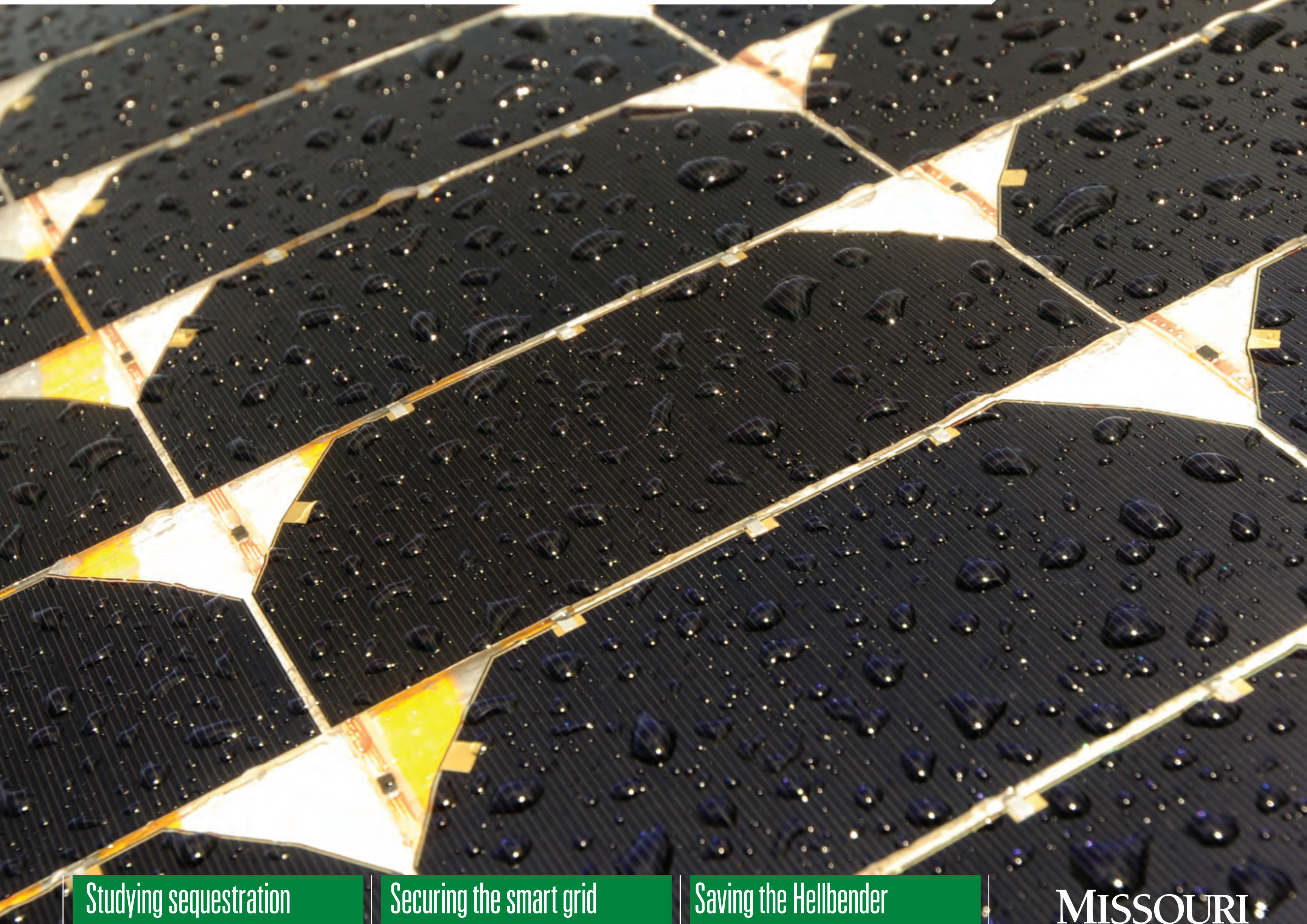
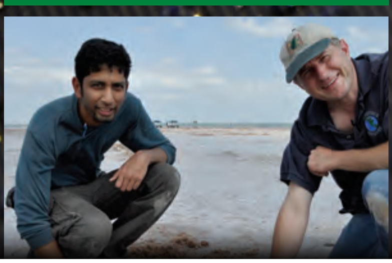
re:search

An inside look at innovation and discovery at Missouri University of Science and Technology

Fall 2010



Studying sequestration



Securing the smart grid

Saving the Hellbender

Missouri S&T
University of Science & Technology

Dear Colleague,

IT IS WITH GREAT PLEASURE that I inform you that FY10 was another record year for new awards and expenditures at Missouri University of Science and Technology. New awards reached a significant milestone, exceeding $50 million, and finished the year at $52.3 million. As I plan for the years ahead, I first want to reflect on the amazing accomplishments of our outstanding faculty, staff and students during this past decade. I applaud their successes and wish to highlight a few achievements.

» Research and other sponsored program expenditures doubled from $22.2 million to $44.7 million while enrollment increased by about 50 percent and the number of full-time tenured/tenure-track faculty remained essentially the same.

» A number of externally funded multidisciplinary centers were established with Missouri S&T either leading or collaborating with other universities to bring to bear the necessary expertise to solve complex problems. They include four National Science Foundation (NSF) Industry/University Cooperative Research Centers (High Energy Dielectrics, Intelligent Maintenance Systems, Friction Stir Processing, Electromagnetic Compatibility), the NSF Engineering Research Center for Future Renewable Electric Energy Delivery and Management (FREEDM) Systems, the Federal Aviation Administration Center of Excellence for Aerospace Particulate Emissions Reduction Research, the Center for Aerospace Manufacturing Technologies (CAMT), the CAMT Industrial Consortium and the U.S. Department of Transportation National University Transportation Center.

» Several of our early career faculty received highly competitive and distinguished NSF CAREER awards (Bill Fahrenholtz, Mehdi Ferdowsi, Chang-Soo Kim, Ray Luechtefeld, Glenn Morrison, Carsten Ullrich, Ganesh Venayagamoorthy, Thomas Vojta, Kai-Tak Wan, Jee-Ching Wang, Maciej Zawodniok and Rosa Zheng). Ganesh Venayagamoorthy received the Office of Naval Research Young Investigator Award and Josh Rovey received the Air Force Office of Scientific Research Young Investigator Award.

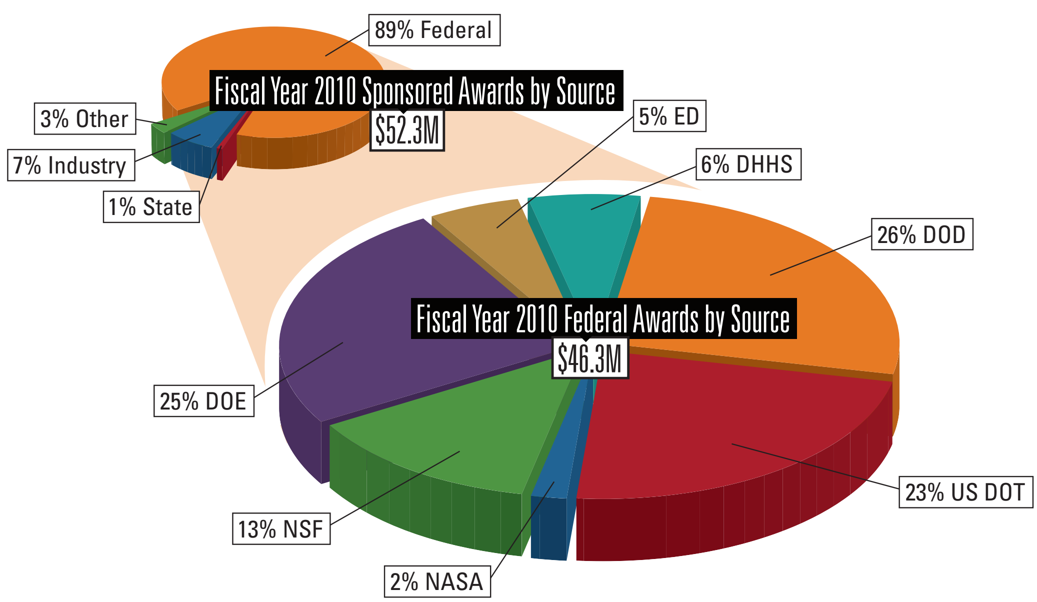
The next decade will bring a new set of problems requiring fundamental advances, new discoveries and innovative strategies in a rapidly changing global economy. I am confident we will continue to not only develop transformative solutions with the necessary vigor and resolve, but also foster innovation to commercialize cutting-edge research results to create new jobs and economic prosperity.

I invite you to read some of the current research efforts at Missouri S&T in this Fall 2010 issue of *re:Search* magazine and look forward to hearing about all the exciting news from your campus.

Sincerely,
K. Krishnamurthy, Vice Provost for Research

Fiscal Year 2010 Summary

Proposals Submitted	528
Dollars Requested	$259.1M
Proposals Awarded	327
Dollars Awarded	$52.3M
Total Expenditures	$44.7M
Faculty Involved with Sponsored Activities	231
Invention Disclosures	34
Patent Applications Filed	25
Patents Issued	12
License/Options Signed	12



re:Search is the annual report on research, innovation and discovery activities at Missouri University of Science and Technology, formerly University of Missouri-Rolla. Published by the Office of Sponsored Programs, *re:Search* highlights only a portion of Missouri S&T's vibrant, focused research program. For more information about Missouri S&T's research, contact:

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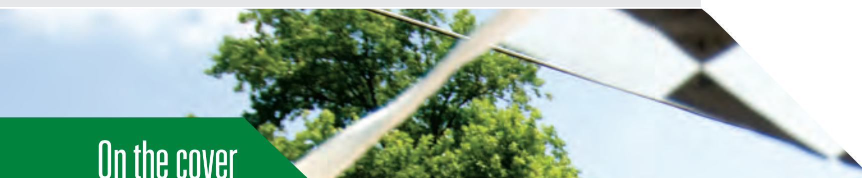


On the cover

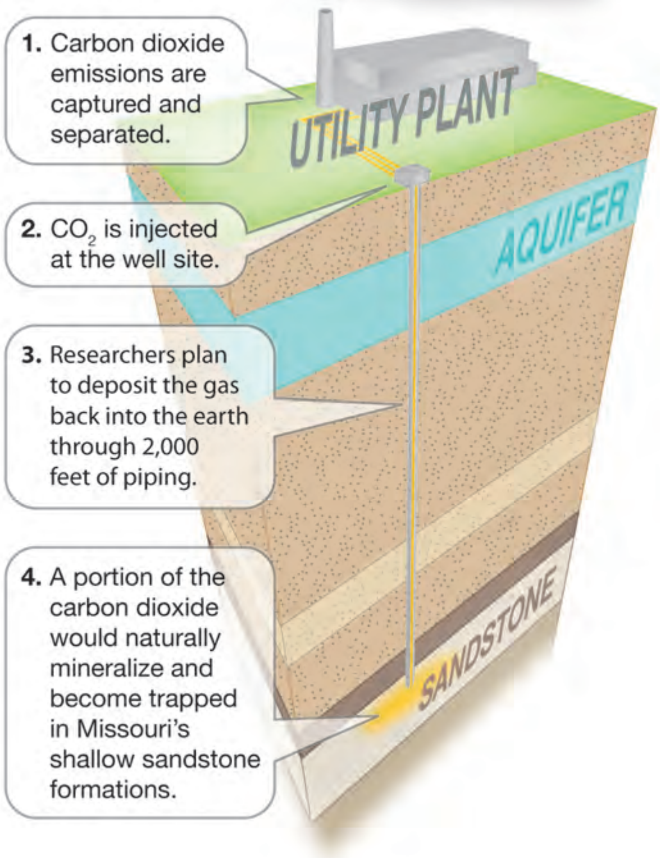
Panels from *Solar Miner VII*, Missouri S&T's entry in the 2010 American Solar Challenge, are cooled down with a gentle rinse of water. Like most electronic devices, solar panels operate more efficiently at cooler temperatures.

Solar Miner VII crossed the finish line in Naperville, Ill., in fifth place in June. The six-day race began in Broken Arrow, Okla. Seventeen teams entered the race, but several dropped out along the 1,200-mile route, which went through Oklahoma, Kansas, Missouri and Illinois.

Details about the race and posts from the road are available at **experiencethis.mst.edu**.

Graduate student Varun Paul and associate professor David Wronkiewicz collect microbial samples at Great Salt Plains Lake, Okla. Microbes may induce chemical changes in fluids that promote the formation of carbon dioxide-bearing minerals (carbonates). Isolating such microbes may allow us to use them for carbon sequestration processes.

Shallow sandstone sequestration



Studying sequestration

UTILITY COMPANIES AROUND THE COUNTRY ARE commissioning carbon dioxide studies in anticipation of regulations that would limit emissions. In Missouri, researchers are trying to figure out ways to sequester carbon dioxide in rock formations that are located at relatively shallow depths.

Missouri S&T is involved in a two-year carbon sequestration study funded by the U.S. Department of Energy (DOE) through City Utilities of Springfield, Mo.

The idea is to capture and separate carbon dioxide emissions, then return the gas permanently to the earth. In many areas of the country, the carbon dioxide can be disposed of in extremely deep formations, where it is sequestered under pressure in a supercritical fluid state. That is not possible in most of Missouri due to predominantly shallow geological features.

Missouri S&T researchers are studying the feasibility of depositing the carbon dioxide gas into sandstone formations that are approximately 2,000 feet deep. "Shallow sequestration of carbon dioxide gas has not been studied extensively," says Shari Dunn-Norman, associate professor of petroleum engineering at S&T. "We are trying to understand as much as possible about the process."

An exploratory well at a test site in Greene County, Mo., is being drilled. Core samples will be collected to gain insight about critical rock properties that can affect the sequestration process. Then laboratory studies will be conducted to gain a better understanding of the geochemical processes that occur when carbon dioxide is injected into sandstone formations.

If initial results are favorable and the project advances, a limited quantity of "food grade" carbon dioxide gas (the type that is used to carbonate soft drinks) will be injected into the subsurface at the test site. The researchers plan to monitor subsurface conditions to see how the carbon dioxide moves through the sandstone.

"We want to look very closely at the geological features to determine things like porosity, permeability and the processes by which minerals precipitate to capture carbon in a solid form," says David Wronkiewicz, an associate professor of geological sciences and engineering who is also working on the study. "We need to know how much carbon dioxide the formation can hold and the economics of storing it."

“We want to look very closely at the geological features to determine things like porosity, permeability and the processes by which minerals precipitate to capture carbon in a solid form. We need to know how much carbon dioxide the formation can hold and the economics of storing it.”

— David Wronkiewicz, associate professor of geological sciences and engineering

Other researchers on campus are working on ways to make sure sequestered carbon dioxide stays sequestered. “To successfully store CO_2,” says Runar Nygaard, assistant professor of geological sciences and engineering, “it has to be kept in place in the storage unit by a sealing formation acting as a cap rock.”

Nygaard is working with Andreas Eckert, assistant research professor of petroleum engineering, and Baojun Bai, assistant professor of geological sciences and engineering, on DOE-funded computer simulations related to shallow sequestration. The total amount of the funding is expected to be $917,602.

“Powerful numerical codes will be used to conduct a simulation of the CO_2 injection and possible leakage,” Nygaard says, “and laboratory experiments will be conducted to find the best materials for sealing fractures.”

Providing a future generation of scientists and engineers with skills to successfully work in a carbon sequestration industry is also a major goal of the DOE, which is funding a third project at S&T focused on training students in carbon-based geochemistry and biogeochemistry reactions. Wronkiewicz is heading up the $299,590 project to enhance classroom, laboratory and field experiences.

Medhi Ferdowsi and Andrew Meintz are helping S&T better prepare students for careers in electric and hybrid vehicles.

Plugging into the future

WHEN MEHDI FERDOWSI AND ANDREW MEINTZ offered the inaugural class on electric and hybrid vehicles last January, they made an instant connection with students from a variety of engineering disciplines.

Seventeen students enrolled in the course, even though it was not widely advertised. “They obviously see this as a new field that is going to grow and ultimately become a new career path,” says Ferdowsi, assistant professor of electrical and computer engineering.

Fueled by $5 million in stimulus funding through the American Recovery and Reinvestment Act of 2009, Missouri S&T is developing a new undergraduate minor in advanced automotive technology to better prepare students for the plug-in economy.

Last semester’s introductory course, taught by Meintz, a Ph.D. student in electrical engineering, was S&T’s opening into the new world of plug-in electric vehicles. Students from various disciplines enrolled to learn about the different fuel, powertrain and energy storage systems electric cars and hybrids require.

This semester, S&T is offering half a dozen courses for both undergraduate and graduate students.

“Developing new course material is hard, especially when you’re talking about a new car that hasn’t even been developed yet,” says Ferdowsi. But he sees a huge payoff. “We will have a pipeline of students prepared for this industry.”

An experimental wind turbine stands adjacent to a Stonehenge replica on Missouri S&T's campus.

Bruce McMillin — professor of computer science

Keeping the smart grid secure

The old power system is being transformed into a "smart grid," which will integrate renewable energy generated from wind turbines and solar panels housed in homes and businesses into the existing grid through the internet.

WE OFTEN USE THE INTERNET to manage key aspects of our lives — our finances, health, relationships — so the thought of also managing our home's energy supply online may not seem scary. But as our nation's outdated power grid goes digital, the implications of opening up yet another area of our lives to the online world has some people worried.

The old power system is being transformed into a "smart grid," which will integrate renewable energy generated from wind turbines and solar panels housed in homes and businesses into the existing grid. Appliances will communicate with each other to decide when they should run, and any excess energy will be sold back to power companies.

While these new infrastructures will certainly be more efficient, the massive amounts of data exchanged will also increase our vulnerability to security breaches. Information about our daily habits — when we're home, when we're on the computer, when our appliances run — might be accessed by a third party. It could be the bored teenaged hacker down the street, or someone or some thing more sinister.

Another challenge is ensuring participants in this new system play fair and don't hold back their renewable energy to sell at peak hours and premium prices — thus helping their own bank accounts but hurting everyone else's.

Bruce McMillin, professor of computer science at Missouri S&T, is working on solutions to these challenges. By using information flow analysis, born in computer science, he is working to develop security measures for these new distributed systems.

“This is a new application of information flow analysis,” he says. “We’re using it to reveal design and implementation issues that would compromise the system’s confidentiality.” In this instance, confidentiality is considered violated when information flows from one domain to another domain (such as inside a house to outside the house).

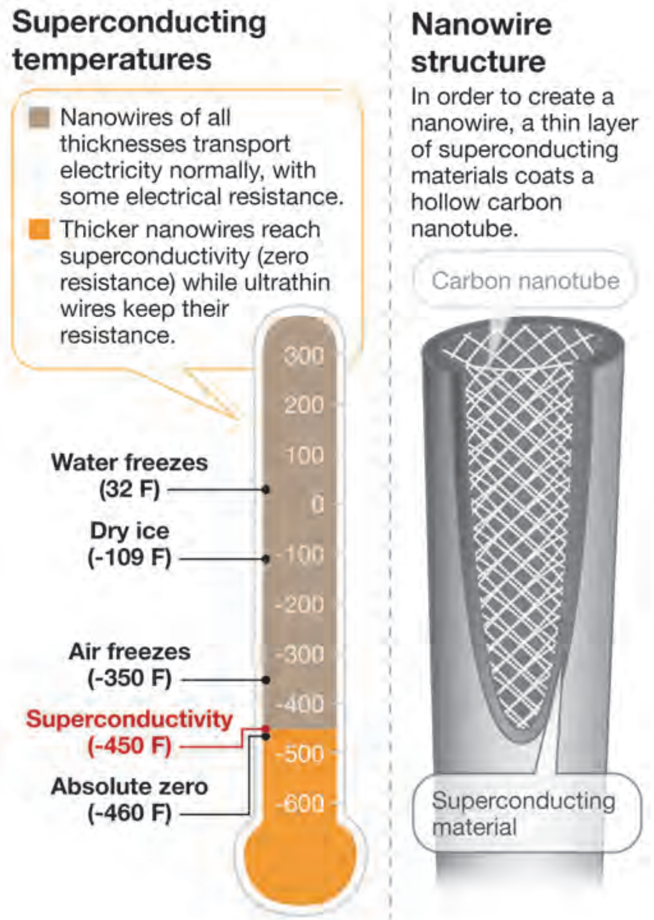
McMillin is working with the National Science Foundation’s Energy Research Center for Future Renewable Electric Energy Delivery and Management (FREEDM) Systems. Missouri S&T is one of seven universities in the United States and Europe involved in the program. Five members of the S&T electrical and computer engineering faculty are also part of the FREEDM team, including site director Mariesa Crow and co-investigators Badrul Chowdhury, Keith Corzine, Mehdi Ferdowsi and Jonathan Kimball.

“We’re looking to use distributed grid intelligence (DGI) to manage the smart grid,” says McMillin. DGI would allow software to manage a home’s energy usage and would detect, isolate and correct any problems that might occur, while fully coordinating with other systems in the home.

McMillin says smart grid systems couple intelligent cyber action with physical operation, which makes determining the information flow much more complex.

“It’s a fundamentally different security challenge because parts of these renewable technologies are visible to anyone,” he says. “You can see if the sun is shining, if the wind is blowing. There is no absolute secrecy.”

McMillin is applying confidentiality properties such as non-deducibility to this future infrastructure. A system is considered as non-deducibility secure if information does not flow from one protected domain to another, lower-level domain. This ensures that the lower-level user cannot deduce any information about the system. In a non-deducibility secure system, observing that the sun is shining on a solar panel does not tell the observer anything about how the collected energy is used, nor anything about the internal information of the DGI — thus limiting a potential attacker’s information.



It turns out you *can* be too thin

THIN IS IN, RIGHT? Not if we’re talking about superconductivity, says Missouri S&T physicist Thomas Vojta, who is studying superconductivity in ultrathin nanowires, which are only a few billionths of a meter wide. These nanowires can be produced thanks to recent advances in nanotechnology.

Measurements reveal that sufficiently thick wires completely lose their electrical resistance at low temperatures, which is the hallmark of superconductivity, Vojta explains. Wires that are too narrow keep their resistance down to the lowest temperatures.

Vojta believes this is likely caused by magnetic impurity of atoms on the surface of the wire that break up the Cooper pairs responsible for superconductivity.

“Superconductivity is one of the most fascinating phenomena in physics,” Vojta says, “and nanoscale superconductors offer unprecedented control over system parameters, which makes them great laboratories for testing the fundamentals of quantum mechanics. Moreover, they are at the heart of the quantum information revolution, since small superconductors are among the most promising candidates for the qbits in future quantum computers.”

Water world

WALKING DOWN TO THE LITTLE RIVER, we can already smell the stench. Though there is evidence of trash everywhere, much of the smell is coming from the river itself. A few lizards scurry along the rocky bank, but nothing appears to be swimming in the water. One of the students collects a sample that is contaminated by raw sewage.

The river is in Guatemala, near the city of Antigua. Since 2002, Curt Elmore, an associate professor of geological engineering at Missouri S&T, has been bringing students to this country to study water quality. Most of the drinking water here is contaminated. The water is especially dangerous for kids who may not be strong enough to survive an illness caused by fecal pathogens.

Several years ago, Elmore and a group of students installed a well at an orphanage in the little town of Lemoa, which is a three-hour drive from Antigua through mountains and clouds. Thanks to visitors from S&T and funding from the National Science Foundation, the children in Lemoa now have access to safe water.

It's unclear how much damage relatively small amounts of pollution can cause, but when it comes to the health of a stream's ecosystem, or maybe even the overall condition of a country's water, Huang sees the hellbender as a kind of aquatic canary in the coal mine.

Back on campus, Yinfa Ma is monitoring water closer to home. Using funding from the Missouri Department of Natural Resources, Ma is studying water samples from the state's rivers, lakes and wells. He is looking for the presence of pharmaceutical chemicals, pesticides, herbicides, and toxic forms of algae.

Ma says the water quality is worse in the summer, when chemicals from farming activities reach stream systems, than in the winter. But, for the most part, the news has been good. "Some minor contamination is expected, but we haven't seen anything that's reached a level of concern," says Ma, Curators' Teaching Professor of chemistry at S&T. "We just want to stay out in front of any potential problems."

Meanwhile, Yue-Wern Huang, an associate professor of biology at S&T, is trying to figure out where all of the hellbenders went. The hellbender is one of the largest salamanders in the world. They once thrived in the pristine streams of the Ozarks and Appalachia. Now they're almost extinct.

It's increasingly hard to find them and catch them, but Huang has been taking blood samples from hellbenders for nine years to see if their chemistry is changing over time. His research is funded by the Missouri Department of Natural Resources, the Missouri Department of Conservation, the U.S. Geological Survey, the Environmental Protection Agency, the St. Louis Zoo and the Missouri Water Resources Center.

Huang's theory is that higher-than-normal estrogen levels in streams are disrupting the reproduction rates of hellbenders. The estrogen can come from pesticides and herbicides as well as from hormones in the waste of farm animals. It's unclear how much damage relatively small amounts of pollution can cause, but when it comes to the health of a stream's ecosystem, or maybe even the overall condition of a country's water, Huang sees the hellbender as a kind of aquatic canary in the coal mine.

"The hellbender is very primitive," Huang says. "It may be very sensitive to human activities that impact the water."

Rising stars

Joshua Rovey — assistant professor of mechanical and aerospace engineering
Air Force Office of Scientific Research Young Investigator Program Award

WITHIN THE NEXT DECADE, power available to space vehicles is expected to increase dramatically, so the next generation of space vehicles will need an advanced propulsion system. Joshua Rovey, assistant professor of mechanical and aerospace engineering at Missouri S&T, is studying high-density ionized gas plasma that could be used as propellant for those next-generation spacecraft.

Rovey is developing the Missouri Plasmoid Experiment (MPX) to study the plasma physics of a high-density, heavy-gas plasma propellant.

He says the high exhaust velocity of electric propulsion systems make them desirable, but they're slow.

"In other words, electric propulsion systems have great gas mileage, but don't accelerate quickly because current spacecraft don't have enough power," Rovey says. "As power levels increase, what's needed is a new type of propulsion system that has a higher specific power. It must be able to process the higher power levels, but also be lightweight. A higher-density plasma propellant may make this possible."

Through the MPX, Rovey is designing a test article for experimentation with the high-density ionized-gas propellant. He plans to begin fabricating the device near the end of 2010.

Maciej Zawodniok — assistant professor of electrical and computer engineering
National Science Foundation CAREER Award

CURRENT PASSIVE RADIO FREQUENCY IDENTIFICATION (RFID) technology could allow tracking of grocery shipments from supplier to store, help monitor a store's inventory and attach vital information to individual items. Maciej Zawodniok, assistant professor of electrical and computer engineering, hopes to extend the existing tracking ability in terms of range, consistency, volume and sensing capability, from the store to the home.

Take eggs, for example. Zawodniok can see a day when a carton of eggs can be tracked from the chicken farm all the way to a family refrigerator. Store employees will know when the carton arrives and when it is set to expire. Once purchased by the consumer, the eggs can be monitored via RFID technology by the home refrigerator, letting the homeowner know when it's time to buy more eggs. By adding sensors to the RFID tags to measure temperature, such perishable groceries can be monitored even more closely. If stored at too high a temperature, they may expire sooner than expected. If they're too cold, they may crack and arrive damaged. All of this information would be available without in-person inspection.

Zawodniok believes that by allowing RFID devices to work together toward a common goal, their communication capability and range will increase. The challenge he faces is making the technology work over long distances, while increasing the accuracy and reliability of the communication.

Zawodniok thinks he can meet that challenge by using beam-forming and a multi-hop network to transmit the data. He plans to use a whole network of devices — devices that can be as small as the tip of a pen — to transmit one signal.

"By redirecting the signal toward a specific device or location, that signal will be focused," Zawodinok says. "It will increase the amount of energy, similar to a lens focusing a beam of light. A tightly focused beam delivers more energy per area even though no more light is used."

"The long fibers will absorb more energy as they pull-out during the pressure wave or impact, cutting down on the potential for failure during an explosion or earthquake."

— Jeffery Volz (far right), assistant professor of civil, architectural and environmental engineering

Concrete solutions

CONCRETE MAY SEEM AN UNLIKELY MATERIAL for engineering advances. But at Missouri S&T, two professors are working to tailor mixes to improve concrete's ability to withstand blasts and quicken repairs.

Jeffery Volz, assistant professor of civil, architectural and environmental engineering, believes adding carbon fibers to conventional reinforced concrete could significantly improve a structure's ability to withstand blasts, hurricanes and other natural disasters, and diminish secondary fragmentation.

"The long fibers will absorb more energy as they pull out during the pressure wave or impact, cutting down on the potential for failure during an explosion or earthquake," Volz explains.

John Myers, associate professor of civil and architectural engineering, knows the difficulty involved with fixing blast damage, particularly in Afghanistan and Iraq, where improvised explosive devices (IEDs) create huge potholes and damage roadways.

That's why he's working to develop a sustainable mix that can repair an IED crater within two hours. Currently it can take a day or more to fix the craters, which risks soldiers' lives as they guard the repairs and wait for them to harden.

"In addition to the advances in the optimization and sustainability of the rapid-set materials, the repair material will contain integrated systems to deter and identify if the repair has been tampered with," Myers explains. "This will provide added security post-repair for our soldiers in the field."

Both projects are supported by grants from the U.S. Army Research Lab through the Leonard Wood Institute and involve partnerships with Missouri small businesses.

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Artist rendering of first building at Missouri S&T's Innovation Park

Research + commerce = innovation

THE FIRST BUILDING of a research park on Missouri S&T property in Rolla is scheduled to be completed this October. Campus officials see Innovation Park as a way to bring university researchers and high-tech businesses together to expand S&T's economic impact, create jobs and commercialize innovations.

In 2009, the University of Missouri Board of Curators provided approximately $3.25 million in bond funds to Missouri S&T to finance construction of the first building. The single-story building will have 18,500 square feet of office space. Missouri S&T has tenant commitments from several companies.

MISSOURI S&T

We invite you to take a closer look at Missouri S&T. Start by reading the stories inside this report, then stay connected with us online at **research.mst.edu**.