 2012 annual report features nine students, faculty and alumni who describe their personal stories of innovation. We asked them a common set of questions: What are the components of a great idea? How did the college and its environment support your innovation? Why does it matter to you, to the university and to the world?

No answers were identical, but many common themes emerged. Innovators tend to be driven by the desire to make something better: to solve a problem, improve a process or fill an underserved need. They also frequently cover uncharted territory, and must accept risk and uncertainty as part of the process. They commonly spoke of the need for persistence and commitment, often in the face of initial failures and skepticism from peers. And they gain satisfaction from seeing their ideas implemented and validated by real-world use.

The results can be transformational. We hear from alumni who have started companies built on university-based work, and those companies have enormous potential for Wisconsin’s economy. SHINE Medical, which is making medical isotopes used to diagnose and treat cancer and heart disease, recently announced plans for an $85 million plant to employ 120-plus people in Janesville. And Virent Energy, the producer of fuels made from waste biomass, already has 120-plus employees and is poised to massively scale up operations with a new biorefinery.

But we’ll also see from these vignettes the importance of innovation as a process, a way of thinking and even a way of life. Eric Ronning, the 2012 student winner of the Schoofs Prize for Creativity, was so inspired by the entrepreneurial process that he decided to take an acting class to enhance his presentation skills. And Justin Beck and Chris Meyer, two alumni who recently won Innovation Days prizes, are both firmly entrenched in Madison’s growing entrepreneurial scene.

Equally important is what innovation means to the life of the university and the nature of inquiry. Biomedical Engineering Associate Professor Kristyn Masters describes it as embracing the meandering path. “It’s a mindset that allows you to accept when things supposedly don’t work because everything is part of the larger scheme, the larger process that gets you there,” she says. That path can lead to unexpected advances in the research laboratory as well as the classroom.

Without question, the broadest impact of innovation is taking place in the classroom, where it reaches thousands of future engineers. The college is an established campus leader in technology-enhanced learning. We have captured lecture content online, freeing more classroom time for team learning, student-to-faculty mentoring and technology-infused lesson plans. We have transformed traditional library study space into hubs for interactive learning. And we are working toward redesigning 75 percent of all core courses in a blended format of online and personal instruction. This will give our students the rich learning environments that they are accustomed to and that match the needs of 21st-century engineering.

In everything from the emergence of online learning to the need for new financial models, innovation will define the future of the university. It will also shape the future of engineering as the profession advances the frontiers in energy, sustainability, human health, infrastructure, manufacturing, and security.
UW-Madison is recognizing 2012-13 as the Year of Innovation, offering a chance to reflect on what this concept means to the university and to society. With $136 million in research and more than 100 patent disclosures annually, the College of Engineering has worked to cultivate innovation as standard operating procedure in our classrooms and labs.

The best way to appreciate innovation—what it means, where it comes from and why it matters—is to hear it described directly from our students, alumni and faculty. We chose nine engineers—who also happen to be inventors and entrepreneurs—to tell their stories. Meet these innovators in our 2012 annual report video. Find it on the college playlist at youtube.com/engineeringuw.

Harnessing chemistry for cleaner air and water

Marc Anderson has logged more than three decades of work in developing thin-film materials that have scores of applications for the environment. One of the most promising applications may be AquaMost, a new Madison company specializing in removing pollutants from water.

“All of our technology starts with fundamental nanoscience. We make nanoparticles in suspension for use in beneficial coatings. As an example, we make self-cleaning windows. We make coatings for cleaning up the air and water in the environment. We make coatings for improving batteries, corrosion control and sensors. Our students are actually doing practical things that they can see benefit society. The work causes a great deal of enthusiasm on their part for doing useful and practical things. One of the best things we can do is to let students learn independently and start fiddling around in the laboratory with some of our ideas.

I have about 25 patents through the Wisconsin Alumni Research Foundation, dating back to the early 1990s. I dream about ideas when I sleep. I get ideas when I’m listening to people talk. One friend described me as a popcorn popper without a lid.

One advantage I may have is that I’m a civil and environmental engineer, but I’m also a colloid chemist. So I’m always thinking about somebody’s problems from a different perspective. I think that working in fields where you have little background is actually helpful. You have to accept some level of discomfort; you have to be sort of be an on-the-job learner.”

Connecting millions to online mobile games

PerBlue is a Madison mobile and social gaming company launched in 2010. The 40-employee company is best known for its flagship product, Parallel Kingdom, the first location-based role playing game which now has more than 1 million users. Beck won the 2009 Schoofs Prize for Creativity.

“When we started Parallel Kingdom, the idea of putting a game on a cell phone was kind of new and raw. But the fact that we were going
to put a full role-playing game into a cell phone was way out there. And the fact that we were going to sell virtual goods and make money by selling virtual coins, there were lots of people saying, ‘There’s no way that’s going to work.’

What we realized is if we set a paywall, many new players would just leave the game. So by introducing a currency, we were able to take a less risky approach, because we made it possible for people to pay as much as they wanted but also pay nothing at all.

I think great ideas are synthesized from other roots, like connecting two things from different worlds. And when you connect those two things, you get something new. Ideas are always built off of other ideas, and so I think it’s about piggybacking off of other innovations.

There is pretty much not one day I look back on the decision to start PerBlue that I ever regret it. It has only done magnificent things for my career and my personal development. Once you look at the world through the lens of entrepreneurship, you can really never go back.”

We are very fortunate to have a number of very bright people who want to come to work for Virent, particularly from the University of Wisconsin. Initially, we were collaborating with researchers at the university. Then we started hiring people, including chemical engineers and chemists, electrical engineers, and so we started attracting people to Virent. We have developed kind of a pipeline with the university and are helping young people understand what you can do within an innovative company such as Virent.”

“Before becoming a chemical engineer, I grew up on a farm in Michigan. As Virent has grown, I’ve noticed a lot of commonality with farming. You need to be very self-sufficient. Farmers take risks with things like the weather. Sometimes cash flows aren’t going well and you learn to make do with what you have. When you’re on a farm, when something goes wrong, you fix it. And that’s really the mentality we have here.

Innovation comes from this question of ‘what if?’ When you ask that question, you don’t know the answer. It’s along the lines of pushing boundaries, taking ideas from one industry and combining with ideas from another, bringing them together and saying: Can we make this work?

Replacing crude oil with sustainable alternatives

Cortright is a leader in the field of catalytic processing of biomass-derived feedstocks into chemicals and fuels. He earned his chemical engineering PhD in 1994 from UW-Madison under Professor Jim Dumesic, and holds more than 125 patents and patent applications. Virent is a growing Wisconsin success story, with products ranging from soda bottles to jet fuel. The goal: replacing crude oil with biomass.

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Breaking barriers with technology

After a family accident provided personal perspective on the needs of people with disabilities, Martin changed his research focus to assistive technology. UW-CREATE employs faculty and students to work on community requests for devices that improve everyday life—everything from baby strollers to accessible skis.

“The goal of UW-CREATE is to provide technology to assist individuals with disabilities in being able to live independently and participate in life to the fullest extent possible. This goal will not happen with existing technology. Many assistive technology devices aren’t safe. They are unreliable. They often don’t meet the intended design function.

Our sit-ski technology has brought me the most satisfaction. With the help of Isthmus Engineering, we’ve now built 350 sit skis for cross-country skiing. It’s such an amazing story, because people who were not engaged and not participating in life, had success on the sit-ski and it opened up all sorts of possibilities. There were people who all of a sudden became athletes and started thinking about employment. I think they just started having success, and they were able to do things they couldn’t imagine before.

I don’t think of innovation as a light bulb going off, or suddenly somebody having a brilliant idea. I subscribe to the Edison idea of innovation. If we frame the problem with enough care, and we keep questioning whether we understand it, and we follow a formal, rigorous process, we may end up with something where people say, ‘Wow, that’s innovative.’ The process, if followed with fidelity, is amazing in terms of what it will yield.”

(Continued on next page)
Scaling up the inventor’s garage

Meyer launched Sector 67 in 2010 as a prototyping shop for technology and engineering startups in Madison. His love for innovation was fueled as a mechanical engineer at UW-Madison and as a regular in entrepreneurship competitions.

“When I was a kid, my neighbor had a shop with a car lift and a bunch of tools my brother and I couldn’t afford. We were always bugging him to throw our car up on the lift. And when I went UW-Madison, I realized we have these great research tools all around us, but none of the equipment is readily available. So I wrote up a business plan for Sector 67 and pitched it at the Burrill competition. I had a ton of fun learning about it and thought it was realistic to launch. And sure enough, I took second place and won $7,000, which covered the first couple months of rent.

We have a culture of saying, ‘Nothing’s impossible.’ We’ve probably got resources around here to be able to stick anything together, and it might not work perfect like a professional prototype, but it comes at one-tenth the cost. Almost everything here has been repaired, salvaged or recovered.

We turned a welder into an electric discharge machine the other week, and that’s a $40,000 or $50,000 tool that we built from junk.

Innovation is a slippery word. Some people think of it as a novel thought, and I don’t see it that way. It’s more of taking something that already exists and applying a twist and reinventing it just a bit. All those small improvements stack up to make really novel concepts. I think innovation’s really synonymous with improvement.”

Greg Piefer
CEO, SHINE Medical Technologies
(BSEE ’99, MSEP ’04, PHDep ’06)

Shining a powerful light on disease

Piefer earned his UW-Madison nuclear engineering PhD in 2006 and immediately began putting fusion concepts to work. SHINE seeks to become a world leader in the manufacture of

Creating materials to help wounds heal faster

Masters’ research on cell-material interactions is working toward treatments that can help control cellular behavior to improve patient health. Her research has incorporated biomaterials into the healing process, with applications in heart and blood vessels, tissue engineering and more.

“It’s a very memorable moment for me when my lab switched directions. My lab was really interested in heart valve tissue engineering. We were growing these heart valve cells in the lab, and my student kept coming to me with pictures of the cells. The cells looked really awful. And it was very frustrating because I was thinking, ‘How are we ever going to make these heart valves if we can’t even get the cells to grow right?’

But as we grew diseased heart valve cells really well, we suddenly realized there was a great application for this: We can figure out how the disease is happening in the first place, because that’s not very well understood right now.

This isn’t the only example in my lab of an apparent failure, at first, generating an exciting and successful new project. Academia is great at helping people embrace the meandering path. That mindset allows you to not get as frustrated when things supposedly don’t work because everything is a part of the larger scheme, the larger process that gets you there.

That’s why I value academic research. It’s the foundation for a lot of these innovative ideas that we can then translate into commercial ideas. But ultimately it’s that freedom to do that meandering and go through that cloud that generates so many of these discoveries.”

Kristyn Masters
Associate Professor of Biomedical Engineering

“We don’t have failures here. We have learning experiences.”
—Randy Cortright—

CHRIS MEYER
FOUNDER, SECTOR 67
(BSME ’08, MSME ’10)
Designing healthier components for female cyclists

A fruitful partnership with Wisconsin’s own Trek Bicycle helped Ploeg merge her research with her personal passion for cycling. The result is an influential line of new bike saddles and gloves designed with gender differences in mind.

“The Trek project brings many things together for me. As a female cyclist, I have a lot of interest in making bicycle riding not only more comfortable, but safer for women. So it’s more than just a comfort issue; it’s really a health issue as well.

I think we did make a big impact with this project. The research data got translated very quickly into a product. We basically had a year of research and a year of development, and then the products we designed were in stores. Trek came up with the awesome name of InForm for this series of products, which started with the saddle designs and then expanded to our research on riding gloves.

To me, innovation means more than just a good idea. It means something that actually gets used. I think there are a lot of good ideas, but unless they get applied, the value of the innovation hasn’t been realized.

We work as a group, and innovation comes from all kinds of sources. It can be planned and organized, or very unexpected. And I love being in this type of environment that helps produce these innovations. But I don’t feel like it’s my innovation, or that I’m the innovator and it’s my product. It’s absolutely a collaborative process.”

Eric Ronning
ME SOPHOMORE, 2012 SCHOOFS PRIZE WINNER

Building a low-cost prosthesis for the Third World

With his functional, inexpensive, aesthetically pleasing prosthetic hand, Ronning won the 2012 Schoofs Prize for Creativity. He fabricated the hand on a 3-D polymer printer.

“Low-tech prosthetics are limited to the hook and pincher, claw-like design, and I saw a huge area for improvement. My first prototypes kept on failing; it was hard emotionally and motivationally to keep going. My first proof of concept is kind of dangerous to even hold, because it’s really sharp in certain points, and when I showed it to friends, they thought I was crazy. It looks like the Terminator hand.

But pushing ahead, my fourth prototype worked. It proved to be one of the most rewarding experiences of my life.

Innovation to me is commitment—I think commitment to your idea, because everyone has innovative ideas on a day-to-day basis. But those who are committed to seeing them through are the ones who you hear about, such as Edison or Steve Jobs. The most influential ideas that have shaped our world seem to be some of the more simple ones, for instance, the printing press or the wheel, architectural arches and the assembly line.

There are an estimated 200,000 new amputees in Haiti after the earthquake. Being an amputee in Haiti is different than being an amputee, say, in the States. In Haiti, you can almost be treated as subhuman, because the physical ability to get water or get food every day is so vital to life. My innovation helps with this problem, by giving the functionality that the amputee needs, but also the aesthetics.”
Although he grew up on a dairy farm in a tiny, central-Wisconsin community—rather than a small coal-mining town in West Virginia—Dennis Bahr sees elements of his childhood in the movie *October Sky*, a film based on the true story of Homer Hickam, a coal-miner’s son who ultimately became a NASA engineer.

Hickam’s passion was rocketry; Bahr focused heavily on electronics and medicine. While Hickam’s coal-miner father opposed his dream, Bahr’s dairy-farmer father encouraged Bahr and his brother to leave the farm. “We never even joined Future Farmers of America in school,” says Bahr. “We took math, physics, everything else that we could, and I think it came from Dad.”

In school, both Hickam and Bahr reached for the proverbial stars, thanks to the encouragement of a female science teacher. “Her attitude was, ‘You’ve got to live up to your potential,’” says Bahr.

Today a biomedical innovator and an entrepreneur who has founded or co-founded several companies, Bahr certainly has lots of potential. Ideas for new products or improvements on existing products constantly are swirling through his head, and when he speaks, it’s with the wisdom and foresight of a widely read, highly educated, savvy guy who can identify “the next big thing” almost before there’s a need for that thing.

After earning bachelor’s (’68) and master’s (’72) degrees from UW-Madison in electrical and computer engineering—and securing his status as an ABD (all but dissertation) in the same field—Bahr took a job as an engineer at Nicolet Instrumentation (now Thermo Fisher Scientific) in Madison.

There, supervisor and now longtime friend Alan Kahn once called Bahr the worst employee he ever had—but not because Bahr performed subpar work. “I was always off onto something new instead of doing what the company wanted me to do,” laughs Bahr. “It’d always come up with new ideas and want to work on them. I finally realized that’s me. I can’t do an 8 to 5 job. That would drive me crazy.”

So Bahr left Nicolet to do the work he still considers a hobby: Quite simply, he invents stuff.

Among his inventions are pulse oximeters, advanced blood-pressure monitors, vital signs monitors, an intracranial pressure monitor, and a generator for cardiac ablation. He holds 13 patents, wrote a book chapter, and has published in a wide variety of scientific journals. He has tested products on himself in his laboratory and on patients in operating rooms. “We’d always target the market—not go out and invent something and say, ‘Now what do I do with it?’” he says.

For the past several years, he has collaborated with Biomedical Engineering Professor Emeritus John Webster and colleagues in the University of California, San Francisco, Women’s Health Clinical Research Center on a National Institutes of Health-funded project to develop a device that accurately measures hot flashes in women.

And in the process of researching and refining the device, Bahr earned his PhD in biomedical engineering from UW-Madison in 2012—a full 40 years after he earned his master’s degree.

Worn on the sternum, the ingenious hot flash monitor capitalizes on hydrogel technology to adhere to a woman’s skin without trapping sweat beneath it. Within a three-day period—which provides doctors enough data to identify and regulate treatments—the device can identify 90 percent of a woman’s hot flashes.

Bahr also wrote the algorithms and software that help doctors make sense of data from the hot flash monitors. Now, Middleton, Wisconsin-based Simplex Scientific will make and sell them, and Bahr has moved on to the next big thing.

This time, it’s nuclear engineering, and Bahr is working with several longtime collaborators to perfect a new inexpensive “desktop” deuteron accelerator, a device that has applications in national security and in making radioisotopes used worldwide in tens of millions of diagnostic medical procedures annually. “I’ve thought about this, and I’ve always wanted to build something like this,” says Bahr. “I read in *Scientific American* or somewhere about the molybdenum shortage and realized we could build an accelerator that could do things that nobody else could.”

For now, Bahr and collaborators Richard Schmidt and John Peterson are self-funding their project, and as with his prior inventions, he’s following his recipe for success. “One, you have to have an idea that’s really needed out there. Second, you have to build a good team,” he says. “Thirdly, attack the possible ‘show-stoppers’ first and make sure they can be resolved.”

Then there’s that one critical ingredient—the seasoning with which Bahr spices each of his endeavors—wrapped up in a piece of sage advice: “When you get a job initially out of school, don’t do it for the money. Do it for the fun—for something you’re really interested in,” he says. “That’s one thing I’ve learned about life. Life is not money. Life is fun.”

And Bahr is not about to retire from fun.
WORKING TO BE DISCOVERED

Co-ops help company find ‘rock stars’

At his first College of Engineering career fair in 2008, Scott Walhovd (CBE ’11) encountered an unusual sight: a corporate booth with no waiting line of hopeful students. The sophomore engineer made a beeline to the open booth and laid the groundwork for his first big work experience, an eight-month co-op.

The company happened to be Bemis Company of Neenah, a name that Walhovd didn’t recognize then. His timing was fortuitous: Walhovd happened upon not only a co-op, but a long-term professional home with a Fortune 500 company.

“The co-op experience was phenomenal,” says Walhovd, who has worked full-time with Bemis since August 2011. “Bemis supplies you with great mentors. They give you as much direction as you need, but they really let you run free.”

Assigned to the packaging company’s specialty films facility, Walhovd would soon be working directly with an outside vendor to improve Bemis’ label printing presses. He played a lead role in acquiring the equipment and implementing it in the production line.

“Working on the floor, I found a lot of job satisfaction,” he says. “Our job as process engineers is to make the operators’ lives easier by making their machines run better. When they come up and thank you for it, it’s a reward unto itself.”

In the typical arc of an engineering career, one would expect a big leap between “first job” and “ideal job.” But co-ops take some of the guesswork out of the employment matchmaking by giving students in-depth, full-time experience, while offering companies an extended look at the talent.

For Bemis, co-ops have become a major strategic focus for hiring. The company will have as many as 30 co-op hires a year from multiple universities working across 10 U.S. facilities, and some of the best get invited for second terms. About 40 percent of Bemis’ entry-level engineering hires annually come from co-ops.

“That’s one of the goals of the program, creating kind of an eight-month interview process,” says Tyler Polson, Bemis on-campus recruiter. “Our hope is not to be recruiting for full-time employees outside of the co-ops who have already worked for us. That would be the perfect scenario.”

Polson says he looks for students who can build rapport quickly, ask intelligent questions and have an affinity for hands-on work in the plants. These students often team up with operators who have decades of experience. “The ones who really thrive are the ones who have a very down-to-earth personality and have a lot of respect for the operators,” he says.

Greg Vandenlangenberg, Bemis vice president of engineering, says co-ops have become an integral part of his 45-member team, which executes the Bemis capital plan and designs and installs equipment across 16 North American plants. Most of these projects have a six-month installation phase, making it a perfect time to plug in co-ops.

“At our company, we really try to push the envelope of the technology that’s out there,” he says. “They get to play with a lot of new toys.”

Vandenlangenberg says his project engineering division has become an employee feeder across the whole company. Co-ops get self-directed, problem-solving challenges in safety, maintenance, resizing and adapting machines, and major installations, giving them a lot of versatility.

“We’re a materials science company and we win or lose by innovating in that area,” he says. “We want to find the rock stars who will help us succeed long-term.”

Ben Weight (ECE ’11), also a Bemis co-op veteran and current employee, says the hands-on floor work really separates the Bemis experience from other co-ops. Weight likes to take on projects that “surprise” people by coaxing machines to do things far beyond their original design.

“One of the cooler parts of Bemis is we take a vendor’s machine and modify it in multiple, multiple ways to make it do what we want,” he says. “We get the most out of everything we have.”

Weight says his co-op also greatly changed his outlook on academics.

“I remember learning things in school that I thought I would never use in a million years in the real world,” he says. “And it came up within weeks at the plant.”

—By Brian Mattmiller
Active, engaging education.

Anywhere.

And right here.
In every building on the College of Engineering campus, there are classrooms and lecture halls packed with students listening to lectures. Yet, increasingly, that very traditional way of learning is not the only way UW-Madison engineering students are learning.

“The 50-minute lecture is one of the most inefficient methods for human learning to occur,” says John Booske, the Duane H. and Dorothy M. Bluemke professor of electrical and computer engineering. “Permanent memory is—for most of us—limitless, but it all has to go through working memory, which is a very limited cache process. We process knowledge best in chunks.”

And the College of Engineering is paying attention, drawing on a suite of hands-on, collaborative, cultural and technological tools to meet the educational needs and expectations of today’s students—the “digital natives.”

At the same time, it is preparing well-rounded engineers who can think innovatively and take the lead in solving some of the world’s largest problems.

Driving forces

The demand for multidisciplinary, multi-mode learning continues to rise among today’s students, and satisfying it while offering complementary world-class hands-on student experiences is a matter of staying globally competitive. “In order to prepare the next generation of engineers, we need to teach them in a way that represents the world they’ll be living and working in,” says College of Engineering Dean Paul Peercy.

The nature of that world is wired, mobile and immediate. According to Pew Internet and American Life Project reports, undergraduate student technology and Internet use is virtually ubiquitous: 98 percent of students use the Internet frequently, 93 percent have high-speed Internet connections, 92 percent connect wirelessly to the Internet, while 63 percent use their smartphone to connect to the Internet.

As to how all that connectivity figures into campus life, University of Washington researchers interviewed 560 students at 11 campus libraries and learned that technology is key in student learning habits. They use Facebook to arrange study groups, smartphones to capture lectures for repeated listening, and YouTube tutorials as references for solving difficult problem sets. Electronic course materials—both official and unofficial—factor heavily into their learning processes. “I am no longer bound by what the professor gives me in a class, and his perspective on something,” said one student quoted in the study. “There are lots of engineering forums that I can just Google.”
The College of Engineering is taking a more strategic approach to providing high-value electronic content. Here, this educational culture change has foundations in Engineering Beyond Boundaries, a college initiative begun in 2005 in large part to address factors—including technology acceleration and the fusion of disciplines, global competition in education, and shifts in funding for sustaining higher education—in our rapidly changing world. Its goal is to adopt approaches that move education and research beyond disciplinary, cultural and technological boundaries.

Under the initiative, the college has funded nearly 50 innovative projects—among them a course that combines biology and engineering, new tools for teaching statics, video lectures on the core principles of design, a certificate program in sustainability, and a certificate that blends engineering and the arts.

However, as effective as the projects were, their impact largely was limited to a single course here and there, says Steve Cramer, College of Engineering associate dean for academic affairs and a professor of civil and environmental engineering. “If we were really going to change how engineering is taught at Wisconsin, it couldn’t just be in a brand new, ‘one-off’ elective course,” he says. “It had to hit the core of our courses, and it had to be implemented in a sustainable way.”

Thus, the college Academic Planning Council, with encouragement from the college Industrial Advisory Board, set a new strategic directive: moving 75 percent of engineering core courses to a new “blended learning” model that leverages video-captured lectures and web-based course management tools to enhance in-class instruction.

It’s an ambitious goal that aims to use college-wide technology-support services to help instructors replicate prior successes in technology-enhanced courses.

**Time well spent**

In the College of Engineering, Wendt Commons—a recent merger of the Engineering Learning Center, Wendt Library and Engineering Media Services—offers instructors not only pedagogical insight, but also technological expertise that ranges from video lecture capture services to support for web-based teaching software.

Greg Moses was among those who, early on, recognized the potential of blended learning approaches. “There’s a pathological fear that student performance will worsen if you don’t lecture to them,” says Moses, the Harvey D. Spangler professor of engineering physics and a blended learning pioneer. “But there’s no evidence of that.”

In fact, online video lectures enable instructors to improve and increase their one-on-one time with students. It’s a model Moses—who with researcher Mike Litzkow developed the eTEACH web multimedia delivery tool—has followed for more than a decade.

On their own time and at their own pace, students can watch online lectures to learn basic facts, then come to class prepared to ask questions, discuss concepts, and participate in group problem-solving exercises.

Shifting lectures online also allows instructors to do more with fewer resources. Hussain Bahia, a professor of civil and environmental
engineering, used on-demand video lecture modules and lab tutorials
to transform a high-demand civil and environmental engineering
course without sacrificing student-instructor “face time.” And Dan
Klingenberg, a professor of chemical and biological engineering,
and colleagues consolidated three distinct fluid mechanics courses
into a single multidisciplinary course by breaking lectures into
topics, rather than 50-minute chunks. Now, instead of lecturing each
week, professors attend discussions in which students apply general
concepts from lectures to their particular engineering discipline.

As in the fluid mechanics course, online lectures also afford
instructors like Booske the flexibility to spend in-class time helping
students apply course concepts. “I walk around the classroom as
a coach,” he says. “I keep them on task, using more of a Socratic
method—rather than telling them the answers.”

Hands-on connections
Technology-aided instruction isn’t limited to web-based learning.
Seeing an opportunity to improve the experience for his introductory
lab courses, Electrical and Computer Engineering Associate Faculty
Associate Mark Allie moved his students from traditional lab work
to Mobile Studio, a portable lab kit that originated in 2007 with
Rensselaer Polytechnic Institute Professor and electrical and
computer engineering alumnus Ken Connor. When paired with a
laptop, Mobile Studio can simulate all the equipment Allie’s students
need for basic experiments with current, voltage and frequency.
“Students can do everything with just the Mobile Studio board, with
minor exceptions,” he says. “We’re reinforcing concepts from lecture,
so we can easily cover the material with a USB-based device.”
And, Mobile Studio lab kits are inexpensive and portable, giving
students independent access to lab tools, encouraging them to learn
at their own pace, and even allowing them to creatively experiment
on their own time.

Rethinking the classroom
Housed jointly on the fourth floor of Wendt Commons and in space
across campus in College Library, the Wisconsin Collaboratory for
Enhanced Learning Center, or WisCEL, offers a more sophisticated
suite of technological tools, including wall-mounted video monitors
and circular clusters of workstations that hold laptops for each
student. During the day, instructors use those spaces as flexible,
collaborative classrooms that make teaching more spontaneous
and personal than a traditional lecture hall.

Flexible spaces like WisCEL also allow instructors to rethink every
aspect of conventional teaching—including something as basic as
office hours—to offer students experiences that better suit their
needs as developing engineers.

Engineering Physics Associate Professor Robert Witt, who teaches
statics—a course among the toughest undergrad engineering
courses—began holding office hours in WisCEL. “Other students were
always there, so we could help each other out or listen to the answer
of another student’s questions,” says Melissa Markquart, a civil and
environmental engineering senior who took Witt’s spring 2012 course.

In fact, the students who traditionally would have lined up for
help outside Witt’s office often spontaneously morphed into a unique
“breakout” study session. And the collaborative space also encouraged
students to be inquisitive and engage with their instructor. “Asking
questions during lecture can be intimidating,” says Markquart.

“Professor Witt’s willingness to do his office hours this way signaled
to me that he cared about the students and our learning.”

Whether they occur in a flexible technology-rich study space, in
a blended course or through other innovative teaching approaches,
experiences like Markquart’s enhance the relationship students have
with their instructors, engage them in the material, and ultimately,
better prepare them to thrive in a global economy.

“No only do technology-enhanced learning experiences enable
us to use our limited resources more efficiently, but we also are able
to reach students in a way that is meaningful to them,” says Peercy.

“By creatively adapting our educational delivery methods, we are
demonstrating to students the emphasis we place on providing
them a high-quality, high-value educational experience. And they
will graduate from UW-Madison knowing they have the skills and
knowledge to make a difference today—and in the future.”
Understanding how a cell makes a decision in response to a drug or stimuli—to grow, to move, or to die—could give doctors richer insight into why, in many cases, different therapies work for different patients. The key to understanding how cells make these decisions may lie within the network of proteins inside those cells.

Using individual protein markers to determine the best treatment for patients isn’t a new idea; however, a single protein is just a small part of the network of active proteins in a cell. Instead, Assistant Professor Pamela Kreeger and her students track how multiple proteins interact with one another as well as their relative balances to one another, creating a picture of what protein messaging looks like within the cells of a given patient.

Knowing what the protein network looks like in the cells of a patient who responds to a therapy could help doctors determine the best therapy for newly diagnosed patients. For example, in ovarian cancer patients, who generally are diagnosed very late, quickly identifying the best therapy could drastically improve patients’ odds of survival.

A model that explains the differences among ovarian cancer patients also could help explain why a drug mired in the trial process isn’t working as expected. “Our hope is that our models could potentially rescue a drug from trial by figuring out why one group of patients responded and not another,” says Kreeger.

Kreeger also is using this approach to understand conditions beyond ovarian cancer—for example, understanding how cells make decisions in wound healing could help researchers develop better bandage materials, or help identify therapies for endometriosis, a condition in which the uterine lining grows outside the uterus.

In addition to working to understand the decision making within cells, Kreeger gives undergraduate students a chance to explore a career in research by offering them posts as researchers in each of her lab’s projects. “I think some undergrad classes, especially the early ones, can seem so disconnected from what they want to do as engineers,” says Kreeger. “I think it’s useful for them to see that your intro biology and chemistry are really giving you tools that you’re going to use long term.”
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Spotting ovarian cancer, before it’s too late

At just 28 percent, the five-year survival rate for women diagnosed with ovarian cancer is much lower than in other cancer cases. And, the disease can easily go unnoticed, making it difficult to find effective treatments. “There are very few symptoms associated with ovarian cancer,” says Associate Professor Paul Campagnola. “When it gets detected, it’s usually too late.”

While his colleagues work to find the most efficient therapies for patients in the later stages of the disease, Campagnola and his students are using more nuanced analysis of tissue imaging to diagnose ovarian and breast cancer earlier. Understanding what tissue changes preclude the development of certain cancers could help doctors diagnose ovarian cancer earlier and give patients a wider window in which to seek treatment. “We’re trying to develop a physical and biochemical understanding of the changes that happen as cancer develops,” says Campagnola.

The key lies in understanding the extracellular matrix (ECM), the tissue made up of collagen and elastin that essentially holds the body together. The ECM supports all organs, including the skin.

“It’s increasingly recognized that there are changes in the collagen—particularly in the extracellular matrix—that accompany almost all cancers,” says Campagnola. “Almost all cancers are epithelial—that’s the top layer of cells—but they interact with the tissue below it.”

Modeling how cancers can dictate the types and concentration of different collagens in the ECM nearby, Campagnola hopes to identify less common “collagen isoforms” as markers that could be used to screen women at risk for ovarian cancer regularly, improving their odds of an early diagnosis.

Campagnola and his students are developing a combination of optics and imaging techniques that could improve the odds an ovarian cancer patient has at survival. And they are imaging different mixtures of known collagen types with a variety of techniques to see if they can differentiate between normal and abnormal ECM structure. That, says Campagnola, is key to an accurate diagnosis.

The language of stem cells, decoded

Stem cells are biological building blocks, the starting point of human life. But without proper direction, they’re not very useful when it comes to treating disease. “If we just take stem cells and inject them into you, they will simply become a cancerous tumor,” says Assistant Professor Randy Ashton.

Working in the Wisconsin Institutes for Discovery, Ashton is seeking to instruct the development of human stem cells in the lab by using the molecules cells already use to communicate with one another. “We are trying to understand how particular tissues arise in development,” says Ashton. “Then, using human pluripotent stem cells, we can replicate the signals that allow those structures to develop in order to create tissues that would be therapeutic for different degenerative diseases and disorders.”

For several years, Ashton has worked with two cellular communication molecules—sonic hedgehog and ephrin ligands—that factor into how a stem cell determines which blueprint to work from when it is differentiating into a specific cell type. “Basically, a stem cell can ‘sense’ what’s in its environment, and then it makes a decision to determine whether it’s going to become a muscle cell or a brain cell,” says Ashton.

Using recombinant “mimic” forms of each molecule to instruct the stem cells and a biodegradable 3-D scaffold to hold a cluster of cultures together, Ashton has grown increasingly complex tissue structures, specializing in the central nervous system. “Eventually, we want to be able to rationally design a material that mimics the biological cues that would drive the development of your spinal cord, liver or other organs,” says Ashton.

Building organs and complex tissue structures has obvious benefits—transplanted spinal tissues could be useful in treatment for spinal cord injuries and motor neuron diseases, for example—but there are broader applications as well. Deeper understanding of stem cell instruction could yield deeper understanding of the origins of specific diseases. “We can start to understand how a given disease develops as the tissue develops,” says Ashton.
A multidisciplinary perspective on biological systems

For more than a half century, the Petri dish has served as a living laboratory for biologists who intensively studied its contents and advanced our understanding of how microbial and mammalian cells behave.

Now, however, researchers are drawing on knowledge and tools in such diverse areas as genetics, computer science, ecology and engineering to study how those cells and their molecular components work together as a "group," or system—for example, to fight infections or to grow and thrive. "The idea is that biology will be advanced through not just the standard approaches of molecular and cell biology, but increasingly, by drawing on perspectives and methods from the quantitative and physical sciences," says Professor John Yin. "We’re trying to understand the systems—how interactions among the molecular parts define cellular and multicellular behaviors."

In the realm of human health, understanding biological systems is key to discovering why people get sick, how to prevent illness, and how to treat disease. Yin leads the systems biology research theme in the Wisconsin Institute for Discovery at UW-Madison. The theme includes evolutionary systems biology and experimental systems biology. Yin’s group focuses on translating the biology into quantitative, computable, predictable models of how viruses grow and how a viral infection spreads over time and space. Recently, the researchers have studied how fluid flows—such as those in the lung—that efficiently spread and invade new host environments.

In industries such as the petrochemical, pharmaceutical, food and agricultural industries, hydrogen-based chemical reactions have huge applications. "For example, upgrading of oil to gasoline, and in making various biomass-derived products, you need to hydrogenate molecules—to add hydrogen—and all this happens through catalytic transformations," says Paul A. Elfers Professor Manos Mavrikakis. A chemical reaction transforms a set of molecules (the reactants) into another set of molecules (the products), and a catalyst is a substance that accelerates that chemical reaction, while not itself being consumed in the process. How quickly those reactions occur affects how quickly products are produced.

And while scientists long have known that adding trace amounts of water can speed up chemical reactions in which hydrogen is one of the reactants, Mavrikakis and his collaborators recently discovered why. He and Flemming Besenbacher, a professor of physics and astronomy at the University of Aarhus, Denmark, drew on their respective theoretical and experimental expertise to study metal oxides, a class of materials often used as catalysts or catalyst supports. They found that when water is present, hydrogen diffuses rapidly via proton transfer, or proton "hopping," in which hydrogen atoms from the oxide surface "jump" onto nearby water molecules and make hydronium ions, which then deliver their extra proton back to the oxide surface (at a different position than the hydrogen started on that surface) and liberate a water molecule. In fact, at room temperature, water makes hydrogen diffuse 10,000 trillion times faster on metal oxides than it would have diffused without water. In the absence of water, heat is needed to speed up that motion.

The process works in the hydrogenated surface area: The team saw that, on a nanoscale "path" on iron oxide templated with hydrogen atoms, water found the path, stayed on it, and kept moving within its boundaries.

The UW-Madison researchers—including chemical and biological engineering research scientist Guowen Peng, PhD student Carrie Farberow, and PhD alumnus Lars Grabow (now an assistant professor at the University of Houston)—received funding from the U.S. Department of Energy Office of Basic Energy Sciences.
Building blocks of the blood-brain barrier

For the first time ever, researchers have coaxed both embryonic and induced pluripotent stem cells to form the endothelial cells of the blood-brain barrier—an advance that may unlock some of the most closely guarded secrets of this virtually impenetrable wall.

The blood-brain barrier, which separates circulating blood from the fluid that bathes the brain, depends on the unique qualities of endothelial cells, the cells that make up the lining of blood vessels. In many parts of the body, these cells are spaced so that substances can pass through. But in the capillaries that lead to the brain, endothelial cells nestle tightly, creating a semi-permeable barrier that allows essential nutrients and metabolites into the brain while keeping pathogens, harmful chemicals—and many therapeutic drugs—locked out.

The new cells exhibit both the active and passive regulatory qualities of those cells that make up the capillaries of the intact brain.

The use of induced cells, which can come from patients with specific neurological conditions, may be especially important for modeling disorders that compromise the blood-brain barrier. Additionally, because the cells can be mass-produced, they could be used to devise high-throughput screens for molecules that may have therapeutic value for neurological conditions or to identify existing drugs that may have neurotoxic qualities. They also could help developmental biologists learn more about how the barrier co-develops with the brain, because neurons develop at the same time as the endothelial cells.

The team, including Professor Eric Shusta (center), Professor Sean Palecek (right), Ethan S. Lippmann (left; now a postdoctoral fellow at the Wisconsin Institute for Discovery) and Samira M. Azarin (now a postdoctoral fellow at Northwestern University), published its findings in the June 24, 2012, edition of the journal Nature Biotechnology.

The National Institutes of Health and the National Science Foundation supported the research.
About Yosemite National Park, the famous naturalist and conservationist John Muir once said: “It is by far the grandest of all the special temples of Nature I was ever permitted to enter.”

With majestic granite cliffs, waterfalls, clear streams, giant sequoia groves and a wealth of biological diversity, this 1,169-square-mile wilderness boasts a rich natural and cultural history. It attracts more than 3.5 million visitors annually and hosts hundreds of researchers who, in the interest in preserving the park’s history and biodiversity, study everything from its archaeology to hydroecology.

Associate Professor Steven Loheide is among those researchers. With colleague Jessica Lundquist of the University of Washington and former postdoctoral researcher Chris Lowry, Loheide began conducting research in Yosemite in 2007 on a National Science Foundation-funded project focused on restoring mountain meadows in a changing climate.

Now in the second phase of that project, Loheide, master’s student Kyle Ankenbauer (below) and former postdoctoral researcher Chris Lowry received funding from the National Park Service to collaborate with Colorado State University ecologist David Cooper and the Yosemite hydrologist Jim Roche and restoration ecologist Sue Beatty on a study of how the park’s expansive Tuolumne Meadows has degraded over time.

Stream health is key to the study: Wide or deeply incised stream channels both cause a drop in water levels in the stream, which then causes a drop in the water table within the meadow, making it more difficult for native plants to access the groundwater they need to thrive in the dry Sierra Nevada summers.

In an effort to understand the mechanisms that maintain Tuolumne Meadows in a degraded state and make it difficult to restore, the researchers are focusing on the extent to which deer feeding reduces the willow population along stream banks and how willows along those banks affect sediment deposition. They also are studying how a drop in the water table over time affects soil moisture and the soil’s ability to retain the moisture necessary to support native wet meadow vegetation.

The researchers’ goal is to develop a broadly applicable modeling framework that links ecological and hydrological models and provides a scientific basis for conversations about whether to undertake a restoration project and how to design it.

In Yosemite meadow, study could spark conversation about restoration
Digging into energy from the earth

Drawing on data gathered from a heavily instrumented Adams County, Wisconsin, home, Assistant Professor James Tinjum is seeking to provide scientific support for a deep insulated single-hole (DISH) geothermal heat pump system, a novel heating and cooling method that capitalizes on heat stored in geological structures deep underground.

However, the Adams County DISH system employs a single, 1,400-foot-deep well, installed with funding from the UW-Madison Innovation & Economic Development Research Program. There, Tinjum, Associate Professor Dante Fratta, Geology Professor David Hart and their industry partners are studying whether higher temperatures at that depth will make the entire system more efficient, and in the long run, more cost-effective and environmentally friendly.

Because even “green” technologies use materials and non-renewable energy resources to manufacture and install—and in some cases, operate—the researchers also are conducting a life-cycle assessment. “This will be one of the first instrumented deep-well projects that will supply life-cycle science to the practice,” says Tinjum.

In addition, to further inform the science underlying geothermal heat pump system choices and to fill the Wisconsin-sized hole in national geothermal gradient maps, the team has drilled and instrumented six 1,000-foot-deep wells in strategic locations around Wisconsin.

Nine students—funded through a three-year National Science Foundation research experience for undergraduates grant in energy geotechnics—are actively participating in all aspects of the research, from field analyses to the life-cycle assessment. Tinjum, who shares his appointment with the Department of Engineering Professional Development, also will incorporate the research results into short courses for professional engineers.

When Assistant Professor Matthew Ginder-Vogel joined UW-Madison in spring 2012, he added yet another dimension to the university’s renowned interdisciplinary group of faculty in environmental chemistry. This broad group includes a dozen or so faculty experts in environmental technology, and aquatic, terrestrial and air pollution chemistry.

Ginder-Vogel focuses on redox-active environments, or those in which chemical reactions cause an increase or decrease in oxidation state, to study processes that control the dynamics of nutrients and contaminants in environments like wetlands, estuaries and lake bottoms. “Most universities have one or two faculty members in environmental chemistry,” he says. “Here, I can focus on what I do best and collaborate with people who complement what I do.”

Drawing on a combination of field- and lab-based experiments and state-of-the-art microscopy and spectroscopy, his research has broad global—as well as local—applications. For example, he could study how to anticipate or control arsenic or chromium contamination of wells or waterways, assess the efficacy of stormwater retention ponds designed to mitigate nitrogen and phosphorus runoff into lakes and streams, or determine whether plutonium or uranium at a nuclear storage site will remain fixed or need to be removed.

In addition to an educational background that includes chemistry, geological and environmental sciences, and plant and soil sciences, Ginder-Vogel also worked as an environmental chemist at Los Alamos National Laboratory. Most recently, he led the analytical and pilot cement plant teams at Calera Corporation, a California startup that focuses on reducing carbon dioxide in the environment by capturing it from industrial plants and converting it to carbonate cements and concrete.

Although the challenges he tackles and the solutions he develops can be extremely complex, Ginder-Vogel’s research, ultimately, is relevant to everyone. “The common theme is applying environmental chemistry to determine and control what ends up in our water, sediment and soils,” he says.
A quasi-optical internet backbone

Trunks of fiber optic cable make up most of the Internet’s backhaul—the network that links smaller networks across the globe together into the World Wide Web. But installing fiber between remote locations can get expensive. Professor Akbar Sayeed (left) and Assistant Professor Nader Behdad (right) have developed a new communication architecture that could offer those same connection speeds wirelessly, employing an improved form of multiple-input and multiple-output communications (MIMO) technology.

Similar to how fiber optics pack thousands of data streams into a single cable, high-frequency MIMO communications can pack more wireless data streams into a single antenna array by arranging them in tightly packed beams, a concept pioneered by Sayeed’s research group. While the core concept has been around since the early 2000s, Sayeed observed that conventional MIMO systems running at millimeter-wave frequencies left a lot to be desired—most designs either contained inefficient gaps between antennas, or an efficient but prohibitively complex array containing thousands of antenna elements. “I thought we could do better than that,” says Sayeed.

Leveraging Behdad’s antenna expertise, the pair of researchers have developed a system that uses a lens array to steer data-bearing beams quasi-optically, rather than depending on hardware and software to direct them. That significantly decreases the computational and hardware complexity required to transmit data at very high frequencies.

Steering high-frequency beams with lens antennas also allows for more active beams per array, meaning more users, and more importantly, more data. “Current systems run below five gigahertz,” says Sayeed. “This system runs at 10 to 20 times higher frequencies, with much more bandwidth.”

The Wisconsin Alumni Research Foundation is helping Sayeed and Behdad realize the technology as a commercial product through its accelerator program. The technology eventually could be used in mobile broadband networks, but for now, the most logical market for the system is in the backhaul, where it could bring the speed of fiber to areas too remote to lay cable. “Rather than digging and putting fiber in, you could have a couple of towers with these millimeter wave systems,” says Sayeed.
For morning bus commuters, a reliable Internet connection can transform dead time in traffic into a jump on the day’s tasks. But between their high cost and low data caps, smartphone data plans are a less than ideal solution for riders hoping to get serious work done in transit.

Associate Professor Suman Banerjee (also computer sciences) thinks bus passengers can get that bandwidth via new wireless systems that tap into TV whitespace—the underused portions of broadcast space normally reserved for television and wireless microphones.

With funding from the National Science Foundation, Banerjee and Professor Parmesh Ramanathan are refining network hardware that can detect unused portions of the TV spectrum, tune to the open frequency using precise software radios, and transmit between towers and access points on the bus. The two hope to have the hardware in place on Madison Metro buses in fall 2012.

TV whitespace doesn’t have the associated spectrum costs of other wireless data communications, and a network using it can cover more geographic area with fewer towers.

“For morning bus commuters, a reliable Internet connection can transform dead time in traffic into a jump on the day’s tasks. But between their high cost and low data caps, smartphone data plans are a less than ideal solution for riders hoping to get serious work done in transit.”

While the potential for the technology is tremendous, building a network with real hardware will be critical to understanding how city-sized wireless networks should be designed and managed. And though mainstream adoption of TV whitespace for data communications might take years, Banerjee says the Madison Metro project is an important first step. “It’s potentially a big revolution in the wireless industry because it opens up spectrum in a new way,” he says. “It can lead to very innovative solutions in the future.”

For travelers aboard high-speed passenger trains aren’t fond of being flung across the train car each time it rounds a corner, so the cars come equipped with tilting suspension systems that allow them to lean into each turn to compensate for centripetal force. As passenger trains get faster and faster, demand for more adaptive, reliable suspension systems will continue to rise. And by Associate Professor Paul Milenkovic’s calculations, the future of tilting suspension systems—or adaptive suspension systems in general, even for cars and trucks—may be more rooted in the theorems of the past than in high-tech robotics.

Studying the work of 18th- and 19th-century mathematicians and astronomers like Sir Robert Ball, Julius Plücker and Michel Chasles, Milenkovic has simplified their complicated calculations in order to apply them more easily to systems using mechanical linkages—any series of connected parts with a defined range of motion—to control how a vehicle moves. “There’s still a role for a kind of automation which is a result of geometric arrangements of linkages, rather than programming of a computer,” says Milenkovic.

The result could be simpler, more efficient suspension systems for myriad vehicles.

By improving what vehicle engineers can predict and design for mathematically, Milenkovic believes his research could improve the performance of passive tilting suspensions—like those found in Talgo trains or the UAC Turbotrain—to the point that they could match the speed and performance found in active suspension systems that require control from servo-guided robotics. “Something that is done passively has potentially lower costs and lower maintenance, since you don’t have to see if the system has lost power or its hydraulic seals,” he says.

Beyond the rails, Milenkovic’s work has implications for any system that controls motion through a series of linkages, which could range from consumer autos to military vehicles like tanks. More precisely designed and controlled vehicle suspensions could enable vehicles that are more power efficient and cost effective to produce, but remain extremely safe.
Scanning the sky: Lasers monitor wind turbine blade health

Thousands of wind turbines across the United States generate an estimated 48,000 megawatts of cumulative power. Blades on these massive systems can reach 50 yards in length and represent one of the biggest maintenance challenges to keeping turbines under power.

“These turbines are interesting machines because they are so large, they are quite flexible and really are running within fairly fine tolerances,” says Assistant Professor Matt Allen. “There is a range of speed that they can operate in. If you go beyond that speed then you’re likely to get failure very quickly. In a high wind, they reach overspeed and can explode.”

Operators monitor data on performance and power output and inspect turbines that underperform. This might include visual inspection with binoculars, climbing the rigs or in the worst case, using a crane to take the system apart. Testing blades with sensors involves stopping the system, climbing it, mounting a sensor, climbing down and devising a telemetry system to send data.

“The problem with wind turbines is that the vibrations are so slow that you’re talking about hours for each test. It can take days or weeks to get an idea of how forces are affecting the blades,” says Allen.

He has devised a system that uses a laser to collect data over the whole length of a blade, quickly giving operators critical information— from the ground—about the stress a blade can withstand.

“Rather than leave the laser fixed, we have it quickly sweeping back and forth relative to how fast the blade is vibrating, so it’s almost like a barcode scanner,” says Allen. “We have a new theory for what to do with those measurements and how to understand it. In the end, it gives an operator an understanding of how the blade is bending in a variety of frequencies.”

The world’s largest stellarator uses external magnetic coils to generate fields that can contain the extreme conditions required to fuse nuclei. The Large Helical Device (LHD) operating in Japan creates a magnetic bottle that can hold hot plasma with the intention of recreating conditions for nuclear fusion akin to those on the sun.

Shaping and controlling these fields is somewhat like analyzing a soap bubble for its weakest spot and creating a solution to keep it afloat.

Professor Chris Hegna analyzes magnetic fields to understand the conditions that cause them to fail. “We generate these magnetic fields externally and what we would like to do is precisely control what they are doing in the confinement region where the plasma exists,” Hegna says. “Since the fields are still in the three-dimensional phase, they are sensitive to small perturbations that give magnetic irregularities in the confinement region and produce things we don’t want.”

The irregularities are small magnetic “islands” that can overlap, creating a path for the hot plasma to escape.

Generally, these islands are something to avoid. However, researchers at LHD intentionally have directed fields to create islands in an effort to study their properties. They found the plasma was able to heal itself. The magnetic islands completely disappeared under the proper conditions, a result that was in sharp contrast to existing theoretical models, which were unable to predict magnetic island healing.

Hegna developed a new theory to explain the phenomena based upon the properties of the plasma flow. His theory was tested experimentally and validated. “If the flow physics is of the right amplitude and the right structure, it can produce enough of a plasma response that it can actually completely offset the magnetic field perturbation generated externally,” Hegna says. “So what happens is the plasma spontaneously cures itself.”
UW nuclear engineering: A 50-year history of excellence

In 1942, in a reactor known as Chicago Pile-1, physicist Enrico Fermi and his team achieved the world’s first sustained nuclear reaction. Three years later, in the final weeks of World War II, the United States exploded two atomic bombs on Hiroshima and Nagasaki, Japan, demonstrating to the world the destructive power of nuclear.

After the war, however, nations around the world focused on developing nuclear energy for peaceful civilian applications, including medicine and generating electricity. Argonne National Laboratory offered to help Big 10 universities develop curricula for their own nuclear engineering educational efforts—and as a result, in 1953 UW-Madison formed an interdisciplinary committee of nationally renowned educators and researchers to set the university’s program in motion. With now-Professor Emeritus Max Carbon as its first chair, the Department of Nuclear Engineering officially formed in 1963.

In 1958, the committee hired Carbon to establish the nuclear engineering bachelor’s, master’s and PhD curricula. He oversaw construction of the university research and training reactor, which achieved initial criticality in early 1961, and recruited and hired top faculty and staff (among them Henry Barschall, Harold Forsen, Bill Vogelsang, Mohamed (Bill) M. El-Wakil and Charlie Maynard), an effort that garnered the program immediate ongoing recognition as among the best in the nation.

Initially, the faculty focused on fission reactor engineering; in the 1970s, they added the emerging research areas of plasma physics and nuclear fusion. “This second area of growth, accompanied by growth in physics and electrical engineering, has made UW-Madison the premier fusion research university internationally,” says Wisconsin Distinguished Professor Michael Corradini, department chair from 2001 to 2011.

By 1980, the number of students enrolled in nuclear engineering at all degree levels exceeded 200. In 1995, recognizing common research and educational threads, the nuclear engineering and engineering mechanics (which this year marks its 125th anniversary) programs merged and the Department of Engineering Physics was born. In the 1980s and 2000s, several “rising stars” joined the faculty, further solidifying each program’s high national ranking.

It’s success that’s rooted in the people who, for more than a half century, have worked to improve and innovate nuclear engineering research and education at UW-Madison. “And as a result,” says Corradini, “our graduates now are national and international leaders in virtually every aspect of the field.”
Through an ongoing partnership with the Johnson Controls North America building efficiency business, Faculty Associate Carl Vieth (left) and Faculty Associate Thomas Smith have created a benchmarking tool called a competency model that will enable the business to make more informed, strategic talent-management decisions.

Headquartered in Milwaukee, Wisconsin, the business focuses on delivering products, services and solutions that increase building energy efficiency and lower operating costs. It has an aggressive growth strategy that calls for developing a new corps of energy engineers—however, engineers who have a very specific set of energy skills and knowledge are difficult to find.

To provide Johnson Controls with a clear vision for hiring and training high-performing energy engineers, Smith and Vieth conducted a study of personnel currently working in the building efficiency business analysis and design, construction, and building management specialty areas. Through a variety of interviews, surveys and self reports, the two gathered an array of data from the engineers, as well as from their managers, staff in the Johnson Controls home and field offices, and Johnson Controls customers.

From the data, Smith and Vieth built and validated a model that defines key skills and attributes of high-performers.

The Johnson Controls North America building efficiency business implemented the model as a tool to help it assess its growth needs, and find, hire, train, evaluate and promote employees. “It’s a cornerstone tool within talent management for human resources activities,” says Vieth, who is EPD director of corporate education.

He and Smith also collaborated with Johnson Controls staff to design a professional development curriculum that helps the building efficiency business meet its goals. Already, the company has slashed training time for new energy engineers from two years to just six months.

The competency model also helps Johnson Controls develop its current workforce—an effort critical to ongoing excellence within the organization, says Don Albinger (right), Johnson Controls vice president of energy engineering and technology. “The Engineering Professional Development team is an important partner in helping us identify the ‘science’ around our employee-development needs,” he says. “This roadmap for recruitment and development is a critical element in delivering energy efficiency and sustainable solutions for our customers around the world.”
Through new online master’s degree, sustainability engineers will add value to industry

Geared toward practicing engineers, the new online Master of Engineering in Sustainable Systems Engineering program prepares students to understand and inspire change within their organization relating to complex systems and their effect on the quality of water, land, air, energy, economics and society. “This degree program will provide engineers with the skills to lead change within their organizations and communities,” says Associate Faculty Associate Marty Gustafson. “The program not only focuses on skills related to leadership of sustainability initiatives, but it recognizes the need for technical specialization in particular fields.”

Students in the program, which begins in January 2013, will focus on the technical aspects of three specializations: energy production and distribution, facilities and built environment, and infrastructure. They will take 24 credits of required and elective courses that cover such topics as industrial ecology sustainability tools; sustainable improvements of complex systems; sustainable sciences, natural resources and conservation; renewable energies; environmental systems modeling and optimization; and change management and environmental decision-making, among others. They also will complete a three-credit sustainability capstone project.

Sustainable systems experts are in high demand in engineering fields. The new master’s program creates opportunities for students to engage in activity-based learning that enables them to explore how sustainability will apply to their professional lives and their interests, says Professor Patrick Eagan. “For engineers, it’s a topic that needs to be explored and a competency that should add value to their career,” he says. “Companies and other institutions seek engineers competent in sustainability practices.”

The new master’s program builds on the strengths of existing UW-Madison online graduate engineering programs, which U.S. News & World Report ranked No. 1 in 2012. The department worked with several units throughout the university, including the Office of Sustainability and the Nelson Institute for Environmental Studies, to design the comprehensive program. “These partnerships are essential to adding value to the program participants and their organizations,” says Eagan.

More: sse.engr.wisc.edu

The International Organization for Standardization (ISO) 9000 standard for quality management, which has now been adopted by more than 1.25 million companies, has had many positive effects on investment, market share, sales growth, sales margins, competitive advantage, and avoidance of litigation. ISO is now preparing ISO 55000, a new standard for asset management. “ISO 55000 has been conceived as a very broad standard, which can affect the management of physical assets in all types of organizations, both public and private,” says Faculty Associate Thomas Smith, a member of the ISO 55000 standards committee and the editor of one of the key sections.

The members of the standards committee represent 37 countries and numerous business areas, from commercial real estate, mining, and manufacturing, to utility systems, large-scale property management and physical infrastructure. This new international standard draws from many of the already existing standards developed by the participating countries, but extends to cover new ground. ISO 55000 specifically requires a life-cycle view of physical assets and places asset management in an organizational strategic context.

Smith says strategic asset management is a complex undertaking and ISO 55000 takes a management systems approach. The standard is written to be compatible with other management systems standards: ISO 14000 for environmental management, ISO 5000 for energy management, and others for safety, security and quality. Many organizations will implement these standards together.

The standard currently is in draft form. After circulation for comment from the 162 ISO member countries, the standard will be officially released in early 2014.

The Department of Engineering Professional Development offers a series of asset management courses that will address this standard and other best practices in asset management.

More: epd.engr.wisc.edu/2012asset

New standards take strategic view of asset management

Committee members hail from around the world.
It’s the stuff of dreams: Better healthcare at home

Tucked away in a deep corner of the Wisconsin Institutes for Discovery Building on the UW-Madison campus, a six-sided room (pictured) called the “CAVE” uses coordinated computer projections to create immersive, virtual-reality world in which virtually anything is possible. “Almost anything we dream, we can actually make,” says Moehlman Bascom Professor Patricia Brennan.

For part of her research, Brennan has created a virtual house—complete with creaky doors, faucets that turn on and off, and a stunning exterior view of Niagara Falls—which she and her research group are using to study and improve how patients care for themselves at home.

Housed in Brennan’s Living Environments Laboratory, the CAVE alleviates the researchers’ need to move into a patient’s guest bedroom to study his or her home healthcare behaviors or challenges. Rather, it allows them to simulate any number of scenarios, including how visual cues in the home could encourage people to take better care of themselves—for example, by quitting smoking or exercising.

The researchers also are using their imagination: Collaborating with colleagues that include renowned UW-Madison neuroscientist Richard Davidson, Brennan is studying ways to stimulate changes in the brain that help people more effortlessly choose health-promoting behaviors. In the CAVE, she can measure whether an imagination-stimulating experience has an effect on brain patterns that can help ward off unhealthy desires—like the desire to light up a cigarette. “Then we’ll look at what visual cues we can place in clinical or neighborhood settings that might perform that same kind of stimulation,” Brennan says.

Brennan’s research is just the beginning: Since computer programmers create virtual environments in the CAVE, it offers almost endless possibilities. For example, one student is using the CAVE to study how best to organize supplies in operating rooms, while another researcher is testing a “heads up” display that provides food nutrition information—an advance particularly important to diabetics or people with food allergies.

Someday, they may be a reality, but for now, says Brennan: “In the CAVE, we can experience these things.”
While technologies such as navigation systems, cell phones and MP3 players can distract a driver’s attention to the road, those same technologies can help older adults be safer drivers.

Accident risk follows a distinct pattern over a person’s lifetime. It’s high for young people, then lessens as they gain experience and reach middle age. Then, however, accident risk increases as drivers enter their senior years. “At 80 you’re just as dangerous as a 20-year-old,” says Emerson Electric Quality and Productivity Professor John Lee. “As we get older, we fall into bad habits. Because driving is somewhat forgiving, we can drive dangerously and not suffer any consequences for years.”

This onset of consequences, he says, has several causes. When people retire, their commuting patterns change and their ability to hear, see and concentrate decreases. Older couples often drive as a team; the passenger might check blind spots and help navigate. When one spouse dies, the remaining one is left without that help. But for many older adults, losing the ability to drive triggers a loss of independence, weakens social networks, and speeds their entry into care facilities.

Collaborating with researchers in the UW-Madison Center for Health Enhancement Systems Studies, Lee is studying ways technology can enable seniors to drive longer and more safely. One of the simplest solutions, for example, is planning routes in advance to ensure older drivers know exactly where they’re going. On-vehicle sensors can help them avoid physical hazards and make a safe turn, or in the not-too-distant future, do much of the driving for them.

Lee will share his findings with auto manufacturers such as GM, Nissan and Honda with the hope that future vehicle designs reflect the needs of older drivers, too. “The main point of this project is to provide the voice of the older driver into the design process so it enhances mobility and safety,” he says.
In thermoelectrics, vibrations are key

More and more, researchers are finding that things behave differently when observed on the nanoscale. Associate Professor Paul Evans has devised an x-ray analysis technique that allows researchers to study vibrations or how electrons travel in nanoscale samples of silicon crystal. Researchers knew the vibrations were occurring, but 99 percent of them were invisible because the tools to look at them were not sensitive enough.

“The physics boils down to a pretty solid set of rules,” Evans says. “The issue is that when you change the number of atoms, the total number of atoms, and you put some boundaries in, the frequencies of the vibrations change, just a little bit.”

Understanding how the frequencies change at such a miniscule level ultimately could help engineers manipulate the vibrations of small structures and create more efficient thermoelectric devices.

The thermoelectric effect is the direct conversion of temperature differences to electric voltage, and vice-versa. Thermoelectric materials can be used to capture waste heat and convert it to electricity or can convert electricity to cool lasers or small portable refrigerators. The advantage is that thermoelectrics are small and require no coolants or moving parts.

The disadvantage is that current materials cannot operate at low cost with high power efficiency. Evans’ discovery could lead to improved or even new materials for use in thermoelectrics.

“People have looked at materials for use in thermoelectrics that have large amplitude vibrations in the crystal,” Evans says. “There are crystals that make big vibrations and scatter phonons effectively and don’t conduct heat very well but still conduct electricity. So the things that are in your thermal electric cooler are bulk thermal electrics. But if you can make things small and manipulate their thermal conductivity—make nanomaterials that have excellent thermal electric properties—that’s the hook. If you want to make better thermal electrics then you need to understand the fundamental inputs into the heat cell.”

Nanoscale piezoelectric materials could shake up chemistry

Pollution controls, fuel cells, pharmaceutical and chemical manufacturing all rely on catalysts to facilitate the chemical reactions that create useful products from raw material. Although not consumed in those reactions, catalysts can be limited, deactivated or otherwise destroyed in the process. Finding plentiful, durable low-cost catalytic material can create new pathways to sustainable, efficient production of energy and industrial goods.

Piezoelectricity is the ability of crystals, ceramics and other materials to generate an electric field potential difference in response to applied mechanical stress.

Working with zinc oxide nanomaterials, Assistant Professor Xudong Wang and his student Matthew Starr are exploring how the piezoelectric effect can enhance catalysts and improve the catalytic ability of otherwise overlooked materials.

By straining a piezoelectric material in an aqueous solution, Wang’s team can modulate the electronic states at the surface of materials. This opens a new strategy for mechanically manipulating the electrical potential and chemistry of catalysts.

The group oscillated a piezoelectric cantilever in deionized water. The current generated by the piezo effect generated hydrogen and oxygen, demonstrating a direct conversion between mechanical energy and chemical energy.
Without high-temperature coatings, the metallic parts of a jet engine would melt away in a crucible of 2,500-degree Fahrenheit heat. Professor John Perepezko and his team have developed a new, molybdenum-silicon-boron coating that could allow engines to operate at even greater temperatures, promising more efficiency and longer life for parts operating in extreme conditions.

Perepezko discovered the material in identifying key aspects of alloy stability and examining oxidation response. His team has demonstrated that the coating provides excellent protection up to almost 3,600 degrees Fahrenheit.

“If you want to increase the efficiency of a thermal engine, you have to increase the temperature difference between the sink temperature and the operating temperature or ambient temperature,” Perepezko says. “You can’t refrigerate the world so you have to change the operating temperature.”

If implemented in jet engines, the material could improve thrust, save fuel and keep millions of tons of greenhouse gas from the atmosphere.

The discovery is patented and licensed through the Wisconsin Alumni Research Foundation and currently is used by high-tech material manufacturer H.C. Starck to produce massive electrodes that heat vast swimming-pool-sized vats of molten glass. Perepezko’s team also has developed a two-stage process for including the material in ceramics and composites, greatly expanding the potential for their use.
Building the virtual laboratory

Everything in physics is governed by equations, which can be solved to predict, for example, how grains of sand collide, how a tablecloth falls across a flat surface, or how water flows around obstacles. And as computing power becomes cheaper and more accessible to universities, the potential for research applications with large computers is skyrocketing.

Using math and heavily validated modeling to simulate how different types of bodies and surfaces interact, Associate Professor Dan Negrut and his students are building a software infrastructure that can be used to solve engineering problems of all types—providing a new, virtual laboratory for mechanical research.

With simulation, it’s possible to test cars before they’ve been built, for example, or to explore the dynamics of costly or dangerous experiments without the expense or delay of having to build or replace prototypes.

Negrut focuses on granular dynamics, such as sand or dirt particles that move and collide, flexible bodies that can change shape in response to pressure, and fluid flow in different settings.

In a project funded by the U.S. Army, for example, Negrut’s students look at ways to represent terrain as a deformable, flexible medium—more representative of mud or dirt than sand. Combined with how a vehicle tire (another deformable, flexible structure) behaves, they can create simulations of how off-road driving might feel in real-time. The Army hopes to use these simulations for driver-training programs.

Negrut’s work also has the potential for medical applications. Human blood can be treated as a series of cells (small, colliding bodies) moving through plasma (a fluid flow) in a blood vessel (a flexible body). Being able to model all three aspects will help researchers find new ways to deliver drugs on a molecule-by-molecule basis to different parts of the body. “The computer becomes a virtual microscope or telescope,” says Negrut. “In an ideal world, we would be able to simulate everything.”
After ACL reconstruction, finding small motions that cause big problems

People who tear their anterior cruciate ligament, a ligament in the knee that provides stability to the connection between the tibia and femur, usually must opt for a complete ACL reconstruction with a portion of another ligament.

However, about 90 percent of people who undergo reconstructive ACL surgery develop osteoarthritis—knee pain, swelling and stiffness—within 20 years. Many of these people first injured their ACLs as young athletes, which means that in their 40s or 50s, they’re facing debilitating knee pain that often only a total joint replacement can fix.

Associate Professor Darryl Thelen and graduate student Jarred Kaiser (pictured) think the reason for this lies in tiny changes to knee motion following ACL reconstructive surgery. Over a person’s lifetime, knee cartilage fibers align to support precise distributions of different types of forces. So, even small changes after a surgery essentially could turn the knee against itself, damaging the cartilage by stressing it in places and ways it can’t handle.

The team is overcoming one major challenge—how to image the knee’s real-time motion in three dimensions without extremely specialized equipment or large amounts of radiation—by adapting MRI techniques currently used by cardiac researchers. Working with Medical Physics Assistant Professor Oliver Wieben, Thelen and Kaiser use the MRI to take images at different points in a continuous cycle in which a subject flexes and extends the knee against an external load (pictured) to simulate walking. By combining images from many cycles, they gain a clear 3-D video of a single cycle.

So far, they’ve found that the knee can move dramatically differently after an ACL reconstruction, even when an orthopedist might not detect any irregularity. Along with Radiology Associate Professor Rick Kijowski and Orthopedics Assistant Professor Geoffrey Baer, they’re imaging subjects before and after ACL reconstruction and tracking how specific changes in motion correlate to early indicators of osteoarthritis—which can emerge within a year or two of surgery—in the knee cartilage. Thelen hopes his research can help form guidelines for surgery that lead to more normal motion, reduce wear on knee cartilage, and decrease the chance of osteoarthritis.
FACTS AND FIGURES

The UW-Madison College of Engineering is among the most innovative and consistently highly ranked U.S. colleges of engineering. We are internationally renowned for our leading-edge research and widely recognized for our ability to transfer technological advances into real-world applications via myriad partnerships with industry. Through our world-class undergraduate, graduate- and professional-level educational programs, we enable students to develop as thoughtful, ethical leaders and to acquire the technical expertise they need to tackle complex global engineering challenges.

Excellent online engineering master’s programs
On Jan. 9, 2012, U.S. News and World Report ranked UW-Madison No. 1 for its online graduate engineering programs in the categories of teaching practices and student engagement and student services and technology. UW-Madison is one of only three universities that made the U.S. News and World Report honor roll for top-quality online engineering degree programs.

Research and innovation excellence
- 136 invention disclosures to the Wisconsin Alumni Research Foundation in 2010-2011 fiscal year
- More than 10 consecutive years of 100+ patent disclosures
- 44 research centers
- 21 research consortia with more than 400 industrial and governmental members

Educational excellence
U.S. News and World Report rankings:
- 13th—undergraduate program (tied)
- 17th—graduate program
- Most academic departments rank in the top 20; some rank in the top 5

Faculty excellence
- 2 professors named to the Institute of Medicine
- 28 professors named to the National Academy of Engineering
- 3 professors named to the National Academy of Sciences
- 120 faculty recipients of National Science Foundation Presidential Young Investigator, PECASE, or CAREER awards

Printed photonic crystal mirrors shrink on-chip lasers
Electrical engineers at UW-Madison and the University of Texas at Arlington have devised a new laser for on-chip optical connections that could give computers a huge boost in speed and energy efficiency. The team published its findings on July 22, 2012, in Nature Photonics.

Research expenditures 2002-11

By the numbers: 2011–2012
Engineers earn high national honor

Wisconsin Distinguished Professor of Geological Engineering and Civil and Environmental Engineering Craig Benson and Engineering Physics Professor Emeritus Max Carbon were among 66 new members and 10 foreign associates elected to the National Academy of Engineering in 2012. The academy cited Benson for improvements in design, construction and monitoring of earthen liners and covers for municipal hazardous and radioactive waste landfills, while it recognized Carbon for establishing engineering educational programs for nuclear reactor design and safety. Election to the NAE is among the highest professional distinctions accorded to an engineer.

Annual enrollment

Undergraduate students
Graduate students
Professional engineering education students

Total expenditures

Research
Instruction and Education
Engineering Professional Development
Alumni and Industrial Gift Funds
TOTAL

Patent disclosures 2002-11

Differential tuition expenditures

Research expenditures by source

Total funding by source

The college has posted more than a decade of 100 or more patent disclosures.
STUDENT ACHIEVEMENTS

Student innovation

- Qualcomm Wireless Innovation Prize: Modernized inventory system wins second-annual competition.
- Global Stewards Sustainability Prize: Sustainable, recyclable electric motors win one of three $15K prizes.
- Innovation Days: Inexpensive prosthetic hand wins $10K prize.
- Probe seeking life on Saturn’s moon earns team a spot at international space conference.
- Through NASA program, engineering mechanics and astronautics team tests spacesuit dust-removal system.
- Biomedical engineering undergraduate team takes second place in the Collegiate Inventors Competition.

International opportunities

- 138—Students who studied abroad, for academic credit, in fall 2011 and spring and summer 2012
- 30—Countries they visited

Internships, co-ops and career opportunities

- 141 students on co-op—fall 2011
- 126 students on co-op—spring 2012
- 245 students on co-op—summer 2012
- 518 students on internships—summer 2012
- In two career fairs, thousands of students talked with recruiters from more than 300 local, state and national corporations.

High-tech silver dressings ward off infection

Applied onto the business end of artificial skin, nanofilms that release antibacterial silver over time can eradicate bacteria in full-thickness skin wounds in mice. Such antibacterial wound dressings could benefit millions of people worldwide who suffer from serious burns or chronic wounds. A multi-university team of researchers, including UW-Madison chemical engineers, described the results in a paper published in the August 2012 issue of the journal Annals of Surgery.

Technique promises abundance of key heart cells

Writing May 28, 2012, in the Proceedings of the National Academy of Sciences, a team of chemical engineering researchers described a way to transform embryonic and induced pluripotent stem cells into critical heart muscle cells by manipulating one key developmental pathway. The technique promises a uniform, inexpensive and far more efficient alternative to the current complex method.

Engineering Professional Development impact

- In 2011, students who participated in EPD continuing-education courses came from 50 U.S. states, Washington D.C., Puerto Rico, and 82 countries around the world.
- 7—Distance-delivered master’s degrees
- 11—Certificate series
- 25—Technical and professional subject areas ranging from the basics to high-level topics
- 75—Faculty and support staff
- 800—Course instructors
- 3,000—Short courses per year
- 11,000—Annual enrollment

Hybrid vehicle teams five-year successes

- 2007—Hybrid Chevy Equinox Crossover SUV earns 2nd place in the Challenge X Competition
- 2008—Hybrid Chevy Equinox Crossover SUV earns 2nd place in the Challenge X Coast to Coast Competition
- 2012—Clean Snowmobile Team earns 6th place in SAE Clean Snowmobile Challenge

Concrete Canoe Team—National Concrete Canoe Competition five-year successes

- 2007—Descendant wins national title
- 2008—Buckingham earns 6th place
- 2010—Centennial earns 5th place
- 2011—Element earns 2nd place
- 2012—Aurora earns 8th place

Steel Bridge Team—National Steel Bridge Competition five-year successes

- 2007—3rd place
- 2008—6th place
- 2009—12th place
- 2010—13th place
- 2012—6th place
Interdisciplinary Degree Programs

In addition to its nine departments, the UW-Madison College of Engineering offers six degree-granting programs with strong emphasis on interdisciplinary studies. Participating UW-Madison faculty members are based in these schools and colleges:

- College of Agricultural and Life Sciences
- College of Engineering
- College of Letters and Science
- Wisconsin School of Business
- School of Education
- School of Nursing
- School of Medicine and Public Health
- School of Pharmacy

Environmental Chemistry & Technology Program
Marc Anderson (chair)
Tel: 608/263-3264 • Fax: 608/262-0454
mcpossin@wisc.edu
www.engr.wisc.edu/interd/ect

Geological Engineering Program
Craig H. Benson (chair)
Tel: 608/890-2420 • Fax: 608/890-3718
gle@engr.wisc.edu
www.gle.wisc.edu

Limnology and Marine Science Program
Steve Loheide (chair)
Tel: 608/263-3264 • Fax: 608/262-0454
mcpossin@wisc.edu
www.engr.wisc.edu/interd/limnology

Manufacturing Systems Engineering Program
Frank Pfefferkorn (director)
Tel: 608/262-0921 • Fax: 608/265-4017
mse@engr.wisc.edu
msep.engr.wisc.edu

Master of Engineering (Polymer Engineering and Science)
A. Jeffrey Giacomin (co-director)
Tim A. Osswald (co-director)
Tel: 608/262-7473 or 608/263-9538
Fax: 608/265-2316
rhoads@engr.wisc.edu
rrc.engr.wisc.edu/PolEngSci.html

Materials Science Program
Ray Vanderby (director)
Paul Evans (associate director)
Tel: 608/263-1795 • Fax: 608/262-8353
rhoads@engr.wisc.edu
www.engr.wisc.edu/interd/msp

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Carolina Castellanos
R&D Group Leader
Packaging Division
Kraft Foods Corp.

Talaia Cawrse
Inventory Leader
Materials & Demand
Planning Team, GE Healthcare

Tom Gilbert
Product Development Engineer
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Trevor Ghylin
Water and Wastewater Process Engineer
CH2M Hill

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Functional Manager
Digital Group, Plexus Corp.

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Project Manager
American Transmission Co.

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Vice President
Construction Development, Lloyd Companies

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Reactor Engineer
Dominion-Kewaunee Nuclear Power Station

Megan L. Voelker
Plastics Process Engineer
Plaxon Corporation

EX-OFFICIO: Paul Seery, Dean College of Engineering, UW-Madison

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