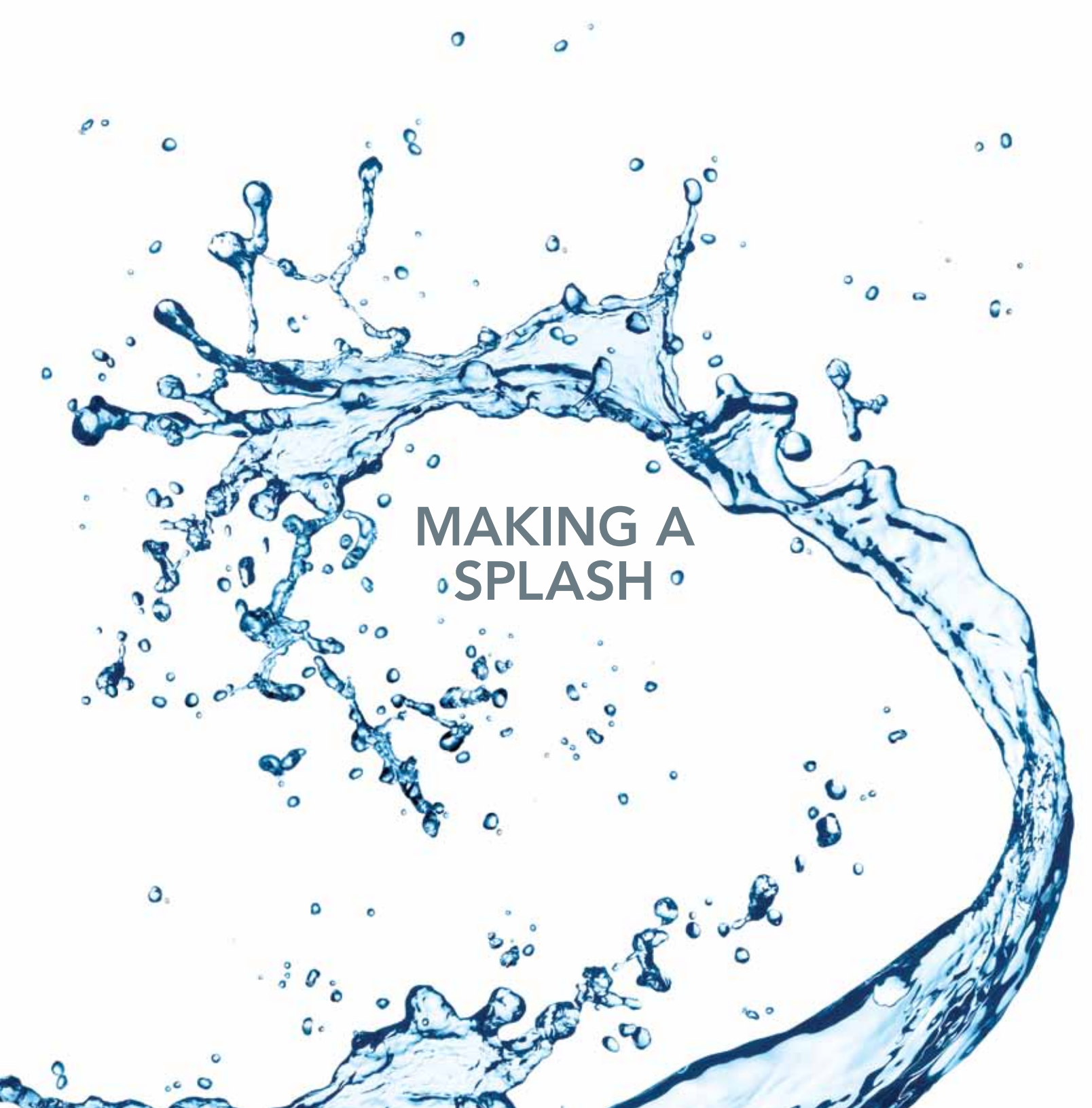
Research

MICHIGAN TECHNOLOGICAL UNIVERSITY › 2010



MAKING A SPLASH

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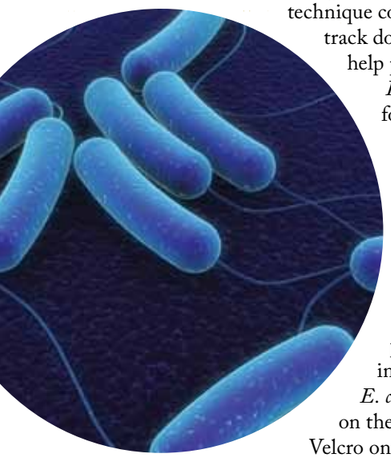
Celebrating 125 Years

On the Cover
Two Michigan Tech physicists, Alex Kostinski and Raymond Shaw, made a splash in the meteorological world last year when they made a discovery that could mean it's raining less than we think.

GLOWING BACTERIA COULD HELP PINPOINT PATHOGENS, CANCER CELLS



A team of Tech researchers led by Associate Professor of Chemistry Haiying Liu has discovered how to make *E. coli* glow under fluorescent light. The technique could eventually be used to track down pathogens and even help pinpoint cancer.

E. coli bacteria are naturally found in intestines and are usually harmless. But virulent strains can cause serious illness and even death.

Liu's team attached molecules of the sugar mannose to specially engineered fluorescent polymers and stirred them into water swimming with *E. coli.* Microscopic hairs on the bacteria hooked like Velcro onto the mannose molecules, effectively coating the bacteria with the polymers. When the researchers shined fluorescent light into the solution, the bacteria lit up under a microscope like blue fireflies.

The technique could be used to identify multiple pathogens by mixing and matching from a library of sugars and polymers that glow different colors. If blue means *E. coli,* fuchsia could one day mean influenza.

Liu is adapting the technique to combat breast cancer. Instead of mannose, he plans to link the fluorescent polymers to a peptide that homes in on cancer cells.

Once introduced to the vascular system, the polymers would travel through the body and stick to tumor cells. Then, illuminated by a type of near-infrared light that shines through human tissue, the polymers would glow, pinpointing the location of the malignant cells.

FROM THE ROOTS UP: GROWING TREES FOR SUSTAINABLE BIOFUEL

New tree varieties with wonder roots could one day supercharge the biofuel industry.

Victor Busov and his team aim to develop poplar trees that thrive in dry, infertile soils. Their work is funded by a three-year, $900,000 grant from the joint USDA and Department of Energy's Plant Feedstock Genomics for Bioenergy Research Program.

"Biofuel crops will be grown on marginal lands," says Busov, an associate professor in the School of Forest Resources and Environmental Science. "These plants will have to be pretty robust, and we're focusing on the roots."

The project has two parts. In the first, poplars will be grown in dry, nitrogen-poor soil, and researchers will track how the trees' genome responds. Then they will modify key genetic "hubs" to grow trees with roots suited to those conditions.

In the second experiment, they will generate random mutations in poplars. If any of the plants thrive in dry, infertile conditions, the scientists will use that information to grow hardier varieties.

Developing trees that like poor, droughty soils could boost biofuel production and reduce dependence on petroleum. Plus, it could bring the biofuel industry closer to sustainability.

"If we start on the wrong foot, we are setting ourselves up for disaster in the long run," says Busov. "Using nitrogen and water more efficiently to produce biomass is simply more sustainable."

MICHIGAN TECH SCIENTIST WINS GOOGLE EARTH COMPETITION

Tyler Erickson, a research scientist at the Michigan Tech Research Institute in Ann Arbor, has created a new way to use Google Earth that lets anyone from a schoolkid to a scientist learn more about the comings and goings of carbon dioxide over North America. His efforts were compelling enough to win a Google Earth contest on presenting scientific results using KML. Programs like Google Earth can display a KML file through time, making an animation.

Most people think of Google Earth as a fun way to zoom around the planet without leaving the comfort of their computer. Tyler Erickson's KML file loads data on atmospheric carbon into Google Earth, so users can watch where carbon dioxide comes from and where it goes over time.

Named "North American Carbon," it relies on data collected by NASA-funded researcher Anna Michalak and her group at the University of Michigan. Erickson's project can help teachers, students, and the general public understand how atmospheric carbon dioxide is measured and how those measurements are affected by factors such as wind and weather.

To see Erickson's program, go to earth.google.com/gallery. In the search field at the top of the page, type "North American Carbon." You will need to download Google Earth software.

"Freedom [is] the first-born daughter of science."

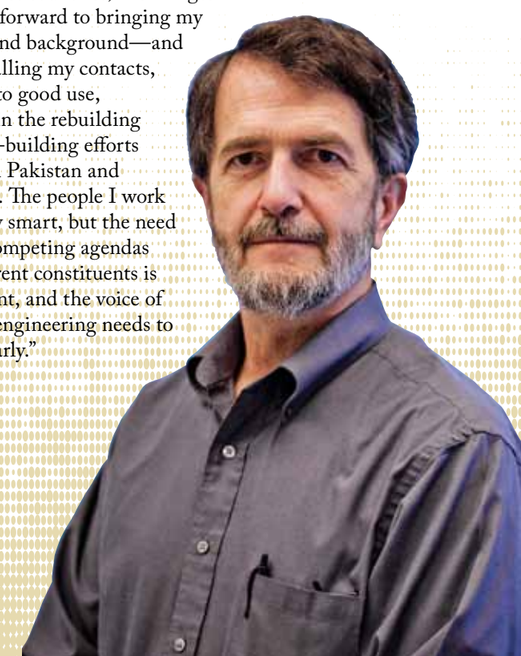
—Thomas Jefferson

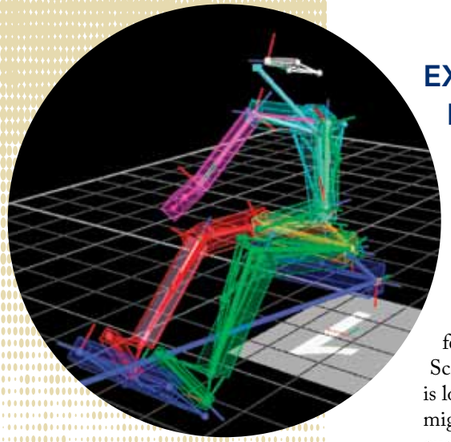
PENNINGTON NAMED JEFFERSON SCIENCE FELLOW

Wayne Pennington, professor and chair of the Department of Geological and Mining Engineering and Sciences, has been named a Jefferson Science Fellow by the US Department of State. Pennington is serving a one-year assignment working full-time as a senior engineering advisor with a group at the United States Agency for International Development.

He will help countries develop strategies to rebuild their infrastructure, particularly in post-disaster and post-conflict settings in Pakistan and Afghanistan. He will focus primarily on better energy development and distribution and on earthquake hazard mitigation.

"I can no longer complain about the apparent lack of knowledge of the oil and gas industry, or of the minerals industry, as our government assists post-disaster or post-conflict countries," Pennington says. "I look forward to bringing my knowledge and background—and frequently calling my contacts, as needed—to good use, particularly in the rebuilding and capacity-building efforts under way in Pakistan and Afghanistan. The people I work with are very smart, but the need to balance competing agendas among different constituents is always present, and the voice of science and engineering needs to be heard clearly."





EXERCISE FOR EVERYONE

Do obese people avoid exercise because the equipment is not designed for them? Does the pain or discomfort sometimes associated with exercise keep them from working out?

Karen Roemer, an assistant professor in the Department of Exercise Science, Health and Physical Education, is looking at how exercise equipment might be hindering workouts of the seriously overweight. Specifically, Roemer records the movements of people of all shapes and sizes as they work out on a rowing machine.

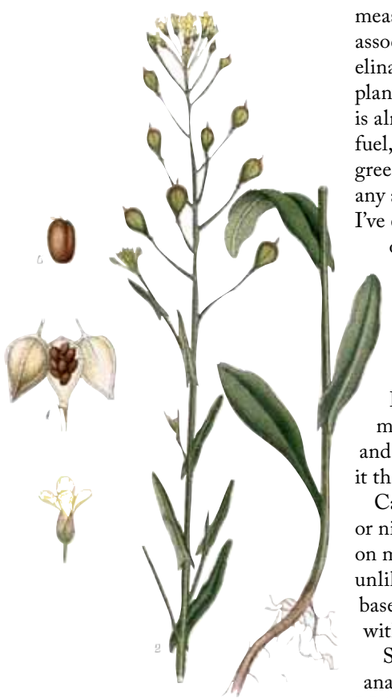
To track movements, Roemer and her team use small, reflective markers attached to the rower's skin and photograph them with multiple cameras. Similar to modeling a golfer's swing for a videogame, the many markers are translated via software that reproduces the movement.

"These are complex biomechanical problems," Roemer says. To model the knee alone, they used MRI scans and collected motion analysis data using eighty reflective markers and twelve digital cameras.

The resulting model looks like it came from *The Matrix:* complicated processes and images broken down by all the markers, then reassembled to resemble the real knee.

"Potentially, we could give equipment manufacturers suggestions for new designs," says Roemer.

JET FUEL FROM CABBAGE'S COUSIN COULD SLASH CO_2 EMISSIONS



The seeds of a lowly weed could cut jet fuel's cradle-to-grave carbon emissions by 75 percent.

David Shonnard, Robbins Chair Professor of Chemical Engineering, measured the carbon dioxide emissions associated with jet fuel made from camelina oil over its entire life cycle, from planting to exhaust. "Camelina jet fuel is almost an exact replacement for fossil fuel, and it exhibits one of the largest greenhouse gas emission reductions of any agricultural feedstock-derived biofuel I've ever seen," he said. "This is the result of the unique attributes of the crop—its low fertilizer requirements, high oil yield, and the availability of its coproducts, such as meal and biomass, for other uses."

Camelina sativa originated in Europe and is a member of the mustard family, along with cabbage and canola. Sometimes called false flax, it thrives in the Northern Plains.

Camelina needs relatively little water or nitrogen fertilizer, and it can be grown on marginal agricultural lands. And unlike ethanol made from corn or soy-based biodiesel, it would not compete with food crops.

Shonnard conducted the life cycle analysis in collaboration with UOP LLC, of Des Plaines, Illinois, a subsidiary of Honeywell, and Targeted Growth Inc. of Seattle.

AN INDOMITABLE MIND

Researcher discovers genes linked to Lou Gehrig's disease

by Marcia Goodrich

Math professor Shuanglin Zhang and PhD student Rebecca Fang

About five years ago, mathematics professor Shuanglin Zhang received news anyone would dread.

He had amyotrophic lateral sclerosis (ALS), commonly known as Lou Gehrig's disease. It would creep though his body, the doctors said, slowly destroying the nerves in his brain and spinal cord that control voluntary movement. Eventually he would become paralyzed, unable to move or speak.

Faced with such a sentence, Zhang did not try to fill his remaining able-bodied days with skydiving, safaris, or a visit to the pyramids. The one item on his bucket list was his work. He resolved to enlist his intellect in the war against ALS.

Zhang is a statistical geneticist and the Henes Chair Professor in Mathematical Sciences. Along with his wife, Qiuying Sha, an assistant professor of mathematical sciences, and other members of his research team, he uses statistical techniques to track down the genetic underpinnings of complex diseases. The team had already found eleven genetic variants, called SNPs ("snips," for single-nucleotide polymorphisms) in genes linked to type 2 diabetes.

There are two types of ALS: The familial form, which accounts for about 10 percent of the cases, is inherited. The cause of the sporadic form was unknown. Zhang had sporadic ALS and suspected that, like type 2 diabetes, it was fundamentally linked to the interactions of multiple genes.

With complex inherited conditions, a number of genes can cause disease when they act together. In the past, finding these gene-gene combinations has been almost impossible because of the myriad calculations needed to match up suspect genes among the half million or so in the human genome. More importantly, the DNA datasets needed to perform the analysis are often unavailable or nonexistent.

Then, while exploring The ALS Association's website, Zhang discovered the information he needed. The datasets detail the genetic codes of over five hundred people, about half with sporadic ALS and half without. Zhang and his team applied their methodology, called a two-locus interaction analysis. It revealed that people with sporadic ALS had a combination of three genes with atypical SNPs.

The mathematicians were not surprised when they tracked down the genes' street addresses. "Everybody has twenty-three chromosomes, and the three genes on chromosomes 2, 4, and 10 interact," explains Sha. "If you have this combination of the three genes, you are at high risk of developing the disease."

Xiaofeng Zhu, an associate professor of epidemiology at Case Western Reserve University's School of Medicine, called the study "very nice work."

"It's very challenging to map genes for complex diseases, and while many statistical methods have been developed, most don't work well in practice," says Zhu. "Zhang's group has developed a method to detect genes and gene-gene interaction in complex diseases and provided evidence that it works.

"Their findings will need to be confirmed by other researchers, but I think this will be very useful for the investigators who are trying to find genes underlying complex diseases such as ALS," says Zhu.

While their discovery does not mean an end to ALS, it could provide medical researchers with valuable clues as they search for a cure. If they find one, it will probably be too late to help Zhang. Since he began the effort to uncover the genetic causes of ALS, the disease has taken its toll. He is now almost completely paralyzed and breathes with support from a ventilator. He continues to work at home with the aid of research assistants, his wife, and an ingenious low-tech tool they developed that lets him spell out words, sentences, and research papers.

The letters of the alphabet are written in five rows on a card, with several letters to a row. A helper points at each row in sequence, and Zhang blinks if the letter he wants is in that row. The helper then reads or points across the row, and Zhang blinks again at the correct letter.

It seems like it would take forever. It doesn't. Using this simple grid and a similar chart of mathematical symbols, Zhang recently completed a paper and submitted it for publication.

Not everyone who gets ALS is willing to live within these constraints. Some decline the use of mechanical ventilators and perish from respiratory failure. Zhang decided early on that he would fight the disease as long as he could.

With help from his wife and research partner, Qiuying Sha, statistical geneticist Shuanglin Zhang has tracked down three genes behind ALS, the disease that has destroyed his ability to move and speak.

"He wants to keep doing his research," explains his wife, Qiuying Sha. "For him, that is the most important thing." Once someone asked him what he would want if he could have one wish granted. "You would think he would say 'to be cured of ALS,' but he said 'a breakthrough in my research,'" she recalls.

✦ ✦ ✦

People with ALS have huge hurdles to overcome, says Sharon Matland, vice president of patient services for The ALS Association. "Despite not being able to speak, not being able to move, they work so hard to stay engaged in life, whether it's doing work, or going to a child's athletic event, or being with their families. They continue to do amazing things."

Many patients participate in research, she says, though rarely as scientists. They volunteer for clinical trials knowing that it may be too late for them to benefit from any discoveries. "They want to do something, and if their participation in a research project will help others, they do it. As in Dr. Zhang's case as an ALS researcher, it is also altruistic.

"It is a devastating disease, and it takes everything away," Matland says. "The fact that Dr. Zhang is able to continue his research is to be applauded. What he has done is outstanding."

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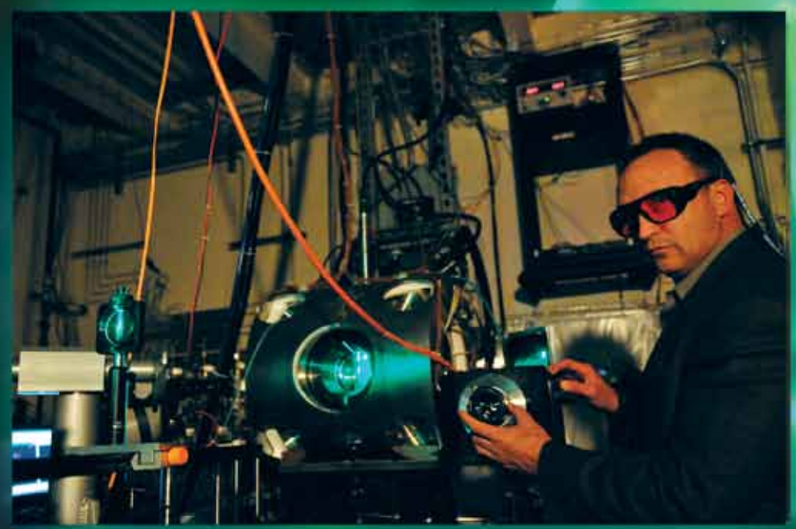
Zhang continues to conduct his research four hours a day in collaboration with PhD student Shurong (Rebecca) Fang. He reclines in his chair with a laptop computer mounted above while they work on their most recent paper, "Two-Locus Analysis for Genome-Wide Association Studies."

In the beginning, as ALS burdened him with one constraint after another, Zhang found the disease nearly impossible to bear. Now, as he blinks out elaborate formulae that may one day save lives, he is more resigned.

"Nothing else I can do, and I like to do research," he says, spelling out the message one letter at a time. ■

MAJOR OVERHAUL

DRIVING A NEW ERA IN ENGINE TECHNOLOGY



by Marcia Goodrich

Clean Machines
Michigan Tech's Jeff Naber aims to understand the most fundamental processes of internal combustion. What he discovers will be used to engineer the next generation of cleaner, more-efficient engines.

Internal combustion engines have been around since the seventeenth century, and they have been powering cars since Karl Benz built his first automobile in 1885. But even in the Information Age, we still don't truly know what goes on inside these workhorses of the Industrial Revolution.

That's not surprising, considering that most of the action occurs when a mist of volatile fuel mixes with air and combusts inside a sealed cylinder. "We have been able to harness that process, but we don't fully understand what's happening," says Jeff Naber, an associate professor of mechanical engineering–engineering mechanics.

To find out, Naber and his research team have put together a glittering array of equipment, paid for in part by a $1.4 million grant from the National Science Foundation. It funds one of four major projects that Naber has a hand in, ranging from this fundamental study of how engines work to graduate education in advanced hybrid vehicles for Detroit's auto engineers.

The NSF-funded lab in the Alternative Energy Research Building includes a laser powerful enough to vaporize carbon and a camera that takes a million frames per second. "This allows us to do some pretty cool stuff," he says.

The laser passes through a clear-sapphire window the diameter of a softball, made from a single, perfect crystal that took a year to grow and polish. The camera captures images of fuel mixing with hot gases and igniting and combusting, courtesy of the laser, within one-thousandth of a second inside the custom-made chamber.

"We have numerous models of the processes that occur, but many are based on empirical correlations," says Naber. "This laboratory allows us to dive deep inside the cylinder and understand what's happening in this dynamic process under extreme pressures and temperatures."

During experiments, the engineers control what's going on in an adjacent control room, where they preprogram the entire process on computers and watch the action on a number of video monitors.

The experimental setup offers huge advantages over a stock internal combustion engine. "It's much more fundamental," explains PhD student Jaclyn Nesbitt. "We can isolate variables and gain a better understanding of individual processes."

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Naber expects to apply that understanding to another project: developing engines that continuously adapt to changing fuels, environmental conditions, and engine variability and wear.

"It's pretty exciting," he says. "It would transform how engines operate."

Combustion control systems are now calibrated according to what Naber calls "the worst case scenario," which works OK on nearly all engines but

not perfectly on any. An adaptable engine would sense those difference and respond throughout the life of the engine. "We could continuously monitor and control combustion to maximize efficiency and minimize emissions" he says. "The goal is to sense what an engine is doing and adjust to it continuously, even as it fires fifty times a second in each cylinder."

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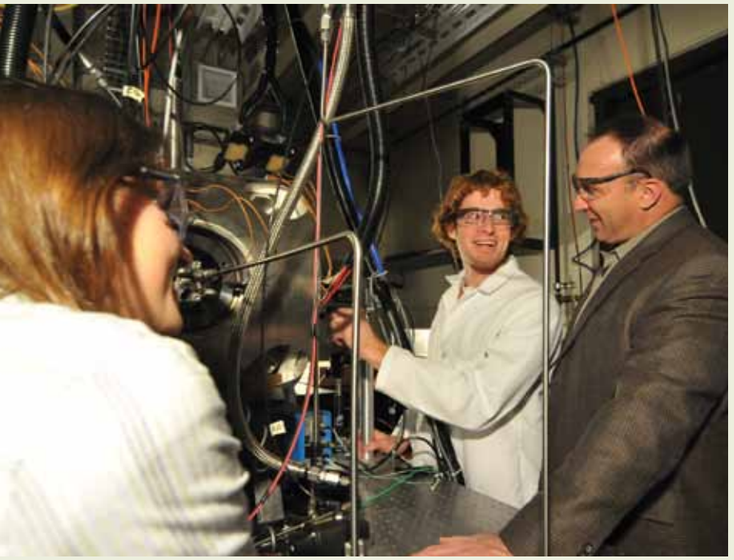
Controls are also key in a $2.8 million research project to reduce diesel engine emissions while improving fuel economy, supported in part by $1.8 million from the Department of Energy. In response to government regulations, diesel emissions have plummeted in the past decade, to the point that the exhaust coming out a tailpipe is often cleaner than the surrounding air. However, those gains have been paid for in increased fuel consumption. If the emissions aftertreatment and engine systems were better integrated, fuel economy could be improved.

"A significant impact of this work will be with respect to biofuels," says Naber. Mixing biodiesel and petroleum-based diesel fuel can reduce emissions, but only so far. Once biodiesel exceeds 20 percent, the aftertreatment system performance can deteriorate. "We need to make a system that works together," says Naber, especially as the industry moves away from petroleum.



"THIS ALLOWS US TO DO SOME PRETTY COOL STUFF"

Jeff Naber, right, and graduate students Jaclyn Nesbitt and Chris Morgan prepare to record the intricacies of internal combustion, courtesy of an elaborate laser-camera system.

Naber leads another project on a different kind of internal combustion engine: a hybrid that runs on flex fuel and meets the world's most stringent emissions standards. "There is no ethanol flex-fuel hybrid available because it's a big challenge to meet these emissions standards," he says.

That work is being funded by a $1.5 million grant from the Michigan Public Service Commission and over $1 million in support from General Motors, Sensors Inc. of Saline, Argonne National Laboratory's Transportation Technology R&D Center, and Michigan Tech.

Flex-fuel engines can burn anything from pure gasoline to E85—a blend of 85 percent ethanol and 15 percent gas. Ethanol contains only 63 percent of the stored energy of gasoline and requires about three times the energy to vaporize. Straight gasoline, however, can cause engine knock in a high-performance engine that would run smoothly on ethanol.

The researchers are addressing ethanol's benefits and rough spots. "Under most conditions, gasoline and ethanol behave similarly," says Naber. "But there are differences under high load—when you put the pedal to the metal—where the ethanol provides a significant benefit—and during cold start, when emissions go up significantly with ethanol blended fuels."

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No matter what the vehicles of the future looks like, one thing is certain. They won't get any simpler.

"Today's vehicles are extremely complicated already. With hybrids we've added a whole new dimension, and with plug-in hybrids, we're going to interconnect two large systems, transportation and the electrical grid." Naber says.

With that in mind, he has led two graduate classes for automotive engineers in Detroit, most recently with funding from the Michigan Academy for Green Mobility, and is spearheading a new Master of Engineering degree program that focuses on hybrid vehicle technologies. The aim is to create a trained workforce that can handle the vehicle design and development challenges and recognize the opportunities arising in a shifting energy landscape.

"We are focusing on developing their technical knowledge in these new areas, so the auto industry can transition from petroleum," says Naber.

Wherever that transition leads, Naber looks forward to being in the thick of it. "For me, the interesting thing about these projects is getting to work on problems that are important and challenging, and doing things that need to be done." ■

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www.me.mtu.edu/research/power
www.me.mtu.edu/researchAreas/aice

PHYSICISTS MAKE A SPLASH WITH RAIN DISCOVERY

by Jennifer Donovan

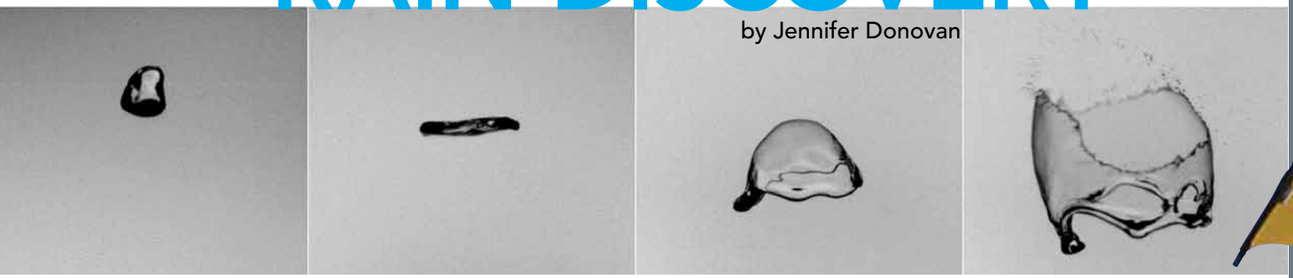


Photo courtesy of Emmanuel Villermaux. It was originally published in his paper "Single-Drop Fragmentation Determines Size Distribution of Raindrops," coauthored with Benjamin Bossa and published July 20, 2009, in *Nature Physics*.

It's conventional wisdom in atmospheric science circles: large raindrops fall faster than smaller drops because they're bigger and heavier. And no raindrop can fall faster than its "terminal speed"—its speed at which the downward force of gravity is exactly the same as the upward air resistance.

Now two physicists from Michigan Tech and colleagues at the Universidad Nacional Autónoma de México (National University of Mexico) have discovered that it ain't necessarily so.

Some smaller raindrops can fall faster than bigger ones. In fact, they can fall faster than their terminal speed. In other words, they can fall faster than drops that size and weight are supposed to be able to fall.

And that could mean that the weatherman has been overestimating how much it rains.

The findings of physics professors Alexander Kostinski and Raymond Shaw, and their Mexican colleagues Guillermo Montero-Martinez and Fernando Garcia-Garcia, could improve the accuracy of weather measurement and prediction.

The researchers gathered data during natural rainfalls at the Mexico City campus of the National University of Mexico. They studied approximately 64,000 raindrops over three years, using optical array spectrometer probes and a particle analysis and collecting system. They also modified an algorithm to analyze the raindrop sizes.

They found clusters of raindrops falling faster than their terminal speed, and as the rainfall became heavier, they saw more and more of these unexpectedly speedy drops. They think that the "super-terminal" drops come from the break-up of larger drops, which produces smaller fragments all moving at the same speed as their parent raindrop and faster than the terminal speed predicted by their size.

"In the past, people have seen indications of faster-than-terminal drops, but they always attributed it to splashing on the instruments," Shaw explains. He and his colleagues took special precautions to prevent such interference, including collecting data only during extremely calm conditions.

Their findings could significantly alter understanding of the physics of rain.

"Existing rain models are based on the assumption that all drops fall at their terminal speed, but our data suggest that this is not the case," Kostinski says. If rainfall is measured based on that assumption, large raindrops that are not really there will be recorded.

"If we want to forecast weather or rain, we need to understand the rain formation processes and be able to accurately measure the amount of rain," Shaw points out.

Taking super-terminal raindrops into account could be of real economic benefit, even if it leads only to incremental improvements in precipitation measurement and forecasting. Approximately one-third of the economy—including agriculture, construction, and aviation—is directly influenced by the ability to predict precipitation accurately. "And one-third of the economy is a very large sum of money, even during a recession," Shaw remarks.

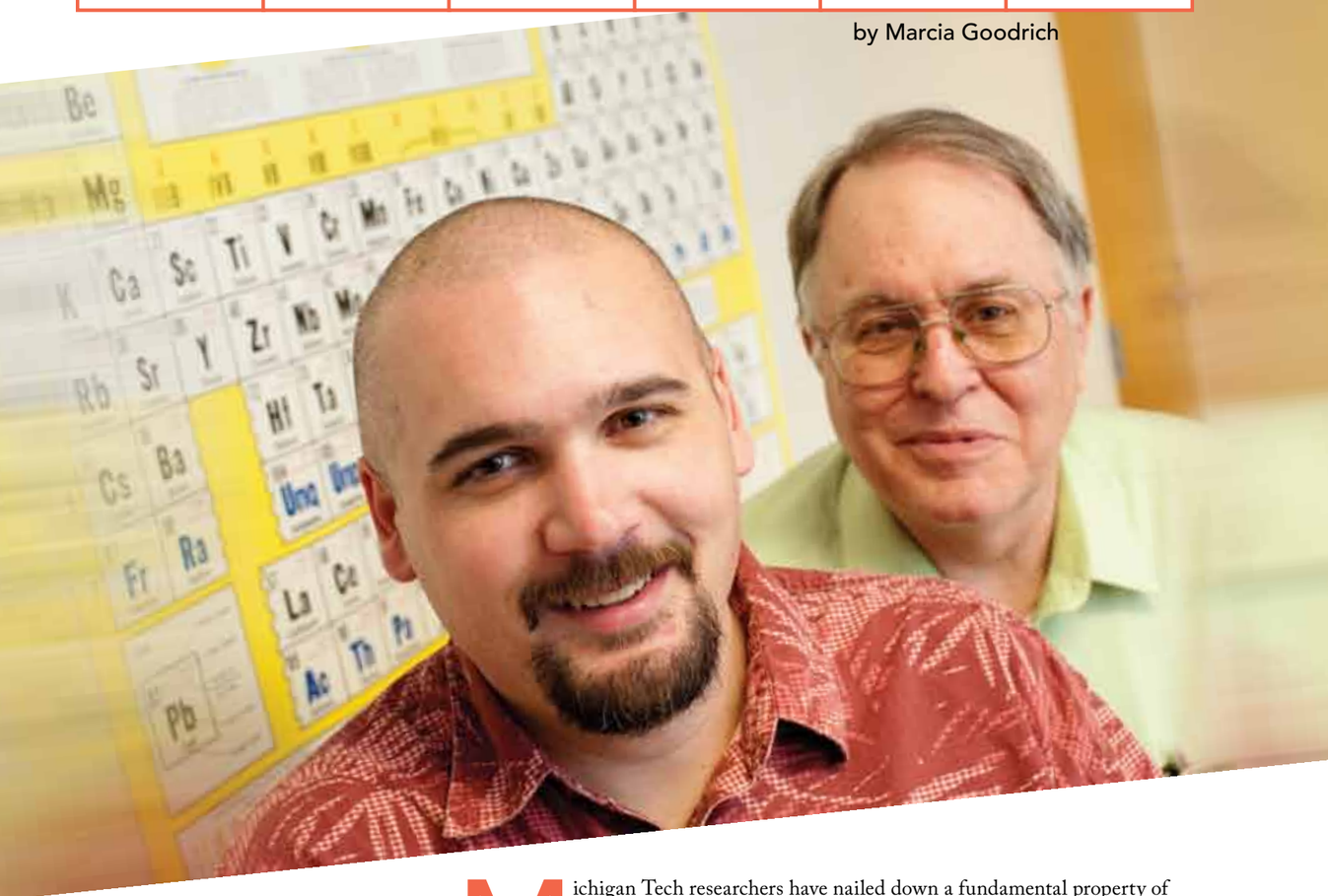
The physicists' research was supported in part by the National Science Foundation and was published June 13, 2009, in the American Geophysical Union's journal *Geophysical Research Letters*. ■

FOR MORE INFORMATION
www.phy.mtu.edu/shaw
www.atmos-sci.mtu.edu

Physicists Alex Kostinski and Raymond Shaw have shown that smaller can be faster, at least where raindrops are concerned.

IT'S NOT E Le Me Nt Ar Y

by Marcia Goodrich



Theoretical physicists Steven O'Malley and Don Beck

Michigan Tech researchers have nailed down a fundamental property of some of the biggest, baddest elements on the periodic table.

Physics Professor Don Beck's research team, including Research Associate Steven O'Malley, has calculated electron affinities for the lanthanides and the actinides, the twenty-eight heaviest elements which make up the last two rows of the periodic table.

Lanthanides, also known as rare earths, are used in the production of lasers and sunglasses. Actinides, the bottom dwellers of the periodic table, are arguably the scariest collection of elements on Earth, including as they do plutonium and other deadly substances.

"Electron affinity" is the amount of energy required to pluck an electron from an anion (an atom with an extra electron orbiting around its nucleus). Elements with low electron affinities (like iron) give away that extra electron easily. Elements with high electron affinities (like chlorine) hang onto it for dear life, so understanding electron affinity is critical for predicting the outcome of chemical reactions.

"I remember learning about electron affinities in tenth-grade chemistry," said O'Malley. "When I began working as a grad student in atomic physics, I was surprised to learn that many of them were still unknown."

They were, in fact, the lanthanides and actinides. In terms of atomic structure, these are perhaps the most complex of elements, which is why no one had been able to calculate their electron affinities before.

Here's what makes them so tricky. Electrons orbit in shells around an atom's nucleus, something like the layers of an onion, but in stranger shapes. Within each shell are a number of subshells. A subshell is like an egg carton: it can hold from one to a certain number of electrons, but no more.

Typically, as you work your way down and across the periodic table to larger and larger atoms, the inner shells fill up with electrons, and then new shells and subshells are formed sequentially and fill up pretty neatly.

That's not what happens with the lanthanides and actinides. Before one subshell in the sequence fills up, additional electrons begin making even more shells. Then, as you move across the periodic table to the heavier atoms, electrons finally occupy all the vacancies in that first shell.

Why would this matter for electron affinity? Several forces hold electrons in their orbits around the atom's nucleus. Two simple ones are electrons' attraction to protons in the nucleus and repulsion away from their fellow orbiting electrons, what Beck calls "the B.O. effect."

A full shell exerts forces that are pretty constant on the electrons orbiting farther from the nucleus, which had made it relatively easy to calculate the electron affinities of most elements. But if there are vacancies in a shell—as there are in the lanthanides and actinides—the electrons in that shell can shuffle around, playing musical chairs, as it were.

The forces exerted by an electron vary depending on which slot it occupies. And, in addition to simple electrical factors, there are other complex variables to contend with at the subatomic level, including relativistic and many-body effects.

Here's how it works with the lanthanides. Before the so-called 4f subshell fills up, the additional electrons begin making new shells. Then, as you move across the periodic table to heavier atoms in the lanthanide series, that 4f subshell is fully occupied with its maximum number of fourteen electrons.

With several electrons bouncing around in those fourteen slots, over two hundred different arrangements of electrons in the 4f subshell are possible in some of the lanthanides. "It's a nightmare," says Beck.

His group of theoretical physicists began their work on electron affinities in 1994, focusing on the lanthanides. Then in 2007 they made a computational breakthrough that allowed them to drill into the "nightmare" middle of the row from both ends, one anion at a time. In just eighteen months, they found electron affinities for all the remaining lanthanides.

With the rare earths under their belt, the team decided to forge ahead with the actinides in 2009. "They were even more complicated," said O'Malley, since even more subshells are involved, and they, too, do not fill up neatly and cleanly. "But having worked on the lanthanides, I knew what to expect."

Armed with advanced methodology and plenty of experience, the researchers finished calculating the electron affinities of the entire actinide row in about five months.

What's next? Their findings will be referenced in the next iteration of the classic text *The Handbook of Chemistry and Physics,* now in its ninetieth edition.

The team's theoretical results have already been partially verified by experimentalists, but the process may take awhile. "Universities don't like to deal with actinides—they are both radioactive and poisonous," Beck notes. ■

FOR MORE INFORMATION
phy.mtu.edu/~donald/lanea.html.

Tech physicists unearth the secrets of atomic heavyweights

ULRICH HANSMANN HONORED FOR RESEARCH ON PROTEIN FOLDING

by Jennifer Donovan

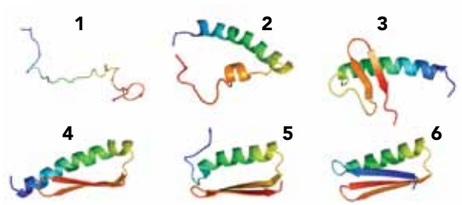
Ulrich Hansmann, professor of physics and leader in computational and biophysics research, has received Michigan Tech's 2009 Research Award.

Hansmann is renowned for his computational modeling of protein folding, a molecular process that, when it goes awry, can give rise to neurological diseases such as Alzheimer's. His work could help uncover the underlying processes causing proteins to misfold, potentially leading to effective therapies.

"Uli's achievements in the protein-folding problem—one of the most significant challenges in science today—have been astonishing," says Robert H. Swendsen, professor of physics at Carnegie Mellon University.

As a leader in the field of systems biology, Hansmann's work straddles the intersection of computing and biology, one of the hottest areas in science. By modeling molecular networks and simulating cellular biophysics, Hansmann aims to give medical researchers new tools to study complex diseases.

"Many biological systems just can't be studied experimentally," he said. "You have to use a computer simulation." Protein folding is a case in point. As proteins form, pairs of molecules join together, a process called dimerization. It happens so quickly and on such a small scale that observing it is impossible with existing technologies. But computer models can predict how and where the molecules latch onto each other and where things might go wrong.



Protein folding processes can make origami seem chaotic. This simulation illustrates how a model protein arranges itself in a specific sequence to create the perfect shape.

"The idea of using computers as virtual microscopes is catching on, and it will have a growing influence on the life sciences over the next ten or twenty years," says Hansmann. He adds that the field is intriguing enough to have captivated billionaire scientist-financier David Shaw, who now leads his own lab that develops computers specialized for simulations of proteins and other biological macromolecules.

Systems biology is more than the next big thing in science, however. It also makes good economic sense. Lab-based experimental research is expensive, and computer models can help scientists narrow their experiments down to the most promising lines of inquiry.

One of the molecules Hansmann and his team are studying is the beta-amyloid peptide, which makes up the plaque that forms in the brains of Alzheimer's patients. "We are interested in the early stages of the outbreak," he says. In particular, they are curious about exactly when peptides become malformed. Does a single peptide fold the wrong way, causing a cascade of plaque formation? Or is this deformation a natural result of countless peptides joining together to form the long polymers that make up plaque? "Each of these scenarios would suggest a different strategy to inhibit plaque formation," Hansmann says.

Although Hansmann is doing cutting-edge work, he is in no way proprietary about it. He has developed a software program called Simple Molecular Mechanics for Proteins (SMMP) that is freely available as open source software. One of his ongoing research goals is to develop public software for molecular simulation of cells. He also helped the John von Neumann Institute for Computing in Jülich, Germany, develop a computational biology and biophysics research group.

He recently was named a Fellow of the American Physical Society (APS). His research is supported by the National Science Foundation and the National Institutes of Health. ■

FOR MORE INFORMATION
www.phy.mtu.edu/biophys

› To view a video of Ulrich Hansmann discussing his research, go to www.techtube.mtu.edu/hansmann

SMARTZONE AT TEN: SMART IDEA

by Dennis Walikainen

Left to right, Steve Fitzgerald of Consistacom, SmartZone CEO Carlton Crothers, and Glen Simula of GS Engineering

It's been a challenge since the mines closed more than forty years ago—attracting new business to the Copper Country.

Over the past decade, at least one great solution has emerged. The Michigan Tech Enterprise Corporation (MTEC) SmartZone has helped twenty-three businesses get up and running, creating 251 jobs directly and supporting another 500 workers in peripheral businesses. The SmartZone, a partnership of Michigan Tech and the cities of Houghton and Hancock, helps entrepreneurs find space, secure financing, create business plans, and market their products and services.

The idea was hatched by the Michigan Economic Development Corporation. It identified communities throughout the state, usually with universities attached, where it could establish SmartZones: places where high-tech economic development would be nourished. Funding for these SmartZone services would come from state taxes captured from new development within Houghton and Hancock.

MTEC SmartZone incubates businesses in four locations: the Powerhouse Building in Houghton, the Advanced Technology Development Complex at Michigan Tech, the Jutila Center on Finlandia University's campus in Hancock, and the newly renovated Lakeshore Center in downtown Houghton.

The Lakeshore Center is the SmartZone's flagship structure, according to Carlton Crothers, chief executive officer. "We have lots of high-tech, moveable elbowroom to accommodate many new companies and their employees, including Michigan Tech students."

Beginning in 2003 with the Powerhouse, a 5,500-square-foot incubator, MTEC SmartZone now manages four high-tech business incubators totaling 51,000 square feet, including the most recent addition, the Lakeshore Center. In fact, the SmartZone administrative staff was elbowed out of the Powerhouse since one of their success stories took flight there: GE Aviation.

A subsidiary of General Electric, GE Aviation has created some fifty positions in the refurbished Powerhouse, focusing on software development, verification, and validation; and mechanical and hardware design, much of it defense related.

Another SmartZone-enabled company is across the lobby from Crothers' new office in the Lakeshore Center. Ford Motor Company has established an IT development center, which employs many Tech student engineers to do information systems support for the global corporation.

Another business, GS Engineering, has hit the big time. The sixty-employee company of mostly Tech engineering alumni has recently secured a $25-million, five-year government contract for military vehicle and materials testing. Owner Glen Simula '80 sings the praises of both Michigan Tech and the SmartZone.

"We wouldn't be here without Tech," he says. "I can't stress that enough. We get asked sometimes why we aren't in Minneapolis or Detroit, but we have this great university right here in this beautiful area. We can attract the kind of engineers who want to live in the Keweenaw. This is home."

The SmartZone helped GS Engineering first by leasing office space. The company moved to a larger site, and now that new building might not be big enough.

"We are talking about expanding this spring," Simula says.

Across the Keweenaw Waterway in Finlandia University's Jutila Center is Consistacom, a business focused on automated call centers and telephone network configuration. It is the brainchild of Steve Fitzgerald '74, who started the business in his house fifteen years ago. Soon, seven people were wedged into a three-person work area.

That's where the SmartZone first came in and leased him space. Since then, the SmartZone has stepped up to help his company survive and grow—big. His current client list includes many famous corporate names that can't be named.

But it wasn't all rosy.

"Without the SmartZone, we would have folded a couple of years ago," he says point blank. "They've helped us in many ways, and we've actually spun-off another company, KPBIZnet, to do telephone work for the SmartZone. We can move in a new business in the morning and get them networked and working by noon."

Fitzgerald also cites the strong Internet connection, via Michigan Tech, as important to the SmartZone's allure. The personalized assistance doesn't hurt either.

"[Program director] Jon Leinonen has helped us and other companies here tremendously," he says. Leinonen routinely coordinates educational sessions for his clients on intellectual property issues, lifecycles of business, and more.

So, it's been a mutually beneficial marriage, Fitzgerald says: he can do work for the SmartZone, and they can help Consistacom thrive in the Copper Country, where, among other amenities, he can hire Tech grads.

"Usually, we are just geeks who know how to do our business but need help with marketing and those other aspects," Fitzgerald says. "The SmartZone gives us that expertise, so we can succeed." ■

FOR MORE INFORMATION
www.mtecsz.com

The newly renovated Lakeshore Center is the latest building to provide space for up-and-coming businesses, courtesy of the Michigan Tech SmartZone.

THREE TECH STUDENTS WIN GOLDWATER SCHOLARSHIPS

Academically, Michigan Tech is batting 1.000. All three of the University's nominees for prestigious Goldwater Scholarships this year were winners of the 2009 awards.

John Mark Gubatan, Hansen Nordsiek, and Eli Vlaisavljevich were named Goldwater Scholars by the Barry M. Goldwater Scholarship and Excellence in Education Foundation. Gubatan is a biochemistry and molecular biology major with a double minor in French and Spanish. Nordsiek is majoring in physics, and Vlaisavljevich is a biomedical engineering major, as well as a defenseman on Michigan Tech's hockey team.

Although Michigan Tech has produced a number of Goldwater Scholars in previous years, this is the first time the University has had more than one winner in any given year.

Goldwater Scholarships—established by Congress to honor the late Senator Barry M. Goldwater—are based on academic merit, research experience, and an intent to pursue a career in science, engineering, or mathematics. Colleges and universities nominate students for the scholarships, which cover up to $7,500 in tuition and fees.

"The Goldwater is one of the more prestigious scholarships you can win as an undergraduate in science, engineering, or math," said Will Cantrell, associate professor of physics and Michigan Tech faculty representative for the program. "It is highly competitive."

Eli Vlaisavljevich, Hansen Nordsiek, and John Mark Gubatan

The Goldwater Scholarship and Excellence in Education Foundation received 1,079 nominations last year and awarded 278 scholarships. Other winners in Michigan include four students at the University of Michigan–Ann Arbor, four at Hope College, and three at Michigan State University.

"Goldwater Scholars usually go on to do very well at getting National Science Foundation, NASA, Department of Energy, and other graduate fellowships," Cantrell noted. ■

BEFORE REFRIGERATORS, THERE WERE . . . OAK LEAVES?

Holistic healers have long touted the benefits of oak leaves as treatment for gastrointestinal ailments, insect bites, and more. Michigan Tech student Nari Kang may have discovered a groundbreaking new use: food preservation.

"This idea has been in my head since high school, after seeing a news story about the chemicals in food," Kang says. "I wondered—what did people do before there were refrigerators?"

Kang, a second-year bioinformatics major from South Korea, was inspired to pursue her research after hearing Korean folk culture stories about the preservative qualities of oak leaves.

"Theoretically, there are several reasons why oak leaves would make good food preservatives," Kang explains. "They contain a chemical component that acts as a natural preservative, they have a drying agent that tends to remove moisture, and they're large, which means they can be easily wrapped around food."

To find out if the leaves might have anti-fungal qualities, Kang gathered leaves from local oak trees and pulverized them. Then she extracted chemicals called terpene trilactones—molecules associated with positive health effects, including increased blood circulation to the brain—and dissolved them in methanol.

Kang then applied the extracts to a fungus often found in many of our kitchens—*Penicillium chrysogenum,* or common bread mold.

After a week in incubation, the results were incredible. Test plates treated with the leaf extract showed drastically reduced rates of mold growth.

"I was very excited," Kang says. "This really interests me."

Her research interests others as well. After presenting at last spring's Undergraduate Expo, Kang nabbed first-place honors in the Undergraduate Research division and created a buzz about potential applications in major food industries.

For now, she plans to focus on additional research, including testing to make sure the extract isn't harmful. Kang considers herself lucky to be at Michigan Tech, where she can tackle the research she's most interested in.

"When I started, I was only a first-year student," she says. "My professor, Dr. Ramakrishna Wusirika, helped me with my idea, showed me how to work in the lab. It's very exciting to be able to work on projects like this as an undergraduate." ■

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MAKING THE MOST OF WHAT WE'VE GOT

Sometimes it seems like we never have enough of what we need most, like time, space, and bandwidth. Alicia Thorsen specializes in finding ways to stretch those scarce resources.

Thorsen, a PhD candidate, applies her computer science savvy in ways that make it much easier for the rest of us to make do with less. She does this through an algorithm that solves the maximum weight matching problem. It is written in a language known as Unified Parallel C, which is designed to make it easier to program the coming wave of peta-scale supercomputers.

Thorsen explains. "Matching has to do with resolving problems where there are conflicts. Let's say the University has lots of courses and rooms, and you have to match up a course with a room. If you have a thousand courses at one time and a thousand rooms, then you haven't got a problem."

But, if those courses start and stop at different times, as courses often do, and if you'd like to keep a few rooms vacant for workshops or retirement parties, then your scheduling problem gets more and more complicated. Thorsen's algorithm makes it easy.

Or, perhaps you are jumping back and forth between several applications on your garden-variety PC, which has only one microprocessor to handle them all. Through maximum weight matching, it can juggle its effort to make it seem to you, the user, that everything is running smoothly.

And Thorsen's work can also help communication networks work better. Cell phone networks are a case in point. "Messages are sent to a destination in many packets," says Thorsen. Those packets can travel down any of a number of routes, and some routes are more congested than others. Her program distributes those packets in the most efficient way, so that more calls get through seamlessly.

Thorsen's efforts earned her high honors at the High Performance Computing and Simulation Symposium held in March 2009 in San Diego. Judges cited not only the elegance of her computer science but also the quality of her writing in naming "Weighted Matching Using the Partitioned Global Address Space Model" the conference's best paper.

In addition to completing her dissertation under the guidance of Assistant Professor Phillip Merkey, Thorsen works in Cupertino, California, as a software engineer for Apple, where she is figuring out ways to block junk email and prevent legitimate messages from being waylaid by spam filters.

"Apple is a great company, and I'm having a great time," says Thorsen. "I wanted to work at a big company with a lot of smart people, so this is my dream job."

The position doesn't require a PhD, she says, but she's grateful for her graduate education. "The depth of knowledge I have allows me to approach problems from a different angle," she says. "I sat down over the last couple days reading a dissertation on detecting junk mail; for me, it's like reading a newspaper." ■

MASTER'S STUDENT ASSESSES A SMALL LAKE WITH BIG PROBLEMS

Iron Mountain's Crystal Lake doesn't live up to its name anymore. A beautiful lake has become a blight.

"People didn't know where to begin to address the situation," says graduate researcher Jarron Hewitt, now a master's student in environmental engineering. So, as part of a Senior Design project, he and his fellow students undertook an investigation of the once-pristine lake, located about two hours south of Michigan Tech.

They first pinpointed the problem: the fifty-acre lake receives stormwater discharges that flush in coliform bacteria from animal waste, which makes it unhealthy, and phosphorous-rich lawn fertilizer, which stimulates algae growth. In the winter, the lake freezes over and the algae die off, sink to the bottom, and turn into muck.

Historically, the lake was 20 feet deep; now it is 9 feet deep. Core samples show that almost all of the disappeared 11 feet of water has been


Photo courtesy of Gene DuCharme

replaced by a thick layer of dead algae and other plant material, which, as it decomposes, uses up oxygen. Telltale, then: lots of dead fish in the spring.

Hewitt and his fellow Senior Design students assessed the condition of the lake and then proposed ways to restore it to beauty and "beneficial uses" like recreation. They came up with three recommendations:

- Divert storm water, the source of the bacteria and fertilizer.
- Aerate the lake to make sure there's more oxygen for fish.
- Dredge the lake to get rid of the muck that recycles phosphorous and consumes oxygen.

Hewitt, who works under the guidance of Professor Marty Auer, is now devising an engineering plan to restore Crystal Lake and estimating the cost. However, he confronts a reality of all enterprise: money, or rather, the lack of it. The biggest job, dredging, would cost several million dollars. Auer calls the assessment "a shovel-ready restoration plan."

Auer calls Hewitt "the face of this project," noting that he has worked with the city council and other civic leaders as well as conducting the engineering studies.

For his part, Hewitt is excited to help the people of Iron Mountain perhaps improve their community. "I feel like I'm giving something back," he says. Back in his hometown of Gwinn, Michigan, before he ever came to Tech, he never imagined such a "hands-on, real-world opportunity."

It is likely that Hewitt will mentor another student in similar work. The community of Fergus Falls, Minnesota, has sought help to assess its own lake, plagued by the same problems, all for the same reasons. Auer will oversee that work, which will begin next spring. That effort will involve another Senior Design project and another master's student, whom Hewitt will coach before he graduates in May. The Minnesota Pollution Control Agency is supporting Michigan Tech's work with a $50,000 grant. ■

GRAD STUDENT DRAWS ON NINETEENTH CENTURY FINDINGS FOR TWENTY-FIRST CENTURY RESEARCH

Deep in the stacks of the Van Pelt and Opie Library, Joe Miller stumbled upon a 112-year-old book that gave him a start.

Miller, who is a builder, recently earned his PhD in civil engineering specializing in heavy-timber roof design, keyed beams in particular. Keyed beams, lovely and useful though they may be, are in one sense an also-ran in the world of wood.

Miller explains in the context of the Upper Peninsula, where the old-growth, white-pine forests were ferociously clearcut in the nineteenth century. "By 1900, all the large trees were cut down," he said. The massive timbers required for constructing large buildings and reinforcing mine tunnels were gone. Builders needed a cheap, local alternative, so they began making big beams out of two smaller ones.

They cut mated notches in the lesser beams, fastened them together, and pounded close-fitting wedges, or keys, into the notches. The technique keeps beams stiff and bound tightly together, which prevents them from slipping (and breaking prematurely) when heavily weighted in the middle.

Keyed beams have been around since the eighteenth century. More recently, builders have adopted other technologies, but they aren't always popular. "A lot of my clients had problems with steel beams or glue-laminated timbers," Miller says. "Aesthetically, they wanted to use a more-natural approach that could be achieved locally."

Now, with keyed beams gaining a new following, Miller has developed the first theoretical model to represent their capacity under load. In other words, how much weight can they take before they break? And what factors determine if a keyed beam will be stiff enough?

Miller has been testing his model against his own experimental evidence using oak, yellow poplar, and wood laminate. "I've found that the inclination and shape of the keys can have an incredible effect" on the strength of the beam, he said.

He's not the first person to study keyed beams, which brings us back to the library and the 112-year-old book. Miller was perusing the library's offerings on the subject when he stumbled across an 1897 reference volume authored by Edward Kidwell, a faculty member at the Michigan School of Mines, now Michigan Tech.

As it turns out, Kidwell was one of the earliest researchers to test keyed beams and document the results. "It wasn't until I'd chosen a school and a dissertation topic that I found his book," Miller says, still struck by the coincidence. On top of this, Miller found Kidwell's century-old reports to be both reliable and engaging.

"I tested his methods, and everything he said appears consistent with our observations," says Miller. "To be reinvestigating a concept that's been around three hundred years is kind of cool." ■

STUDENT TRANSFORMS INTO NATIONAL GEOGRAPHIC STAR

Alex Guth, a PhD student, online lecturer, and Kenyan geology researcher, has been tapped as an expert for a National Geographic television show airing next spring. The focus of the Geographic TV special was the concept of Pangaea, the supercontinent that existed before the current continents parted ways.

The Kenya Rift shows today how continents tear apart, and the island of Madagascar is a consequence of past rifting. Madagascar's past connection to Pangaea is seen in rocks and animals of the island. For example, lemurs, unique to Madagascar, evolved there after the split, leaving their relatives in Africa. Guth works with geology professor James Wood and his East Africa Geology Group, which has undertaken field studies in Kenya for the past two years.

"I couldn't speak as a biologist," Guth said. But, she could discuss her areas of expertise: 1) mapping a visual history of the rift and 2) tracking the history of climate change in the region over the last 10 million years.

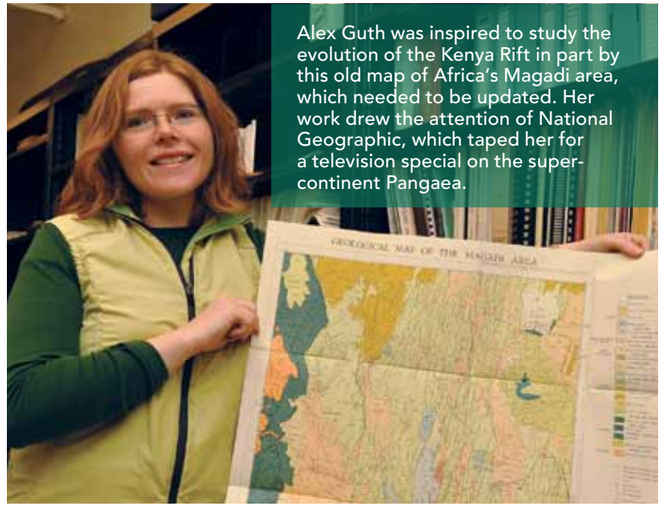
Producers working with National Geographic's TV show googled Alex and discovered that she had some camera-savvy and knew the geology of the Kenya rift area they were interested in portraying.

First, she had to do a phone interview, which turned out to be an audition. "They were asking me questions to see how I would respond," she said. She passed their test, and, when she got on location, she was asked many more questions multiple times.

"They'd keep asking until I smoothed it out," Guth said. "It's funny how you answer questions differently each time."

Spending long hours outside in Africa was not easy for Guth. Thanks to a lack of sunscreen and red hair, "it didn't take long to get sunburned."

She did remember to wear her Michigan Tech shirt, however, much to the delight of University officials.



Alex Guth was inspired to study the evolution of the Kenya Rift in part by this old map of Africa's Magadi area, which needed to be updated. Her work drew the attention of National Geographic, which taped her for a television special on the supercontinent Pangaea.

An additional, somewhat daunting task was explaining her work at a level television viewers could understand. "That means talking not as a scientist but as an ordinary person," she said.

And being on camera presented some other challenges.

"I had to gaze or point at a certain area that really meant nothing," she said. "The lighting would be right, and it just looked good on camera." ■

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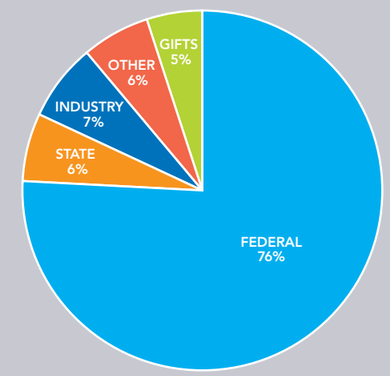
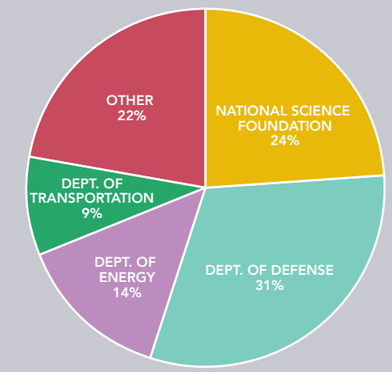
RESEARCH AND SPONSORED ACTIVITY

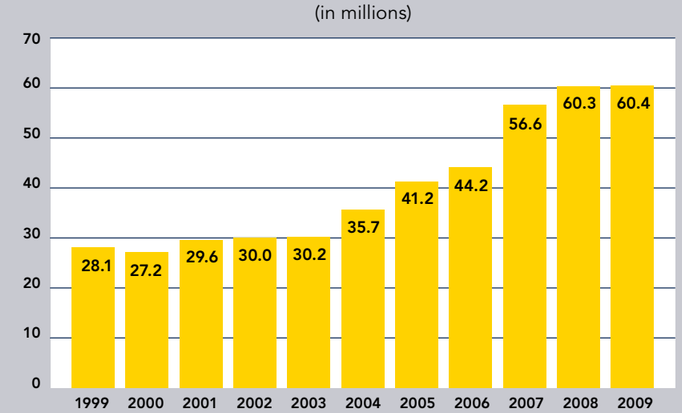
RESEARCH AWARDS BY SOURCE
Fiscal Year 2009



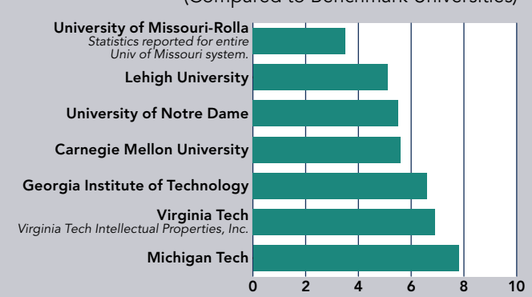
TOTAL FEDERAL AWARDS BY SOURCE
Fiscal Year 2009



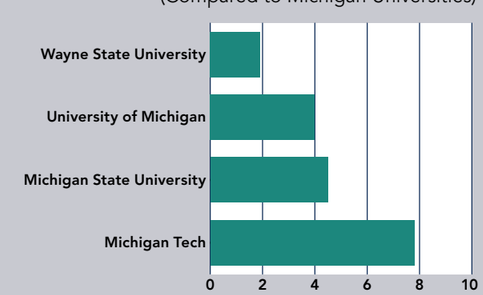
RESEARCH EXPENDITURES
(in millions)



2007 INVENTION DISCLOSURES PER $10 MILLION OF RESEARCH
(Compared to Benchmark Universities)



2007 INVENTION DISCLOSURES PER $10 MILLION OF RESEARCH
(Compared to Michigan Universities)



1885 – 2010

Michigan Tech

Celebrating 125 Years

Michigan Technological University
1400 Townsend Drive
Houghton, MI 49931-1295

In 1932, mining engineer Scott Turner received an honorary doctorate from his alma mater, then the Michigan College of Mining and Technology. Seventy-seven years later, Turner's historic hood was bestowed upon one of the first recipients of the University's PhD in Industrial Heritage and Archeology.

Cameron Hartnell, pictured here in the Michigan Tech Archives, spent four years tracking Turner's history-making work in Svalbard, an archipelago north of Norway, where the Arctic Coal Company pioneered northern mining in the early twentieth century with Turner as its general manager.

Michigan Tech is the only university that offers a PhD in Industrial Heritage and Archeology, which encompasses archeology, historic preservation, the history of technology, and anthropology.