New method for breast cancer imaging
INSIDE THE BOX
A team of UW-Madison researchers is developing a new method for breast cancer imaging better tailored to women with a particularly high risk factor.

By Sandra Knisely

UW-MADISON ECONOMIC IMPACT STATEWIDE HITS $12.4 BILLION
Engineering research benefits companies across Wisconsin.
Read about three successful partnerships.

By Sandra Knisely and Renee Meiller

FUSION EXPERIMENTS EARN NEARLY $11 MILLION IN GRANTS
UW-Madison programs in plasma physics and fusion technology are among the oldest, broadest, largest and most productive programs in the nation.

By Sandra Knisely and Renee Meiller

In Depth
By Dean Paul Peercy

From the Lab
College research news

Who Knew?
Five questions . . . with Electrical & Computer Engineering Professor Giri Venkataramanan

The Next Generation
Engineering students live and learn abroad, make their mark as entrepreneurs, and more

Engineering Beyond Boundaries
Beyond the classroom: Experimental space promotes undergrad learning

Wisconsin Ideas
From Waterloo, Wisconsin, to Washington D.C. and beyond, UW-Madison engineers provide expertise that shapes the world

Badger Engineers
• Field reports: Mark Scheuer and Matt Younkle, in their own words
• An alum to meet: Neeraj Arora
• Young alumni on the move

A New Perspective
How a polymer guy ended up doing tissue engineering scaffold research
By Lih-Sheng (Tom) Turng
In 2011, researchers are celebrating the 30th anniversary of the Wisconsin Electric Machines & Power Electronics Consortium (WEMPEC). Supported by more than 70 corporate sponsors, WEMPEC is an internationally renowned engineering consortium that brings together professors, students and international scholars to research and develop the newest technologies in power electronics, actuators, sensors, drives, motion control and drive applications.

In the WEMPEC lab, electrical and computer engineering graduate student Jonathan Lee displays a static switch, which attaches and aligns a microgrid with a utility grid. Lee is studying ways to extend existing theories and methods about islanding detection—a process that recognizes an abnormal voltage or frequency event and disconnects a generator from a power grid—to microgrids.
Seeding innovation in engineering education:

ENGINEERING BEYOND BOUNDARIES

Four years ago, a new course for UW-Madison freshmen interested in engineering addressed a big question: How can engineers change the world? Today, a bigger audience than we ever anticipated will be contemplating that question. Introduction to Society’s Engineering Grand Challenges, conceived by a team of innovative engineering faculty in 2007, is a multidisciplinary course that builds on the “grand challenges” of the 21st century as identified by the National Academy of Engineering. These are some of the vexing, all-consuming issues of our time: How can we maintain and improve our megacities, where 60 percent of the world’s people live? How can we harness the enormous potential of solar and fusion energy? How do we provide the world with access to clean, safe drinking water? How can we secure nuclear technology and materials to prevent the threat of nuclear or biological terror?

Each of the 14 grand challenges provides a powerful module with which to explore the promise and potential of engineering. Students form teams and dive into a specific challenge, which culminates at semester’s end with a poster presentation on possible solutions. The course started quickly with nearly 100 students in its first year, and now consistently enrolls its maximum of 150 students per semester, including many non-engineering majors.

The founders of the course—Philip Dunham Reed Professor of Electrical and Computer Engineering Susan Hagness; Mechanical Engineering Professor Nicola Ferrier; Chemical and Biological Engineering Professor Daniel Klingenberg; Biomedical Engineering Associate Professor Kristyn Masters; and Civil and Environmental Engineering Professor and Pieper Servant Leadership Chair Jeffrey Russell—recognized that today’s students are motivated to pursue careers that have a meaningful impact on society. And potential future engineers need to be exposed early to the rapidly changing nature of the profession.

The grand challenges course, like many great ideas, proved to be contagious. The faculty leaders seized an opportunity to reach a bigger audience through the Madison Initiative for Undergraduates (MIU), a campus-wide grant program that advances educational ideas that benefit a broad swath of students. Beginning this fall, the MIU will enable the college to double the grand challenges course enrollment to 300 students, including as many as 90 students per year from disciplines outside engineering.

The impact will not stop there. Another exciting offshoot of the course will involve Wisconsin middle-school students. Faculty led by Electrical and Computer Engineering Professor Amy Wendt obtained a National Science Foundation grant to adapt the grand challenges course for eighth-grade students in Racine, Madison, Westfield, Appleton and other Wisconsin communities. These modules are designed to fit within the existing science curriculum, which may help inspire young people who may never have considered a career in engineering.

In another measure of the course’s success, the Neenah-based global engineering company Plexus Corp. saw the great potential of the middle-school module and provided funding to bring it to a Fox Valley school. Especially attractive to the company was the possibility of encouraging more young women and underrepresented students to open their minds to an engineering career.

We are proud of the grand challenges course for another reason. It is one of the ideas funded under “Engineering Beyond Boundaries,” a college initiative to promote a culture of continuous academic improvement. EB2 provides modest grants that help seed innovation, giving great ideas enough initial support to take root and grow. The ultimate goal of EB2 is to move our students beyond the boundaries of the traditional engineering curriculum and forge deeper connections to other disciplines, from business and medicine to social sciences and the humanities.

We have funded 26 projects since the start of this program, and more than 80 percent of these projects have a multidisciplinary theme. Not all of these ideas will find a long-term place in our curriculum, but the best ones have the potential for transformative impact on engineering education.
There's only one place in Wisconsin where a driver can send text messages, speed or engage in other risky behaviors with no risk of an accident: the new UW-Madison Driving Simulation Laboratory.

Drivers not only are certain to survive the experience, but the consequences of their actions could be safer vehicles and roads around the country and even around the world.

The driving simulator, located in the Mechanical Engineering Building, addresses a substantial need to test new vehicle technologies and road infrastructure quickly, say its founders, Emerson Electric Quality and Productivity Professor of Industrial and Systems Engineering John Lee and Civil & Environmental Engineering Associate Professor David Noyce, who also directs the Wisconsin Traffic Operations and Safety Laboratory.

“Vehicles are getting smarter, and we need to get ahead of that rapid change to understand how drivers respond to the technology,” says Lee, an expert in driver distraction. “The fundamental reason for the simulator is to understand how people respond to technology so we can design it better and save lives. The car is designed from the ground up to be the car of the future and something we can use to develop and test next-generation vehicle technology and road infrastructure.”

Funded by UW-Madison and the Wisconsin Department of Transportation, the simulator includes a Ford Fusion with a 24-foot screen wrapped around in front and an additional screen behind the car. Six projectors cast a virtual driving environment on the screens, immersing a driver in as much as 270 degrees of simulation.

The projectors render images at the same resolution the human eye does. This allows researchers to, for example, project signage exactly as it would appear on a physical road. The simulator is motion-based and capable of one degree of movement in any direction.

Flexible software from Realtime Technologies Inc. combined with the high-end hardware will allow researchers to test a wide variety of driver behaviors and responses, many of which aren’t economically or ethically possible to test on physical roads. Drivers could be dosed with alcohol or learn to navigate a new intersection design.

Additionally, the simulator is likely to directly benefit Wisconsin drivers, as Noyce plans to replicate segments of roads around the state that are known to cause traffic problems and test traffic control solutions for those segments.
Early-career engineers honored

The National Science Foundation has recognized three promising young faculty members with prestigious CAREER awards. Funding from the awards supports their leading-edge research in communications technology, chip optimization, and bacterial engineering.

Insect hearing inspires new approach to small antennas

Ormia ochracea is a small parasitic fly best known for its strong sense of directional hearing. Such acute hearing in a tiny body has inspired Electrical and Computer Engineering Assistant Professor Nader Behdad as he studies new designs for very small, powerful antennas—a challenge that has thwarted electromagnetic researchers for more than a half century.

For a structure like an antenna to effectively transmit or receive an electromagnetic wave at a given frequency, its size must be comparable to the wavelength at that frequency. Making the structure’s aperture size physically smaller than a wavelength becomes a critical performance issue. These small antennas aren’t as efficient and don’t work well beyond a narrow band of frequencies.

“Designing small, directional antennas is one of those things we tell students can’t happen,” Behdad says. “But the question is, what if it can be done?”

He has designed a proof-of-concept antenna based on Ormia’s hearing. If successful, the antennas could increase wireless bandwidth, improve cell phone reception and be applied in a variety of consumer electronics and imaging systems.

Doing more with less: Efficient experiments for bacterial engineering

Shewanella oneidensis is a bacterium known for its ability to break down heavy metals. If scientists could engineer the organism in certain ways, it could be used in a variety of environmental and biofuel applications, such as microbial fuel cells or ethanol. However, like many bacteria that are fairly recent discoveries, Shewanella’s metabolic behaviors are not well understood, and establishing this information via traditional experimental approaches would take a very long time.

Chemical and Biological Engineering Assistant Professor Jennifer Reed will design and conduct new experiments that will more quickly reveal answers about the metabolism of organisms like Shewanella. Her approach will allow researchers to test multiple options and combinations of options at once. “We’re trying to essentially do more with less,” she says. “We want to do fewer experiments and get more information out of the experiments we do.”

Reed will develop experiments to test model predictions of how the organism’s cells regulate metabolic enzyme expression. She then will study how to automate the process of refining the models by evaluating discrepancies found between model predictions and experiments.

A matter of timing: New strategies for debugging electronics

Timing errors are a category of complex electronic bugs that can occur after a chip is fabricated. These errors can cause components to slow down and take longer to execute operations.

Electrical and Computer Engineering Assistant Professor Azadeh Davoodi is one of the first people to look at solutions for timing errors, which significantly increase the time it takes to send new products to market.

The validation process can take months and involves manually opening up a chip and examining billions of transistors. Timing errors often are interdependent and emerge only when certain operations are performed together. This means testing for timing errors requires predicting the chip’s behavior during a vast number of possible combinations of operations.

Davoodi’s team will develop special sensor components that can be added to a chip’s design, as well as methods to analyze measurements from the components. The new components will provide custom timing information for a particular chip design, allowing developers to predict, detect and even solve errors more quickly.
Almost since the beginning of recorded history, people have used concrete substances in everything from infrastructure to artwork.

Yet, recently as the early 1900s, there had been little scientific research of concrete and only a few standards existed to guide its modern-day mixing and implementation. UW-Madison Mechanics Professor Owen Withey recognized this deficit and, in 1910, had the vision and ambition to begin what likely is the longest-running university concrete research project in the country.

Planning tests at regular intervals, he and his students cast 100 years’ worth of concrete samples. “They decided that knowing the long-term properties of concrete would be a very valuable contribution,” says Civil and Environmental Engineering Professor Steven Cramer. “They did it with no idea their experiment would ever be sustained. Step by step, the institution was there.”

In total, Withey and his students cast more than 2,500 concrete cylinders in 1910, 1923 and 1937. Later, Withey passed the research to Kurt F. Wendt, a mechanical engineering faculty member who later succeeded Withey as engineering dean. With Engineering Mechanics Professor George Washa, Wendt reported 50-year results based on the 1923 castings.

Cramer was an undergraduate in one of Washa’s last classes and, with Washa and Engineering Mechanics Professor Jesse Saemann, tested the 1937 specimens at the 50-year mark.

Throughout the past 100 years, each researcher conducted additional tests at various intervals. Today, however, Cramer is the only one left—and in fall 2010, Withey’s 1923 longitudinal research project concluded under him.

Because his predecessors kept good records, Cramer knows exactly what went into the concrete mix and how it has performed in past tests. He and his students crushed the last of the 100-year-old samples in a slightly dusty, first-floor laboratory in Engineering Hall. They used a mammoth device called the million-pound test machine, which, using hydraulic pressure, exerts 50,000 pounds of pressure per minute on the concrete cylinders. Based on past results, they tracked how much force it took to break each specimen.

Unlike the early researchers, Cramer and his students also used modern-day tools, including microscopy, to study structural and chemical changes in the concrete. “What our contribution will be is the entire history of the life of these concrete specimens—what they were made out of, what the cement chemistry was at the time, the environmental conditions that they were exposed to, and then the properties at various points in time, from one week to two months, to 10 years to 30 years, to 50 years to 100 years,” says Cramer.

Like their predecessors, he and his students will publish the results. And that will close this century-old project (though Withey’s 1923 castings remain to mark yet another 100-year anniversary). “What’s unique is there’s not a laboratory study that has had the longevity of 100 years that one institution has been able to maintain,” says Cramer.

**Simple math . . . $1,000,000,000**

In fiscal-year 2009, UW-Madison’s total research expenditures surpassed this milestone, according to 2010 National Science Foundation figures.
Air Force honors young researchers

Three UW-Madison engineers are among 43 researchers to receive prestigious Air Force Young Investigator Research Program funding through the Air Force Office of Scientific Research (AFOSR). The program is designed to foster creative basic research in science and engineering, enhance early-career development of outstanding young investigators, and increase opportunities for those investigators to recognize the Air Force mission and the related challenges in science and engineering. The AFOSR selected the recipients from a field of 242 proposals. Their funding periods range from three to five years.

With his three-year, $364,000 award, Engineering Physics Assistant Professor Matt Allen is developing analytical tools that will enable him to create simplified models for each panel of a hypersonic aircraft and then to predict how the vehicle will behave when those panels are assembled onto the aircraft. “Our work will help us to understand and predict the large-amplitude vibrations that would cause the panels to fail,” he says.

Allen currently is focusing on hypersonic vehicles; however, he also is considering other applications, such as cars and wind turbines, in which noise and vibration are important. “Our substructuring methods allow us to think of a system as an ‘assembly of parts,’ which can be advantageous, for example, in the automotive industry, where one company makes the electronics, one company makes the frame, one company makes the seat, and so on,” he says. “With these methods, you can predict how noisy the vehicle will be after all of those parts are assembled, or whether it might have a resonance that will cause things to break prematurely.”

Electrical and Computer Engineering Assistant Professor Nader Behdad is studying a class of synthetic structures known as metamaterials. The structures are composed of layers of metals, dielectrics and other materials that, when layered together, function as a distinct material as far as an electromagnetic wave is concerned.

When a wave hits a material, what happens to it is determined by the material’s index of refraction. By creating particular patterns in a synthetic structure, Behdad is able to engineer functional indexes of refraction out of materials robust enough to survive very high power levels. These structures are a promising alternative to current materials that cannot withstand mega and gigawatt levels of electromagnetic power.

Behdad is designing structures that could be used in high-power phased-arrays, radar systems and satellites. He also plans to study antenna apertures that can shape...
A Petri dish set on a windowsill may not look like a production plant for diesel and jet fuels, but if the dish contains a special type of cyanobacteria, which take in sunlight and carbon dioxide and “spit out” a fuel precursor, that’s essentially the case.

A cyanobacterium is a photosynthetic organism that uses carbon dioxide to grow and produce alpha-olefins. This ability makes the bacterium a promising alternative to Escherichia coli, which is commonly used in bacterial biofuel research but requires sugars or other carbon sources to grow and produce biofuels.

Chemical and Biological Engineering Assistant Professor Brian Pfleger is developing a sustainable approach for creating diesel and jet fuels by engineering a particular cyanobacterium that naturally produces hydrocarbons, called alpha-olefins, which are structured like the molecules of existing diesel fuels. This means the microbial products could be blended with petro-diesel and be used in existing fuel infrastructure.

Pfleger will explore ways to alter the bacteria’s DNA that is responsible for alpha-olefin production. These alternations will make a bacterium produce a higher volume of alpha-olefins than it would on its own.
5 questions with Giri Venkataramanan about sustainability

“A thing is right when it tends to preserve the integrity, stability and beauty of the biotic community. It is wrong when it tends otherwise.”

Electrical and Computer Engineering Professor Giri Venkataramanan uses this Aldo Leopold quote to sum up the idea of sustainability—yet notes that sustainability is much like an onion, with many layers and many variables. “No one person can rightfully say what sustainability is or should be,” he says. “Sustainability pervades everything.”

Venkataramanan’s research focuses on the major aspects of electrical power conversion systems and optimizing these systems for the future. While on sabbatical, he applied his research on rural wind turbine building projects in four countries.

He says learning involves doing, and this belief has made him an exceptionally well-regarded instructor. Among his most recent teaching awards is the 2011 UW-Madison Chancellor’s Distinguished Teaching Award.

Venkataramanan has taught a variety of power conversion and sustainability-related courses, including a section of Introduction to Engineering that taught students the engineering principles of wind energy and how to build actual turbines. He also is involved with students as faculty director of the UW-Madison chapter of Engineers Without Borders.

1. **What does the term “sustainability” mean to you?**

   To me, sustainability represents a vibrant community that does not have to worry about natural, cultural, technical, political, social and intellectual resources to maintain its “life, liberty and the pursuit of happiness” for generations to come.

2. **What drives your passion for sustainability?**

   I spent my youth in a water-stressed community due to the local groundwater table dropping by about 100 feet within a generation because of unsustainable harvests. As I grew up, I have found it hard not to observe this trend being persistent, and continuing to grow on a global scale, and extending into realms that go much beyond water. My observations turned into a passion through my readings of visionaries. I would list Thoreau, Leopold, Muir, Wright and Schumacher, and the list grows. Of course, my years among the mighty mountains in Montana and the (mostly) blue lakes in Wisconsin have only served to fuel my passion.

3. **How do you apply this passion in your research?**

   The field of power conversion that I focus on naturally addresses issues in energy sustainability through its enabling relationship to wind power, solar power, energy efficiency, etc. More recently, I have consciously strived to extend the work across the boundaries into more human-scale applications in deference to the “small is beautiful” paradigm toward sustainability.

4. **What prompted you to develop the certificate in sustainability?**

   As I was developing an education proposal with a relatively modest scope in response to the program that is now framed under Engineering Beyond Boundaries, several College of Engineering colleagues found that we were all responding in our own ways to address the broadly emerging societal concern on sustainability. I think the certificate program brought these efforts together under a collective identity for undergraduates—it was an organic development that grew from our constituents.

5. **What are a couple of the top misconceptions people seem to have about sustainability?**

   I think it is easy to fall into a trap that may narrowly focus only on balancing the energy equation, the water equation, or the dollar equation, etc. It is this trap that has gotten us to where we are today. Until we frame the question to form a holistic picture and examine what development and growth means to us, we cannot address sustainability. Words like “holistic” do not resonate well among us engineers and scientists. We are afraid to challenge ourselves and step outside our disciplinary norms, fearing a loss of our discipline in the process. But the process has begun; it is time for sifting and winnowing.
Certificate in Engineering for Energy Sustainability

In the face of increasing global population and economic development, the equity and sustainability of energy resources are key issues at the center of public discourse today. The Certificate in Engineering for Energy Sustainability, which debuted in fall 2009, offers undergraduate students a suite of courses addressing energy sustainability that span across the engineering curriculum, with firm roots in real-world design and engineering practices. These courses range in topic from environmental economics and renewable energy systems to biorefining and transportation engineering.

Venkataramanan says the certificate could be a stepping-stone to work in NGOs or nonprofit organizations devoted to sustainability. In the private sector, there is growth in the solar photovoltaics and wind energy economies. The field also is ripe for entrepreneurship.

The flexibility in choosing courses also enables students to explore how they might lead this cultural and technological change in ways they can't imagine today. “We have the Wisconsin Idea and it’s an identity that students pick up on as they go through their experience here,” Venkataramanan says. “I think sustainability will be another part of that tradition.”
Every woman over the age of 40 receives the same initial screening for breast cancer: a mammogram. Yet no two women are identical and neither are their breast cancer risks, so a team of University of Wisconsin-Madison researchers is developing a system better tailored to women with a particularly high risk factor.

In 2000, a National Academy of Engineering publication identified breast cancer detection as a healthcare problem in need of an engineering solution. In the subsequent decade, Philip Dunham Reed Professor of Electrical and Computer Engineering Susan Hagness has emerged as a leader in the search for that solution.

The system will offer three-dimensional capabilities similar to a magnetic resonance imaging (MRI) system along with the affordability and accessibility of traditional mammography.

Hagness works closely with Electrical and Computer Engineering Professor Barry Van Veen, and their collaborators span a variety of fields. Electrical and Computer Engineering Assistant Professor Nader Behdad, Duane H. and Dorothy M. Bluemke Professor of Electrical and Computer Engineering John Booske, and Radiology Associate Professors Fred Kelcz and Gale Sisney currently are contributing to the project.

The density risk

Breast tissue is made up of fatty tissues, connective tissues and epithelial tissues, which line many of the body’s surfaces and cavities. Collectively, the connective and epithelial tissues are called fibroglandular tissue, and this tissue determines breast density. If a woman has a high percentage of fibroglandular tissue, her breasts are considered “dense.”
According to research published in the *New England Journal of Medicine*, high breast density can increase a woman's risk for cancer four to six times that of women with predominantly fatty tissue. It's a stronger risk factor than early-onset menstruation or having no biological children. In fact, few other factors exceed dense breast tissue as a risk for cancer; a *Radiology* paper found those that do include a breast cancer gene mutation, age or prior breast cancer.

This strong risk is also fairly common. Around 50 percent of women in their 40s and 25 percent of women in their 70s have breast tissue that is at least 50 percent dense, according to the *American Journal of Roentgenology*. “All of these facts point to the importance of breast density evaluation in assessing a woman’s risk and having clinicians provide appropriate prevention protocols,” Hagness says.

Unfortunately, dense breast tissue makes it more difficult for doctors to accurately screen for cancer. Research in *Annals of Internal Medicine* found as many as two out of every five cancers in women who have high breast density go undetected.

The problem is that mammography is a two-dimensional imaging technique. A mammogram machine takes a three-dimensional volume of tissue, passes X-rays through the tissue and creates a shadowgram. All of the tissue is projected onto that two-dimensional image.

Hagness compares it to trying to find a needle in a haystack. “It’s easier to find the needle if you can sift through the hay layer by layer; it’s much more difficult if you compress all of the hay into a thin pile and view it all at once,” she says.

However, Hagness and Van Veen don’t view their system as a replacement for traditional mammography. “Mammography is the gold standard that has saved countless lives, and we don’t see a need for an alternative for women who are served well by that technology,” Hagness says.

“But there is a population that is currently underserved, and we’re interested in developing a safe, low-cost imaging modality that could be used for evaluating breast density and screening women who are at high risk.”

### An affordable alternative for high-risk women

A three-dimensional image of dense breast tissue would allow doctors to sift through the entire tissue slice by slice. An MRI is an example of a system that can produce these kinds of images, but these scans cost around 10 times as much as mammograms.

Beyond the cost, the accessibility of MRIs is not ideal. Not all clinics or hospitals have MRI machines, and rural clinics are especially less likely to have one. In addition, a time-intensive MRI scan is a difficult experience for claustrophobic or obese patients, who make up a significant percentage of the population.

Instead, Hagness and Van Veen are developing an imaging system that can produce three-dimensional images via microwaves, a technology comparable in cost to a mammogram.

The clinical prototype will look like a box similar in shape and size to a vertical Kleenex tissue box, with tiny copper-colored antennas mounted on each side. Each antenna will transmit a low-power microwave signal, and all the other antennas will record the scattered signals from the breast. Algorithms will reconstruct those signals into a three-dimensional image of the breast tissue.

Safety is a key component of the system. “This will transmit much less microwave power than a cell phone,” Hagness says. “It’s non-ionizing, so there is no health risk.”
Piloting the future of breast imaging

Achieving a clinical prototype has been an evolutionary process that has taken several years of research. From 2002 to 2007, Hagness led a large multi-institutional study to establish that breast tissue microwaves could convey important physiological information. The study involved measuring hundreds of freshly excised tissues from mastectomies, breast reductions and biopsies. The samples included healthy and cancerous tissues with a range of densities. Hagness found that dense fibroglandular tissue does in fact have different electric properties from fatty tissues—a contrast that is necessary to evaluate breast density with microwaves. The work remains the definitive study on microwave properties of breast tissue, and the papers associated with the study have been cited hundreds of times. “We can distinguish dense tissue from fatty tissue, and that’s what you need to determine volumetric breast density,” she says.

Van Veen, who wasn’t directly involved in the tissue study, says the team’s work has evolved because of those findings. “Initially we had assumed tumors were these different objects that would scatter a lot more microwave signals than the healthy tissue,” he says. “But both tumors and healthy tissue scatter similar levels of energy back. That knowledge has changed the type of signal processing we do for this problem.”

The change means a shift from a radar-like approach to an imaging approach that looks for changes over time or changes due to contrast agents. With funding from the U.S. Department of Defense, Hagness and colleague John Booske are studying microbubbles and carbon nanotubes as possible contrast agents that will target tumors and make them more “visible” to the antennas. Overall, the team is focused on moving the clinical prototype forward so the small-scale human trial can begin sometime in the next two years. This means developing and testing the algorithms that will actually generate images from the data gathered from the antennas. The team also is working on the actual sensor array that will be placed around the subject’s breast.

“We’re beginning to make the transition from pure laboratory research toward clinical studies,” Hagness says.

The pilot will test around a dozen women. Participants will lie face down on an MRI support platform and place their breasts in a stabilizing structure that suspends the breast in the prototype “box.” The antennas will send a low dose of safe microwaves through the breast tissue, and the signals will be converted into a three-dimensional image. Participants will also undergo an MRI scan as a control test.

Applying engineering to healthcare

The field of electrical and computer engineering is becoming a more common home for healthcare research, says Booske, who chairs the UW-Madison Department of Electrical and Computer Engineering. “Currently, at least 13 of our faculty are pushing back the research frontiers in topics at the interface of ECE and biomedical or biological technology fields, and more get involved each year,” he says.

“Being involved in this research on breast cancer detection and treatment has been one of the most exciting experiences of my career,” he adds. “My interests and expertise in the science of how electromagnetic waves interact with media has enabled me to contribute, and I’ve learned so much by working alongside the interdisciplinary team of experts brought together by Professors Hagness and Van Veen over the years on this initiative.”
Van Veen says the team’s overall breadth of expertise is what sets it apart from others working on similar research. “From state-of-the-art electromagnetics to sophisticated signal processing, we have a wide breadth that other research teams working on this problem don’t have,” he says. “We’re well positioned to hopefully ultimately solve the problem.”

Solving the problem is the fun part for Van Veen, who jokes about his broad range of signal-processing research experiences. “I like to say I’ve worked on problems from A to Z, though I haven’t quite gotten to Z,” he says. “I started my career applying signal processing to acoustics and have made it to W, wireless communications.”

When Hagness joined UW-Madison in the late 1990s, it wasn’t long before Van Veen began asking questions about her interest in breast cancer imaging, and the two began collaborating. “My expertise is essentially in problems where multiple, different sensors simultaneously measure a physical phenomenon, such as electromagnetic scattering from breast tissue,” he says.

In addition to her expertise in electromagnetics, Hagness is a champion for increasing interest in engineering by showing students how the field can help solve global and societal challenges. She leads an introductory engineering course dedicated to the topic and works on major engineering outreach initiatives.

“All engineering fields offer enormous opportunities to address a variety of challenges in the medical arena. The reason why engineering offers this opportunity is because fundamentally, we’re problem-solvers,” Hagness says. “When a clinical need is identified, it’s a natural fit for engineers to try to address that need, and in electrical engineering, we have a lot of tools and skills to offer.”

“A significant part of the human body is electrical in nature. The nervous system, the brain, cell membranes—electrical engineers can fully understand that side of the human body,” she says.
UW-Madison’s profound impact on Wisconsin’s economy—one that totals $12.4 billion annually—is detailed in a late-March report that underscores the importance of the university to the state’s economic well being. The findings indicate that UW-Madison, along with its affiliated organizations and startup companies, supports 128,146 Wisconsin jobs and generates $614 million in state tax revenue. The report, issued by Madison-based NorthStar Economics Inc., found that UW-Madison research has helped to form at least 283 startup companies in Wisconsin that support more than 21,000 jobs. Economists also found that for every $1 of state tax investment in the university, there is $21.05 in economic activity in the state.

Through their research partnerships with industry, College of Engineering faculty, staff and students play a key role in supporting this economic activity. Here are a few examples of this work.

UW-Madison engineers help
Resilient Technologies reinvent the wheel

In military combat, vehicle tires are critical, as blown tires can mean troops are stranded in dangerous situations. Wausau, Wisconsin-based Resilient Technologies is working on a non-pneumatic tire with a honeycomb-like design, which can’t be shot out and could save lives.

UW-Madison engineers are partnering with Resilient to develop the tire and help the company grow in Wisconsin. Resilient delved into advanced mobility technologies soon after its founding in 2005, and a grant from the U.S. Department of Defense connected the company with a team from Engineering Professional Development (EPD), including faculty associates and program directors Frank Rath and Carl Vieth.

EPD in turn guided Resilient to the Polymer Engineering Center and Kuo K. and Cindy F. Wang Professor of Mechanical Engineering Tim Osswald, who worked with Resilient engineers for two years to refine and test the tire design.

EPD also supports Resilient beyond the lab. The team connects Resilient with non-campus partners, such as machinists and automation companies, many of which are in Wisconsin. “This spins out and expands into the broader state economy,” Vieth says.

Rath and Vieth also advise Resilient on how to move toward military and non-military commercialization. “Frank is vital in directing us toward solutions in many different areas,” says Ed Hall, Resilient chief operating officer.

As Resilient continues to grow as a company, Hall anticipates the company’s relationship with UW-Madison also will evolve. “There are lots of subjects where you can’t just jump on Google and find out who is the best,” Hall says. “The EPD knowledge and resources make it a lot easier to find experts in the field.”

For Rath, it’s rewarding to see a Wisconsin technology startup thrive. “We worked with Resilient before they even had employees. Now they have around 20, and these are high-skill, high-tech jobs—the kind of jobs we really want to see in Wisconsin,” he says.

Hall wasn’t surprised UW-Madison offers so many connections and resources for businesses. “They didn’t look at us as a science project, but as a growing business,” he says. “They were interested because what we are doing could save lives.”
Due in large part to a strong relationship that capitalizes on their respective strengths, UW-Madison and GE Healthcare have pioneered myriad medical advances to improve patient care. Located in Waukesha, Wisconsin, GE Healthcare is a world leader in developing products and services that enable healthcare providers to better predict, diagnose and treat disease.

Now in its 10th year, the company's successful research and intellectual property agreement with UW-Madison allows both GE Healthcare and university employees to work together as a seamless team on cutting-edge technology. In fact, GE Healthcare employee Jean Brittain is an honorary associate/fellow in the UW-Madison Department of Radiology. “How many companies actually commit to having their top researchers on site at the university?” says Jerry Shattuck, a licensing manager with the Wisconsin Alumni Research Foundation, the UW-Madison technology-transfer organization. “That’s an example of what makes this a unique and special collaboration.”

In addition to radiology, GE Healthcare works most closely with medical physics and biomedical engineering faculty, staff and clinicians to develop new technology targeted toward improving clinical care, says Jason Polzin, chief technology leader for software and applications in the GE Healthcare Global Magnetic Resonance Business. “The combination of strong science, engineering and clinical expertise makes UW unique,” he says. “They are able to work ‘bench to bedside’ in developing new technology and then translating it to clinical studies to demonstrate an improvement in diagnosis or clinical outcomes. In many cases, this work becomes part of the GE product—resulting in an impact far beyond the state of Wisconsin.”

To date, UW-Madison and GE researchers have generated nearly 150 patent disclosures. Initially, says Shattuck, many of the patents focused on magnetic resonance imaging; however, more recent advances also capitalize on UW-Madison research strengths in additional areas, such as computed tomography and X-ray technologies.

A less quantifiable benefit of the partnership is the intellectual capital GE Healthcare gains from nearly 100 UW-Madison alumni who now work at the GE Waukesha location, with many in high-level positions. "UW and the Big Ten have very strong engineering programs and GE recruits heavily from those programs through regular campus visits," says Polzin. “Because of its close proximity to GE Healthcare, there is a strong tradition of UW alumni working for GE.”

Keeping Cray computers cool

“It’s amazing to think that some of the world’s most powerful computers come out of Wisconsin,” says Mechanical Engineering Associate Professor Tim Shedd. “I really like the fact that we can help support Cray, a company that’s providing high-paying, good jobs in the Chippewa Valley area.”

Cray Inc. manufactures supercomputers in Chippewa Falls, Wisconsin. In November 2008, the company’s “Jaguar” supercomputer at Oak Ridge National Lab topped the list of the world’s 500 most powerful computers. The Jaguar system held that top position through November 2010.

An expert in cooling methods for electronics, Shedd has collaborated with Cray for the better part of a decade. His partnership with the company began somewhat serendipitously when Adam Pautsch, son of Cray senior engineering manager Greg Pautsch, enrolled as one of Shedd’s doctoral students. Cray asked Shedd and his students, including Pautsch, to investigate ways to cool supercomputers, ultra-powerful high-speed computers that pack so many processors into a small area that keeping the computer from overheating is a challenge.

That research yielded a unique spray-cooling method, two patents, and two additional research projects. David Kiefer, Cray vice president for business development in custom engineering, says the company derived multiple benefits from its collaboration with UW-Madison. “Working with UW-Madison mechanical engineering department—specifically Tim Shedd and his team—enabled Cray to tap their technical expertise, testing capabilities and resources to improve the spray-cooling technology beyond what we could have done in the same time frame, or to the same level of understanding,” he says. “Shedd’s team focusing on the underlying science and analytical methods related to multiphase cooling allows the Cray team to focus on the engineering and implementation of the cooling technology into Cray’s high-performance computing products.”

Now, the company is investigating an opportunity that would enable UW-Madison and Cray to investigate systems-level cooling solutions for future high-performance computers for specific applications.
Dating back nearly a half-century, the UW-Madison programs in plasma physics and fusion technology are among the oldest, broadest, largest and most productive programs of this kind in the nation. On campus, they include approximately 75 faculty and staff members, 60 graduate students and 30 undergraduate students whose education and research frequently cross departmental and college boundaries. And, nearly 350 PhD recipients (more than any other U.S. university) are making important contributions in industry, government, universities and laboratories around the world.

By generating and harnessing plasma, or highly heated ionized gas, in a variety of fusion experiments, these researchers hope to develop technologies capable of delivering a clean, virtually inexhaustible source of energy. They also study the basic properties of plasma, plasma science and astrophysical phenomena, and plasma-aided manufacturing techniques.

At UW-Madison, one key area of emphasis is on magnetic plasma confinement and magnetic fusion; with experts in several additional areas, the programs span three departments in two colleges. These programs—in the Departments of Engineering Physics and Electrical and Computer Engineering in the College of Engineering and the Department of Physics in the College of Letters and Science—receive about $12 million annually in Department of Energy research funding, primarily from the Office of Fusion Energy Sciences.

This past winter, researchers from two UW-Madison plasma fusion experiments received $10.7 million in funding from the U.S. Department of Energy Office of Fusion Energy Sciences. The Helically Symmetric eXperiment (HSX) drew $5.1 million, plus an additional $900,000, while two grants to the Pegasus Toroidal Experiment totaled $4.7 million.
Reshaping fusion research

HSX is one of only two stellarators operating in the United States and is the only machine of its shape in the world.

A stellarator is like a twisted doughnut that uses the physical shape of coils to generate magnetic fields. A stellarator’s three-dimensional magnetic fields theoretically can confine plasma indefinitely because they aren’t constrained by a transformer or the high-current instabilities that plague tokamaks, the most prevalent fusion-research devices. These properties make stellarators the main alternative to tokamaks.

HSX’s special design alleviates particle leakage, a challenge found in other stellarators. Outside the machine’s stainless-steel vacuum vessel is a set of twisted copper coils that form a specially shaped magnetic “bottle” that restores a direction of symmetry to the magnetic field, thereby improving particle confinement.

Electrical and Computer Engineering Professor David Anderson directs the 15 faculty members, scientists and students who make up the core of the HSX team.

HSX research ranges from plasma transport using modulated heating experiments to magnetic field reconstruction and turbulence studies via probes. Currently, students are constructing a beam line that is expected to double the device’s heating capacity and are collaborating with Oak Ridge National Laboratory to develop software codes for HSX.

In addition to overseeing the wide variety of HSX projects, Anderson also is part of a team led by Engineering Physics Professor Chris Hegna to explore the future of stellarator research and study ways to optimize the technology. “Essentially, we’re enfranchised to do some deeper thinking about where we might go from here based on the knowledge we have at the moment,” Hegna says.

Energy inspired by the sun

Among the most promising magnetic-confinement fusion devices for generating energy, a tokamak is shaped like a doughnut with a hole in the center. It uses powerful magnetic fields both to confine and drive a plasma—in the largest experiments, a collection of particles potentially hotter than the center of the sun—as it flows through the device. As the particles collide, they release energy through a nuclear fusion reaction. Understanding how to create, contain, sustain and harness that energy is a primary challenge of fusion-energy research.

Pegasus is a very-low-aspect-ratio tokamak, meaning its center hole is very small and its shape appears almost spherical. Built more than a dozen years ago as a prototype, the experiment now is valuable as a testbed for research that could apply to larger U.S. and international experiments, including ITER, the international thermonuclear experimental reactor under construction in France. “This facility prepares students to work directly on the large fusion facilities,” says Raymond Fonck, Steenbock Professor of Physical Science and Professor of Engineering Physics. “Here, students can do things that people care about all the way up the food chain.”

The new funding provides an opportunity for the experiment to achieve a higher level of technical performance that could align Pegasus research even more closely with large-scale tokamaks, says Fonck. It will support upgrades to the Pegasus power supplies, magnetic field and diagnostic capabilities. Additionally, it will enable Pegasus researchers to build on advances that will allow them study the physics of the device at higher current and higher temperatures. “It’s making that jump to the next level of activity so we uncover the physics that may show up in a fusion reactor scale,” says Fonck. “Once we get to that stage, we are at the position where we need to test those things at a larger facility.”
They visited public gardens, climbed mountains, navigated a megalcity, attended the World Expo, and toured factories. On top of all that, the 17 College of Engineering students who spent summer 2010 in China also took college courses. (The 2011 trip runs May 30 through July 23 and, with 22 students, is filled to capacity.)

The students—many of whom had never traveled far from home—hailed from virtually every College of Engineering department. They traveled to Hangzhou, a city of six million people about 120 miles southwest of Shanghai, where they lived and took classes at Zhejiang University.

Living and learning in China: Engineering students travel to Hangzhou

The annual eight-week Zhejiang University Summer Program began in 2008, thanks to funding from Engineering Beyond Boundaries, a UW-Madison College of Engineering initiative. The program is administered through International Engineering Studies and Programs, which Amanda Hammatt directs. Several faculty and staff, including Mechanical Engineering Professor John Pfotenhauer and Technical Communications Director Laura Grossenbacher, play key roles in overseeing the program.

While in China, the American students blogged about their experiences. Here are three excerpts:

Nick Olp, about Chinese food—“Ordering is usually awkward and most often a mystery. I usually point at pictures on the menu on the left wall or point at the dishes of the people eating around me. After several days of this cycle, I approached with my friends once again and heard one of the cooks in the back say in English, ‘The American boys are back.’ Everyone laughed when we heard this, including the other cooks who have seen us there day after day.”

Jacob Kilbane, about a factory tour—“We got to tour a factory that made large nuts and bolts for wind turbines from raw materials. Although I found the processes for forging, cutting, bending and threading to be very interesting, I found the lack of safety regulations to be of greater interest. In the factory there were workers working with glowing-hot red pieces of steel, massive pneumatic punches, lathes and cranes, and yet only a handful of workers wore safety glasses. I thought this was insane. We were even allowed to get within 3 feet of any machine we wanted to without safety glasses, gloves or words of caution. Our tour guide explained that in some factories, workers may purposely hurt themselves to collect insurance, so factories put up security cameras to deter them. We ended the tour by choosing a large defect nut or bolt to take home as a souvenir.”

John Emholtz, about visiting the Great Wall—“The two-hour bus ride to the Great Wall took us through some interesting parts of the city, so instead of catching up on sleep I was staring wide-eyed out my window. Upon arrival at the Great Wall, I looked up the mountain and already knew I would be exhausted afterwards. I took a cable car up to the first watchtower and marveled at the ingenuity the ancient Chinese people used to craft the most amazing creation I have seen to date. The view from atop the wall was absolutely breathtaking. We walked up for miles along the top of the wall, stopping at each watchtower to rest and appreciate the view until we reached our final destination. At this point we had a choice as to how we wanted to get back down. We could either walk down or take a zip-line over a man-made lake. As young adventurous college kids, we took the zip-line to the bottom where we were relieved to collapse into our bus seats.”
Behide every rubber product is a story that begins deep in the Amazon near a small city called Leticia at the southernmost tip of Colombia. In the early 20th century, 90 percent of the world’s rubber came from this region, at the cost of millions of indigenous peoples’ lives and significant rainforest destruction.

Though Leticia is now a community committed to protecting the Amazon and the rubber industry has changed drastically, the story still serves as a cautionary tale about the quest for raw materials.

The subject is powerful as is; however a group of UW-Madison students had the chance to study the ethics of rubber and other polymers while listening to Amazonian animals howl nearby.

In early July 2010, 12 UW-Madison engineering students, joined by three students from Winona State University, traveled to Colombia for a weeklong course led by Kuo K. and Cindy F. Wang Professor of Mechanical Engineering Tim Osswald. Twenty-five students and five faculty members from the Universidad Nacional de Colombia, Bogotá, also participated.

Osswald has taught Materials Science of Polymers for Engineers at UW-Madison and in Bogotá several times, and last year he was asked to lead the course at the Colombian university’s new Amazon campus and encourage foreign students to attend.

The course kept participants busy with seminars held through the day and evening. However, there were plenty of opportunities for students to explore Colombian culture. The group traveled 100 miles up the Amazon River by boat and met members of the tribe of the Caguas, whose population was decimated by the rubber trade.

Students sampled Colombian cuisine, including piranha and giant worms. They also played plenty of soccer and ran five miles to the Brazilian border.

Overall, the experience gave students a chance to make personal connections with Colombian people and the Amazon environment.

“Rubber was the first polymer used industrially, and it shows that when we are seeking more and more raw materials, some lose perspective,” Osswald says. “As engineers, there is so much we can do that can be good or can do damage, and especially with polymers, we have to keep perspective.”

The students got the message. “A lot of what we learn in class is equations, and we don’t look at where a material comes from and its effect on the people harvesting that material,” says mechanical engineering student Tyler Spriggs.

“Professor Osswald really focused on the effects all the way through a material’s life cycle. It gave us a different perspective to see how the industry affects the environment, in particular,” he says. “I wouldn’t have quite gotten the image in my head if I hadn’t done this course in Leticia.”

The course was such a success that Osswald will continue to teach it in Colombia, alternating summers between the Bogotá and Leticia campuses.

PIRANHAS AND POLYMERS: Students take materials science and ethics course in Colombia
Wisconsin Badgers left tackle Gabe Carimi (#68) experienced nothing short of a dream senior year. Consider this stellar resume:

• Co-captain of the Big Ten championship team that played in the Rose Bowl;
• Big Ten Lineman of the Year and winner of the Outland Trophy recognizing the nation’s best interior lineman;
• And days away from an NFL football career that began with a first-round draft selection to the Chicago Bears.

Anything else?

In fact, a quieter success story played out only about two football field lengths away from Camp Randall, near the UW-Madison engineering campus. Carimi was a graduating senior in civil and environmental engineering who was named to the Academic All-Big Ten for four straight years.

At 6 feet, 8 inches, and 320 pounds, Carimi had no trouble getting noticed on the field. But Professor Jeff Russell, chair of civil and environmental engineering and Carimi’s faculty advisor, says the off-the-field student athlete story is equally remarkable.

“Author Jim Collins, in his book Good to Great, talks about someone he calls a level-five leader,” says Russell. “That type of leader has personal humility but also has really strong professional will. I think Gabe has the elements of both those qualities.”

Combining football responsibilities with a challenging degree program like civil engineering can be compared to having two
full-time jobs, says Russell. Carimi, a Madison native who attended Monona Grove High School, chose engineering due to his lifelong interest in construction and development.

Without hesitation, he credits his academic motivation to his mother. “She would be disappointed if I didn’t make the all-academic list,” says Carimi. “She told me that was what she is most proud of, so I made sure I got after it every year.”

Carimi is very committed to his family and his Jewish faith. His mother has been to every one of his games since middle school and his father, a Janesville-area physician, has been to every college game and most high school games. Carimi roomed in Madison with his sister, a 2009 UW-Madison graduate and member of the women’s crew team.

Volunteerism also is important to Carimi. In seventh grade, he helped build a house for Habitat for Humanity as his Bar Mitzvah project. He has done two college internships with the north Madison firm Rudebusch Development and Construction and has donated his hair to the charity Locks of Love.

For Carimi, his college degree signals both an end and a beginning, says Russell. “When you put all the pieces together with Gabe—as a leader, with his commitment to his family and faith and volunteering—these all play into a person who’s going to be a game-changer and make a difference in the world,” he says.
Matthew Kirk graduated high school with a 1.0 grade point average and assumed his career destiny was in retail or manual labor. Almost 10 years later, Kirk is now an accomplished UW-Madison electrical and computer engineering student with a different credential to his name: award-winning environmental entrepreneur.

Kirk was part of an undergrad student team that won the top prize in the 2011 Climate Leadership Challenge (CLC). Sponsored by the Nelson Institute Center for Sustainability and the Global Environment, CLC encourages UW-Madison students to develop innovative solutions to mitigate climate change. First place comes with a $50,000 cash prize and a one-year lease at the University Research Park Metro Innovation Center.

Kirk’s team developed “Cellulose digesting biogas plants for hydrogen production (CDBP),” which aims to produce hydrogen from agricultural plant waste. CDBP builds on current ethanol-production research, and Kirk (second from right) and his teammates hope that altering biomass processes to yield hydrogen rather than ethanol could eventually create an affordable, accessible source of non-petroleum fuel.

The project began when Kirk’s friend and business student Joseph Keuler approached Kirk; his brother Patrick Kirk, a philosophy student; and David Osmalov, a chemistry student, about developing a hydrogen-run furnace. The project eventually morphed into CDBP, which the group renamed renewH2 after the competition.

“At first, I just wanted to win,” Kirk says of his decision to join the team. Yet over the course of researching and developing CDBP, he discovered a significant interest in solving environmental challenges. “Now the idea of starting a business that makes carbon-neutral energy sounds really cool,” he says.

Kirk didn’t always have the competitive streak that initiated his CLC involvement. “I just didn’t have the right outlook,” he says of his high-school self, who frequently cut and flunked classes, ending up in summer school every year in order to qualify for graduation.

When he did graduate from LaFollette High School in Madison, Kirk worked for a temp agency and then a call center, where he provided tech support for garage door openers. He moved on to a groundskeeper job, picking up trash. It was during this time he decided he wanted more.

Electronic stent deployment system wins top prize at 2011 Innovation Days

A system that could widely expand stent treatments for patients with diseased arteries won the top prize in the Schoofs Prize for Creativity, one of a pair of competitions that make up Innovation Days. The event, which offers more than $28,000 in total prizes, rewards UW-Madison students for innovative and marketable ideas.

For the first time in the competition’s 17-year history, the winning inventor has claimed first place in the Schoofs Prize two years in a row. Mechanical engineering senior Tom Gerald created the MicroMag Stent Deployment System after watching his grandfather struggle with arterial disease. MicroMag is an electromagnetic system to deploy self-expanding metal stents and retract the catheter that inserts those stents. This system would allow surgeons to place stents, the wire mesh tubes used to inflate blocked arteries, in smaller blood vessels than currently is possible.

The winner of the Tong Prototype Prize, the second major Innovation Days competition is electrical and computer engineering student Ray Uhen, who invented Plane Balance. The device is a slim flight-training tool that sits on top of the instrument panel and helps pilots monitor small aircraft coordination, or balance, via a system of color-coded LED lights.

Read more about these and the other award recipients at innovation.wisc.edu/2011.html
Engineering students participated on the four teams that claimed a finalist prize in the UW-Madison Climate Leadership Challenge, which encourages all UW-Madison students to develop innovative projects to mitigate climate change.

“The Climate Leadership Challenge really showcases the amazing talent here,” says Civil and Environmental Engineering Assistant Professor Tracey Holloway, who directs the Nelson Institute Center for Sustainability and the Global Environment, which hosted the competition. “And the top team was composed of undergraduates from business, computer engineering, philosophy, and chemistry. Their success demonstrates the strength of interdisciplinary problem-solving.”

In addition to electrical and computer engineering student Matthew Kirk, a member of team that claimed first prize and $50,000, engineering students from a variety of disciplines were part of the four finalist teams, which each won $2,000.

At age 24, Kirk enrolled at Madison Area Technical College (MATC), intending only to pursue an associate’s degree in electronics. After he started working at Mad City Labs as a part-time software programmer, Kirk decided again that he wanted more. He returned to MATC to take the credits he needed to transfer to UW-Madison; his high school math transcript was so barren he had to start with pre-algebra.

Now at 27, Kirk is in his sophomore year at UW-Madison and majoring in computer engineering. In addition to school, he still works part-time at Mad City Labs. He will balance those commitments with co-founding a company around renewH2 along with his CLC teammates.

Kirk knows he’s now on the right path, but he hasn’t forgotten where he started. “I really want to be successful and go back and talk to kids who are making the same mistakes I made,” he says, adding that he doesn’t have a special math aptitude that was lying dormant in high school. Rather, he credits hard work and discipline with getting where he is now.

“Everyone thinks you need to be expert in math to do engineering, but really, you just need to have an interest in math and science,” he says. “You do have to drop your bad habits, though, which can be a hard thing to do.”

Overall, he hopes his story will have a positive impact. “Kids need inspiration,” he says. “I’m trying to prove that you don’t have to do everything one set way.”

• Biomedical engineering undergraduate students Brad Lindevig and Josh Zent and electrical and computer undergraduate Parikshith Lingamampally were on a team that developed BrightWater Initiative, a self-sustaining purification system to reduce deaths from the consumption of contaminated water in developing countries.

• Civil and environmental engineering graduate student Jeffrey Starke was part of Biogas Growth: Regional and Sustainable Partnerships, which proposes a collaborative network of biogas installations in western Uganda and beyond.

• Engineering physics graduate student Mike Hvasta developed Refrigerator Aider, an innovative ventilation system to boost the efficiency of domestic refrigerators by 10 percent or more without using additional energy or moving parts.

$1,700 in total prizes —
Master Key:
Invented by Steve Wisser.

$1,250 —
Brew Fresh:
Invented by Ben Schneider and Victoria Yakovleva.

$11,000 in total prizes —
The MicroMag StentDeployment System:
Invented by Tom Gerold.

$7,000 — Breast Milk Filter for HIV-1:
Invented by Laura Zeitler and Kimberli Kamer.

$4,000 — Glide Luggage:
Invented by Scott Johane and Jeff Inhofer.
Traditional lecture-style classrooms date back to the 1000s, when the earliest papal universities were established in Europe. Students would listen and take notes as an instructor read verbatim from one of very few copies of a hand-written manuscript.

Though the goals of higher education have changed in the past millennium from producing more clergy members to preparing global leaders, classroom architecture essentially has not. Most courses are still conducted in rooms where students sit in rows facing one instructor, who delivers a lecture.

This basic structure establishes a teacher-centric classroom, where material is presented in a “one-size-fits-all” format that isn’t effective for all students, says John Booske, the Duane H. and Dorothy M. Bluemke Professor and Chair of Electrical and Computer Engineering.

Booske is spearheading an initiative to challenge the traditional setup by creating an alternative classroom space that will better allow instructors to adopt a new paradigm of individual-focused, technology-enhanced teaching strategies.

The Wisconsin Collaboratory for Enhanced Learning (WisCEL) is a joint effort by the College of Engineering, College of Letters and Science, Wendt Commons, UW-Madison Libraries, Division of Information Technology, Facilities Planning and Management and other faculty members and academic services.

The WisCEL team is renovating two spaces on campus to become experimental learning environments for a variety of introductory-level courses. One of those spaces is located in College Library. The other will make up the entire fourth floor of Wendt Commons, the new consolidation of Wendt Library with the Engineering Learning Center and Engineering Media Services.

Though the exact structure of courses held in WisCEL spaces will vary and evolve over time, the team anticipates there will be a heavy emphasis on technology and immediate, frequent feedback for students. Instead of coming to class to listen to a lecture, students might listen to a recorded lecture online and then go to the WisCEL space to tackle practice problems at computer workstations, which would provide immediate feedback as they submit answers. Instructors and teaching assistants also would be available to help students as they work through the problems.

“This really challenges people to ask, ‘How do we engage students and how do we best teach students today?’” says Deb Helman, the director of Wendt Commons. “Space really does influence how people teach, and one of the things we’re trying to create is a space that is as flexible as possible.”

The flexibility of the WisCEL spaces sets them apart from other experimental teaching and learning environments at other institutions. “We haven’t found a combination elsewhere that serves as both teaching space and group study space,” Helman says.

Wendt Commons is a popular location for group study, especially for engineering students. A WisCEL priority for the Wendt Commons location was to create a space that could continue meeting students’ needs, while adding additional instructional functionality. “Students use the building heavily, and they’re always asking for more improved space,” Helman says. “This is a big win for our students.”

Introductory engineering courses in electrical circuits and statics will be held in the Wendt Commons WisCEL space as early as spring 2012. The College Library location will host introductory math, and in the next couple of years experimental language courses also are planned.

“We want to see more students emerge as successful learners and for all of them to emerge from college at higher levels of learning than they are currently,” Booske says. “We’re applying the very best we now know about how human learning occurs and how different learning approaches and spaces maximize or inhibit effective human learning. We’re creating learning environments—a combination of learning methods and the spaces that support them—that will achieve that objective of maximum success for everyone.”

WisCEL is supported by a grant from the Madison Initiative for Undergraduates, a campuswide effort to improve the quality and long-term value of undergraduate education at UW-Madison.

—Sandra Knisely
Engineers team up with Trek for cycling research

During a long bike ride, it's not unusual for cyclists to experience hand or finger numbness, a very common condition known as cyclist's palsy. The condition ranges from mild tingling to, sometimes, long-term nerve damage and hand muscle atrophy over time.

A team of UW-Madison engineers has scientifically measured hand pressure during cycling and studied potential solutions to reduce that pressure, which can cause problems like cyclist's palsy, a condition that Wisconsin-based Trek Bicycle Corporation estimates affects as much as 70 percent of cyclists. Trek has incorporated the UW-Madison findings into the design of a new Bontrager cycling glove that it released in winter 2010.

Mechanical Engineering Associate Professors Heidi-Lynn Ploeg and Darryl Thelen led the UW-Madison team, which studied the effects of seven glove (or no glove) types and three hand positions on the hands of 36 experienced cyclists. Ploeg and Thelen found that much of the pressure on cyclists' hands is concentrated over the ulnar nerve and gloves with proper padding density, thickness and placement are able to reduce pressure over this region of the hand. Also, the team found certain hand positions can alleviate pressure, such as holding the part of the brake attached to the handlebars, a position known as "hoods."

Ploeg, a biomechanics expert and an avid cyclist, says partnering with Trek was a unique opportunity to look at the potential of cycling research. "Cycling is a really accessible activity for people. It's something a lot of people can do and could use to improve their health," she says.

Research informs EPA coal-combustion products ruling

Working with the energy industry through EPRI, the Electric Power Research Institute, Wisconsin Distinguished Professor of Civil and Environmental Engineering Craig Benson, Civil and Environmental Engineering Professor Tuncer Edil and graduate student Jonathan O'Donnell concluded a study that quantified the economic and environmental benefits of using coal-combustion products in beneficial construction applications, such as Portland cement.


Nuclear expert testifies about U.S. reactor safety

In the wake of the devastating earthquake in Japan and the effects of the resulting tsunami on the Fukushima Daiichi nuclear reactors, Wisconsin Distinguished Professor of Engineering Physics Michael Corradini presented testimony April 6, 2011, to a U.S. House subcommittee about the state of U.S. nuclear plants and safety practices.

In his testimony to the Subcommittee on Oversight and Investigations of the House Energy and Commerce Committee, Corradini addressed the effects of the natural disaster on the Fukushima Daiichi plants, the effects of the accident progression on the surrounding region, and how the United States nuclear industry can learn from those events.

Corradini recently was appointed co-chair of the newly formed American Nuclear Society Special Commission on Fukushima Daiichi. The committee will examine the major technical aspects of the Japan accident to help U.S. policymakers and the public better understand the consequences of the accident and its lessons for the U.S. nuclear industry.

Corradini is a member of the U.S. Department of Energy Nuclear Energy Advisory Committee and chair of its Reactor Technology Subcommittee. He is a member of the U.S. Nuclear Regulatory Commission Advisory Committee for Reactor Safeguards and a member of the French Atomic Energy Scientific Committee. He also is involved in national nuclear energy activities for the U.S. National Academies.

Monroe manufacturer partners with UW-Madison on electric truck

Monroe, Wisconsin, is a small city with a big reputation for its cheese. Now, a partnership between manufacturer Orchid Monroe and UW-Madison engineers may expand the city's expertise to include clean vehicle technology. Orchid Monroe is providing support for researchers from the Wisconsin Electric Machines & Power Electronics Consortium (WEMPEC) to develop a particularly rugged experimental electric vehicle: a Ford F-150 pickup truck.

Once graduate students, led by electrical and computer engineering graduate student Phil Kollmeyer (right), and Orchid Monroe engineers convert the truck to an electric vehicle, it will become an up-to-date testbed for a wide range of battery and powertrain performance experiments. Orchid Monroe is providing the truck and equipment, as well as setting aside facility space for students to use.

Orchid Monroe manufactures laminated electrical-grade steel components and assemblies for the automotive, electric motor, generator, lighting, transformer and wind power industries. In the past two years, the company has expanded into developing and manufacturing an electric traction drive system for buses and other large vehicle applications.

"Partnering with Orchid Monroe provides a wonderful win-win situation," says Thomas Jahns, WEMPEC co-director and the Grainger Professor of Power Electronics and Electrical Machines in the Department of Electrical and Computer Engineering. "There are opportunities for them to benefit in the near-term with their business plans, while creating a test bed for us to pursue research into techniques for solving our nation’s long-term energy supply problems."
American naval ships usually conjure images of aircraft carriers or other large vessels far out to sea. The USS Freedom (LCS 1), however, is able to enter water as shallow as 14 feet, giving sailors unprecedented access to regions where the U.S. military is present, such as the Persian Gulf.

In addition to its extreme shallow-water abilities, the Freedom, which was built by the Wisconsin shipyard Marinette Marine, is unique in another way: It’s the first naval vessel to substantially include friction stir-welded components. The components, which directly contribute to the Freedom’s stealth and speed capabilities, came from Brookfield, Wisconsin-based Friction Stir Link Inc. (FSL), which has close ties to the College of Engineering.

Those ties include a research partnership with a team of mechanical engineering faculty and students that is yielding insight into the friction stir-welding process. Those insights have broad applications for transportation and manufacturing companies, both in Wisconsin and beyond.

The connection between UW-Madison and FSL started in the 1970s, when FSL vice president of technology John Hinrichs (who earned a master’s degree in metallurgical engineering from UW-Madison in 1964) worked at A.O. Smith Corporation, which had partnered with college faculty on robotics-related research. Hinrichs collaborated closely with then-student Neil Duffie, who went on to become a mechanical engineering professor. In the mid-1990s, one of Duffie’s students, Chris Smith, worked on advanced robotics with Hinrichs and eventually joined A.O. Smith after graduating with a master’s in mechanical engineering in 1995.

Smith is now the FSL vice president of engineering and operations. Shortly after starting at A.O. Smith, he and Hinrichs developed techniques for robots to perform friction stir welding. In 2001, the pair founded FSL, which is the only company in the world that uses standard industrial robots for friction stir welding.

The connection to UW-Madison resurfaced in 2003 when Duffie introduced Smith and Hinrichs to Mechanical Engineering Associate Professor Frank Pfefferkorn, who now leads a team including Duffie, ME Professor Nicola Ferrier and Assistant Professor Michael Zinn in studying the fundamental science behind friction stir welding and the robotics used in the process. The team collaborates with FSL to better understand the production realities of developing and implementing friction stir-welding technologies. “It really is a team effort,” Hinrichs says. “It’s exciting to be involved in this.”

Friction stir welding is an alternative to traditional fusion-welding techniques, where metals are heated to their melting point and fuse together as they cool and re-harden. Instead, friction stir welding is a solid-state welding technique, where thousands of pounds of pressure are applied via a robotic tool to “stir” metals close to, but below, their melting point. The pressure and heat create atomic-level contact between the metals, and they form new bonds, or weld, without melting. “This isn’t new—people have done this since the first iron-smiths folded metal over and over again and hammered it together to make swords,” says Pfefferkorn. “The idea is to apply temperature and pressure to bond the metal together.”

As traditional fusion-welded parts cool, the metals around the weld area contract at different rates, which can cause significant structural distortions. Those distortions have to be straightened, and in addition to the time and cost associated with straightening, fusion-welded parts often have weld beads protruding from the surface that must be ground down.

The lower temperatures in friction stir welding mean smaller temperature differences and thermal stresses occurring as the metals cool. Usually, the result is limited distortions in the surrounding metal, eliminating the need for costly straightening. Additionally, friction stir welds are smooth, meaning no weld beads form.

“Innovation is what’s going to create jobs and foster industry, and if we they will have an advantage and be able to do something others can’t.”
The lack of distortion makes friction stir welding a valuable cost- and time-saving process for large-structure construction, such as ships, railroad cars and semi-trailer truck beds. Currently, friction stir welding is commercially viable for low melting point metals, such as aluminum and magnesium, and research is ongoing to develop processes to friction stir weld steel and other ferrous alloys.

The UW-Madison team has demonstrated promising new methods to monitor and control friction stir-weld temperature. Mechanical engineering PhD student Axel Fehrenbacher has developed a wireless data acquisition system to measure the temperature exactly where the stir-weld tool touches the joining materials. Those measurements can be monitored to develop predictive models to control the process temperature.

The UW-Madison team is also working on weld quality. Fehrenbacher and PhD students Edward Cole and Ted Shultz have developed experiments and process models for a weld-process control interface for people and computers. The team is studying how to allow FSL to weld together parts that may not be exactly the same size (or fit-up), which could prevent scrapping many expensive large components that don’t perfectly match.

Additionally, the team is studying methods to allow robots to perform friction stir welding on site. Right now, large panels have to be friction stir-welded together by custom-engineered machines at FSL. The panels then are shipped for assembly at, for example, Marinette Marine. “By working so closely with Friction Stir Link, we’ve learned what the biggest challenges are while using friction stir welding in actual production,” says Pfefferkorn.

Friction stir-welded components are an integral part of the USS Freedom design. Madison native Bruce Halverson is a quality assurance manager at Marinette Marine. “The biggest reason we came to Friction Stir Link was the limited distortion, which was critical for radar signature and weight,” he says.

The smoothness of friction stir welds means the aluminum deckhouse of the almost 400-foot long Freedom is very flat, which, combined with an angular design, makes it difficult for radar systems to spot. (Radar waves can pick up flat surfaces only within a very narrow range close to 90 degrees.) This stealth capability is crucial for the Freedom as it navigates a variety of water environments.

Additionally, weight is critical for littoral (shallow-water) combat ships, and the especially thin structure of the Freedom means traditional fusion welding would distort it terribly, says Halverson. “Friction stir welding was a huge advancement in technology that was critical for us to be able to build the littoral combat ship structure.”

The Freedom completed its maiden deployment in April 2010, which, among other missions, involved capturing drug-runner boats carrying several tons of cocaine across the Gulf of Mexico. The Freedom can also be used to quickly deliver humanitarian aid to areas in crisis around the world.

The U.S. Navy will commission 10 additional littoral combat ships from Marinette Marine, producing a significant number of jobs in Wisconsin over the next couple of decades. “It’s why I do what I do,” says Pfefferkorn of working on research with real-world applications. “Next to seeing students graduate and be successful, the best thing is to see technology you work on applied in industry. It’s even better if it’s in a Wisconsin company.

“Innovation is what’s going to create jobs and foster industry, and if we can get companies in Wisconsin to implement these technologies, they’ll have an advantage and be able to do something others can’t,” he says.

—Sandra Knisely
Mark Scheuer (BSECE '82) has turned a lifelong fascination with electronics into a dream company building audio control systems for the aerospace industry. Yet, it was hardly a straight path from tinkering in his grandfather's basement workshop to a degree in electrical engineering. Scheuer is sharing his story of overcoming academic challenges in the hopes it will encourage young people in similar circumstances to follow their dreams.

In 1968, I was in my grandfather's basement with my cousin when he showed me what happens when a wire is wound around a nail and connected to a battery. At 10 years old, I was fascinated by electricity.

In 1972, I became an amateur radio operator and built radios and transmitters as I attended high school in Manitowoc, Wisconsin. By my junior year, I realized that while I was mastering my electronic skills, I was failing miserably in acquiring the knowledge to be college material!

Even when I received our high school's 'Most Improved Student of the Year' award, I didn't qualify to go to college.

So, I attended a local technical school for an associate of science degree in electronics technology and found that achieving good grades was just applying good studying habits and discipline. After the first year of straight A's, I thought I was ready to attend college.

I applied to UW-Madison but was denied admission (understandably) due to my poor high school grades. But thanks to the electrical and computer engineering (ECE) department secretary, I was encouraged to apply to a smaller UW campus and consider transferring later. I attended UW-Stout and demonstrated that I was capable of doing well in academics. After my freshman year, I once again applied to UW-Madison—and this time the department chair accepted my application.

Before I could attend, I needed money for tuition. The next nine months I learned what it meant to feed assemblers on an assembly line where we were paid by the piece. It was physically demanding work, but after all, I did want to get my electrical engineering degree.

I enrolled in the ECE department in 1978. Even with my factory earnings and a student loan I still needed income for living expenses. There was a posting for an ECE graduate assistant position. I found out that it was at the Space Science and Engineering Center (SSEC) working with a satellite receiver system. Perfect! Thanks to the support of now-emeritus ECE Professor James Beyer, the graduate assistant position was changed to undergraduate assistant, and I got the job.

This was the opportunity of a lifetime. I worked side by side with a group of engineers and scientists who provided a tremendous amount of knowledge in both theory and practical application of electronics. SSEC lead electrical engineer Scott Ellington, my supervisor and mentor, gave me a great deal of flexibility on how to solve specific problems encountered when trying to receive the small signals from the polar orbiting weather satellite, TIROS-N.

Because of this experience, my grades and written recommendations by several of my professors, in 1980 I was hired as a summer intern with Hewlett-Packard (HP) in Santa Rosa, California. I worked on the HP8510 Time Domain Network Analyzer, which at the time, was an incredibly accurate instrument. The following summer I interned at the Rolling Meadows HP sales office writing demonstration software for field applications. And before the end of my senior year, I was offered my dream job at HP. So in 1983, I went to work for arguably the most innovative electronics manufacturing company of all time.

By 1984 I had saved enough money to purchase another dream, a well-traveled airplane. Among other things, the airplane needed an intercom. When I researched the intercom market, none of the existing systems met my requirements. So a friend and I designed and constructed an intercom that would set new standards for general aviation intercom systems. We founded PS Engineering in 1985.

While working full-time at HP, getting my own company off the ground, and starting a family, something had to give. While I admired and respected the ethos of Hewlett-Packard and my fellow employees, in 1994 I left my dream job to run my business full time. Leaving a secure and rewarding job was difficult but it proved to be a good move. The enjoyment of creating products and seeing them being used in all sorts of applications is extremely rewarding. The last 25 years have given me the opportunity to build a company that I’m sure even Bill and Dave (Hewlett Packard founders) would be proud of.

PS Engineering has worked tirelessly to innovate, patent, and build many quality avionics that place us as the leading manufacturer of aircraft audio control systems. Our products have been used in such unique places as the U.S. naval warfare department; vintage WWII aircraft, including P-51, B-17, B-29; and even in spaceships known as SpaceshipOne. We are scheduled to blast off again in the foreseeable future with SpaceshipTwo.

I’m looking forward to what awaits my company for the next 25 years. I have a loving, beautiful and supportive wife, and I have children that make me so very proud to be a father. And one more thing I know for sure: The education, support, and opportunities that the UW-Madison had given me as an undergraduate have been the basis for a career in electronics that I could never have imagined when I was in my grandfather's basement.”
We decided to catch up with one of the early champions of our Innovation Days competitions: Matt Younkle (BSEE ’97). Younkle parlayed his success in the 1996 Schoofs Prize into the highly successful TurboTap, a fast-pouring beer dispenser used in sports stadiums across the globe. Now, he’s launching a new venture called murfie.com.

One of the things I loved about being a student was the abundance of opportunities to think creatively. I was a kid with a lot of crazy ideas, including one that involved a way to pour beer faster. Fortunately for me, a new competition for students had sprung up on campus: the Schoofs Prize for Creativity. Sponsored by UW-Madison alumnus Richard Schoofs, this contest was created to reward the individual or team with the best idea for a patentable product. Finally, I had an outlet (with a deadline, a support network and potential prize money) for my ideas! Just this tiny bit of structure was the difference-maker for me.

My fast beer-pouring idea, called TurboTap, took first place in the 1996 Schoofs Prize, and the experience paved the way for what has become a rewarding career as an entrepreneur. In particular, TurboTap was named a top invention of the year by TIME Magazine and is now used to pour tens of millions of beers every year around the world. Next to meeting my wife, the Schoofs Prize was the single-most influential part of my UW experience.

From crazy ideas to career entrepreneur

I recently moved back to Madison after spending over 10 years away, both in Chicago and abroad. In reconnecting with the College of Engineering, I was immediately struck by the high level of entrepreneurial energy that now fills the UW-Madison campus. The Schoofs Prize (and associated Tong Prototype Prize) is still an annual event, and the Burrill Business Plan Competition—which started a few years after Schoofs—is seeing record participation. But these long-running events are now only a fraction of the contests, activities and resources available to students with entrepreneurial ambitions for their crazy ideas.

I haven’t found just one single catalyst for this newfound entrepreneurial energy at UW-Madison. Certainly the economy has something to do with it; with fewer jobs available after graduation, starting a business feels less risky than it used to. Involvement from the Kauffman Foundation has also provided entrepreneurial resources to all corners of campus. Whatever the cause, it’s absolutely inspiring to see so many students interested in pursuing their passion and turning ideas into products and new businesses.

Looking beyond campus, the Madison startup community is doing its part to secure Madison’s position as the creative capital of the Midwest. Groups like Accelerate Madison, Design Madison, Capital Entrepreneurs, MAGNET, and MERLIN offer terrific mentoring and networking opportunities. Last fall, Madison hosted the first Forward Technology Festival, a weeklong series of conferences and social gatherings modeled after the successful South by Southwest festival in Austin, Texas.

Today, I’m completely immersed in Madison’s evolving startup culture as founder of Y Innovation. Another one of my crazy ideas has become my new digital music venture, murfie.com, that allows you to ‘free your CDs.’ While there are certainly easier paths to success than a career as an entrepreneur, I love the journey and have the Schoofs Prize to thank for getting it all started.”

Three engineers are among 13 young Badgers to receive prestigious Wisconsin Alumni Association Forward under 40 awards.

Anthony Eggert (ME ’96) serves America’s most populous state by looking for solutions to climate change, energy security and clean, renewable sources of energy. Eggert is the deputy secretary for energy policy at the California EPA, where he works on clean-energy policy, including energy efficiency, renewable energy and low-carbon fuels and vehicles.

Amidst the chaos of war, Major Rudy Quiles (MEPP ’09) worked to bring stability, opportunity and purpose to civilians in some of the most dangerous parts of Iraq and Afghanistan. A highly competent engineer and manager in the civilian world, Quiles took his skills overseas on two tours of duty as a civilian affairs officer with the U.S. Marine Corps to lead reconstruction and economic development projects in both Fallujah, Iraq, and Afghanistan’s war-torn Nawa District of the Helmand Province.

Dalia Mogahed (CBE ’97) is a senior analyst and executive director of the Gallup Center for Muslim Studies, where she leads the analysis of an unprecedented survey of Muslims worldwide, including in the United States and Europe. She is also the founding director of the newly established Abu Dhabi Gallup Center. With John L. Esposito, she co-authored the groundbreaking book Who Speaks for Islam? What a Billion Muslims Really Think. In 2009, U.S. President Barack Obama appointed Mogahed to the White House Advisory Council on Faith-Based and Neighborhood Partnerships, making her the first Muslim American woman to hold a position of this seniority.
When the doctor came in, he pressed on the tumor in Neeraj Arora’s chest and said Arora had lymphoma. As he recoiled in pain from the pressure on his chest, all Arora could think was, “Dave, you were so right.”

Arora was thinking about his graduate advisor, Industrial and Systems Engineering Professor Emeritus Dave Gustafson, who directs the UW-Madison Center for Health Enhancement Systems Studies (CHESS). Gustafson once had told his students that breast cancer patients reported going emotionally numb as doctors delivered the bad news.

“I couldn’t process anything the doctor was telling me,” Arora recalls of his diagnosis on Halloween 1994. “I was in a daze, and a nurse dressed as a witch bumped into me. She apologized for scaring me, and I told her she did not scare me, but the doctor sure did.”

At the time, Arora was in his third semester as an industrial and systems engineering graduate student. Prior to UW-Madison, he had earned his bachelor’s degree in India and was pursuing a master’s degree in manufacturing at Kansas State University when he visited his sister and brother-in-law, who were students at UW-Madison. During the visit, Arora met with Gustafson and discussed shifting his career toward healthcare.

By the fall of 1994, Arora was working for Gustafson at CHESS and taking classes when he started to feel excruciating pain all over his body. Eventually, he was diagnosed with an aggressive case of non-Hodgkin’s lymphoma.

Among the first people to visit Arora as he began a 49-day stretch in the hospital were Gustafson and Pascale Carayon, Procter and Gamble Bascom Professor in Total Quality and industrial and systems engineering.

Though Arora was worried about losing his position as a research assistant and, by extension, his healthcare, the CHESS team and department friends petitioned the university on his behalf. Arora was able to remain enrolled for a few credits, and Gustafson paid for his health insurance and assured him a job would be waiting.

Gustafson told Arora he had a unique opportunity to conduct quality of care research. “This is the most in-depth internship you can have,” Arora recalls Gustafson saying. Though neuropathy in his fingers prevented Arora from writing for much of those 49 days, he acutely observed and kept track of his experiences. “Making these observations helped me cope and gave me focus,” he says.

While in the hospital, Arora’s weight plummeted to 88 pounds, and he lost so much muscle he was unable to lift his chin or head. He suffered from intense side effects, including mucositis, which prevented him from eating or talking for several days.

Yet throughout, Arora maintained his sense of humor and awareness of what was happening around him. At the heart of his observations were the doctors and nurses providing treatment. He remembers exceptional kindness by particular nurses and doctors, and callousness by others, including the physician who diagnosed him. “You have to be human,” he says. “Be there for the patient; give them hope.”

It took about a year for Arora to be healthy enough to return to school and research full time, but he never questioned that he would go back. “I was so motivated and wanted to give back to the cancer community,” he says. “I wanted to make contributions that would make a difference to patients.”

Arora’s experiences as a patient not only inspired his graduate research but also launched his distinguished career as a cancer communication researcher. After receiving his industrial and systems engineering master’s degree and PhD in 1998 and 2000, respectively, he accepted a position as a research scientist in the Division of Cancer Control and Population Sciences at the National Cancer Institute (NCI), where he was, and remains, the only engineer.

Now a program director in the institute’s Applied Research Program, Arora hopes to facilitate the delivery of patient-centered care that would provide patients and their family members with ongoing support beyond initial diagnosis and treatment. For more than 12 years, Arora’s research has integrated the fields of health communication, cancer control, and public health.
communication, outcomes research and cancer survivorship. His expertise includes assessing patient-reported outcomes, such as patient experiences and satisfaction, information needs and health-related quality of life, and the impact of patient-clinician communication.

In 2007, Arora directed the publication of a comprehensive NCI report on patient-centered communication that aimed to reduce suffering and improve healing. His team outlined a model for healthcare professionals and organizations that includes the need to understand a patient’s worldview, how to facilitate informed decision making, manage uncertainty, and help patients self-manage once at home by developing supportive relationships among the care team, patients and their family members.

The same year, Arora found himself again on the receiving end of clinical treatment. He was diagnosed with congestive heart failure, a possible result of his intense chemotherapy regime. Even though Arora is an especially savvy healthcare consumer, he says the heart condition was an entirely new ballgame.

“There are more fears when you have a family and dreams,” he says.

Though it’s been more than a decade since his cancer went into remission, his heart treatment experiences showed Arora that there is still a need for better clinician communication training. “Things are changing in terms of doctors realizing they need to be interpersonal, but we don’t train doctors and nurses together as a team, and we need to teach all clinicians how to be sensitive to patient needs,” he says.

As he battles his latest health challenges, Arora continues to make significant research contributions. In November 2010, he received a National Institutes of Health award of merit from National Cancer Institute Director Harold Varmus. The award recognizes Arora’s leadership in building a research program to assess, monitor and improve the delivery of patient-centered cancer care.

Arora continues to hold onto lessons he credits to Gustafson. “Do research that truly makes a difference—that’s what CHESS taught me. There’s no point doing research just to get published,” he says. “It has to have the potential to somehow affect the lives of people.”

—Sandra Knisely

In our winter 2010 issue, we ran a photo of alum Mark Polster’s Michigan license plate and asked you to send us photos of the creative ways in which you tell the world you’re a Badger engineer. Here are just a couple of your responses!

Karyn Wagner of North Saint Paul, Minnesota, wrote: “I told my husband, also a Badger, when I moved to Minnesota, the only way I would get Minnesota plates would be with a Wisconsin reference. I think I succeeded!” (Photo above.) Wagner also sent photos of Bucky adorning both her red garage door at home and her graduation cap when she received her master’s degree from the University of Minnesota.

And Paul A. Kuhn of Lake Tomahawk, Wisconsin, says: “I can’t duplicate Mark Polster’s Michigan license plate, but I do tell the world about my UW degree on my Bucky Badger license plate. (Photo below.) Accept the snow and ice wreath, as it is Christmas here in the Northwoods.”
Wonder how a UW-Madison mechanical engineer ended up doing research on cell culture?

I am not talking about me. I actually am referring to Charles Lindbergh, one of our most celebrated student from the Department of Mechanical Engineering. While Lindbergh is famous for his trans-Atlantic solo flight from New York to Paris, it’s less known that he co-authored a book, titled The Culture of Organs, with 1912 Nobel laureate Alexis Carrel.

I am lucky and privileged enough to be taking a similar “detour” with an opportunity to work with a group of multi-disciplinary researchers.

Unexpected twists and turns:

How I ended up doing tissue engineering scaffold research

Imagine a world where people with diabetes no longer have to worry about the food they eat, where a man who suffered a major heart attack can be seen running a marathon less than a year later, where a woman who once needed a cane can now walk through the aisles of a grocery store pain-free. These are the types of advances that tissue engineering can bring to society.

Tissue engineering is an interdisciplinary field that applies the principles of engineering (materials science, polymer processing, engineering design, micro-fabrication and biomedical engineering) in combination with the life sciences (biochemistry, genetics, cell and molecular biology) to the development of biological substitutes that can restore, maintain or improve the functions of diseased or damaged human tissues. Tissue engineering will not only lead to the next generation of medical implants, but also will bypass the need for tissue replacement by fostering repair and regeneration.

Tissue engineering scaffolds are biological substitutes on which healthy human cells can be seeded, proliferated and differentiated into various types of functional tissues, inside or outside of the human body, for medical treatments and drug screening.

Recent stem cell developments at UW-Madison and elsewhere are exciting, and induced pluripotent stem cells hold great promise for regenerative medicine. Tissue scaffolds provide one of the enabling platforms on which the significant benefits of stem cell and regenerative medicine research could be materialized.

Tissue engineering scaffolds are actually complex structures that are made of either natural or synthetic polymers. Depending on how they are fabricated and their required functions, scaffolds come in a wide variety of shapes and structures, with some even mimicking the physical construction of an organ. Many contain numerous tiny micropores, or channels for transporting nutrients, oxygen and wastes.

As the cells grow and penetrate, the scaffold will degrade to provide space for the cells or allow for the release of embedded drugs that then foster tissue regeneration or repair.

While tissue engineering scaffolds are not new, the ability to produce them in large quantities and for a wide array of applications is. The reason that major advances in healthcare have not been seen to date is that there has been no way to provide reliable and reproducible scaffolds to hospitals and clinics around the world. Current patient needs cannot be met by making one scaffold construct at a time in a research laboratory. If we accept the challenge of imitating nature, we must develop a cost-effective manufacturing process for making scaffolds in the same way as other mass-produced products are made. That was our impetus for embarking on this great endeavor.

Anyone who saw the 1967 movie “The Graduate” will probably remember the one word of advice that Mr. McGuire solemnly gave Benjamin: “plastics.” Plastics, which are polymeric compounds with additives added for the purposes of cost and performance, have become the materials of choice for many engineering applications, despite their inferior mechanical properties (compared to metals or ceramics). Factors such as cost-effectiveness, consistency of product quality and feasibility of mass production are what make plastics so attractive.

Of all of the plastics used, approximately one third go through injection-molding machines. This makes the injection-molding process the most important polymer processing method available for mass-producing net-shape plastic components with complex geometries and excellent tolerances.

I’ve been involved in researching and developing various novel injection-molding processes using conventional polymers, biobased blends and nanocomposites for many years. By employing a patent-pending process we developed here at UW-Madison, we can injection-mold 3-D, highly porous scaffolds made of biodegradable materials. In addition, by adding very tiny nanoparticles (on the order of tens or hundreds of nanometers) to the polymer matrix, we can tailor the mechanical properties of the resulting scaffolds. This is very important because, depending on the rigidity of the underlying scaffolds, mesenchymal stem cells actually turn into bone, cartilage or fat cells.

Healthcare is on the precipice of a huge expansion, with tissue engineering scaffolds at the forefront of invention and innovation. The effects of such an advance are far-reaching. The chronic diseases that plague our nation, such as heart disease, cancer and diabetes, could benefit from the drug delivery and tissue repair and re-growth opportunities offered by tissue engineering scaffolds.

Ten years ago, I would not have imagined myself working in the field of tissue engineering. Nonetheless, as I look back, my previous research on injection molding, biobased polymers and nanocomposites has paved the way for this interdisciplinary research opportunity. I look forward to leveraging the magic and science of the self-regenerative power of our cells for advancing the health and well-being of our society.
Human (above) and bovine (below) chondrocytes, the only cells found in cartilage, cultured within nanofibrous scaffolds.
President Obama honors Henderson for mentoring

On January 27, 2011, U.S. President Barack Obama presented Engineering Physics Professor Douglass Henderson one of 15 Presidential Awards for Excellence in Science, Mathematics and Engineering Mentoring, the highest federal award for mentoring in the country. Henderson received the honor for his significant contributions to mentoring pre-college, undergraduate and graduate students and young faculty—particularly underrepresented minorities—in engineering and the sciences. In particular, the award recognizes Henderson’s efforts in establishing and growing the Graduate Engineering Research Scholars program on the College of Engineering and UW-Madison campus. GERS is a unique graduate fellowship program designed to offer students a support network of peers. Through GERS, students become members of a supportive community of UW-Madison engineering graduate students, faculty and staff.