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re: THINK research

Dear Colleague:

I am pleased to send you a reprint of selected articles from the first issue of *Missouri S&T Magazine*, published by the Miner Alumni Association of Missouri University of Science and Technology. Inspired by Missouri S&T alumnus Farouk El-Baz, a member of the National Academy of Engineering and one of 18 committee members chosen by the academy to discuss and develop the list of grand challenges for engineering in the 21st century, this issue was dedicated to showing how Missouri S&T researchers are addressing some of those very issues.

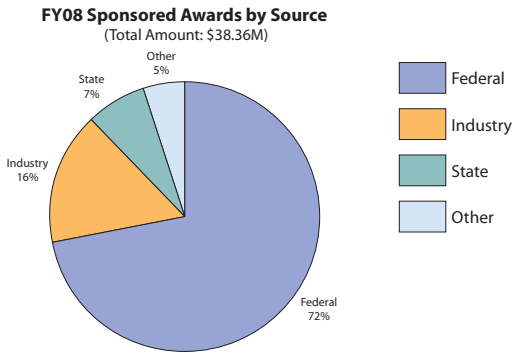
We are proud of another successful year with higher enrollment; new research programs; a record number of proposals, awards and technology transfer activities; national recognition of our faculty; and outstanding performance of our students in national design competitions. Some Missouri S&T highlights from FY 2008 include:

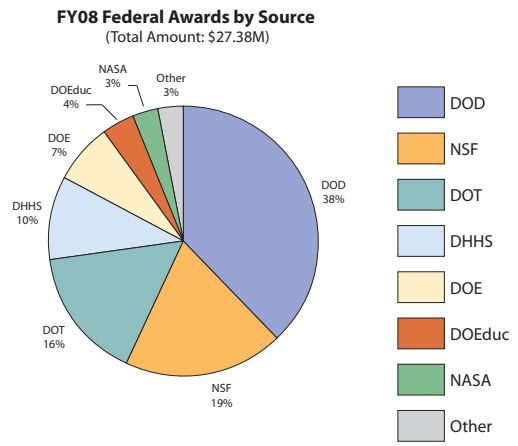
- Selection as home of GE Aviation's new University Development Center
- Inclusion in *R&D Magazine*'s "R&D 100" for helping to develop chrome-free corrosion inhibitor, one of the 100 most technologically significant products in 2006
- Recognition of Dr. Donald Hagen and Dr. Phil Whitefield and their team's research on the role of aircraft emissions on climate change in the Intergovernmental Panel on Climate Change (IPCC) work that contributed to the 2007 Nobel Peace Prize, which was shared with the IPCC
- Society Fellow awards for Dr. James Drewniak (IEEE), Dr. Donald Myers (ASEE), Dr. John Myers (ASCE) and Dr. Donald Wunsch (INNS)

I invite you to read how our outstanding faculty are making a difference and I look forward to hearing about all the exciting news from your campus.

Sincerely,

K. Krishnamurthy, Vice Provost for Research
Missouri University of Science and Technology
(Formerly University of Missouri-Rolla)





FY08 Summary

Proposals Submitted	549
Dollars Requested	$151.14M
Proposals Awarded	369
Dollars Awarded	$38.36M
Total Expenditures	$37.7M
Faculty Involved with Sponsored Activities	252
Invention Disclosures	35
Patent Applications Filed	31
Patents Issued	7
License/Options Signed	15

"Throughout history, engineering achievements were accomplished in response to specific human needs."

- Farouk El-Baz, MS GGph'61, PhD GGph'64

re:THINK research

Five years ago, the National Academy of Engineering came up with a list of the greatest engineering accomplishments of the 20th century. Looking at the list today, it's hard to imagine life without things like electricity, automobiles, satellites or even Internet-equipped cell phones. Still, there will always be plenty of challenges for engineers to tackle. The collapse of the Interstate 35W bridge in Minnesota last summer brought the nation's aging infrastructure under public scrutiny. By autumn, an unprecedented drought in Atlanta had experts speculating that citizens would run out of drinking water in a matter of weeks. Just before the new year, the Energy Information Administration released its forecast for 2008, projecting that gasoline and diesel prices would peak at more than $3.40 per gallon this spring.

Missouri S&T alumnus **Farouk El-Baz**, MS GGph'61, PhD GGph'64, is one man who is uniquely qualified to study challenges. Decades ago, El-Baz helped NASA identify the Sea of Tranquility as a good place to land on the moon. Later, he applied some of the same computer techniques used to survey the moon and count sand dunes in the Earth's deserts to determine the actual size of the "Million Man March" in Washington, D.C. Last April, El-Baz and his staff at Boston University's Center for Remote Sensing announced they had discovered an ancient lake in Darfur – using satellite imagery.

So, when the National Academy of Engineering decided to identify the top engineering challenges for the next 100 years, El-Baz was one of 18 academy members selected to look at the big picture. Funded by a $500,000 grant from the National Science Foundation, the committee sought input from the engineering community and the general public. The Grand Challenges for Engineering, listed online at www.engineeringchallenges.com, represents an array of topics, including energy and the environment – two broad areas that Chancellor **John F. Carney III** outlined as primary research focuses for the campus during a recent State of the University address. *Missouri S&T Magazine* spoke with El-Baz in late December about his work (see page 2).

El-Baz emphasizes that scientists and engineers, in addition to trying to make life in the 22nd century more convenient in general, should be paying close attention to environmental and humanitarian concerns. "In addressing future engineering challenges, it is best to consider first and foremost the needs of humanity," El-Baz says. "Throughout history, engineering achievements were accomplished in response to specific human needs."

Inspired by El-Baz's vision, this issue of our magazine is dedicated to showing you how some Missouri S&T researchers are seeing – and rethinking – challenges of the future. Among the things these researchers are envisioning are new ways to renew vehicles (see page 3), rebuild high-tech bridges (see page 6) and re-grow bones (see page 8).

re: VIEWING the world

Farouk El-Baz, MS GGph'61, PhD GGph'64, used remote sensing technology to help NASA officials determine where the *Eagle* would land in 1969. The producers of *Star Trek: The Next Generation* were so impressed by his work that they named a spacecraft, *The El-Baz*, after him. As director of the Center for Remote Sensing at Boston University and a member of the National Academy of Engineering, El-Baz continues to be a man on a number of missions. He directs multiple efforts to learn more about the world by looking at it remotely through the use of space probes, satellites and other types of sensing technology. One of El-Baz's ongoing passions has been studying deserts to find hidden sources of water. Currently, he's working on a plan that would make water more accessible in war-torn Darfur by identifying the best places to dig wells. El-Baz recently took time to answer some of our questions about his work.

How difficult was it to identify the Sea of Tranquility as an ideal lunar landing spot?

The Sea of Tranquility was only one of five landing sites that were selected for being in the equatorial region, and flat enough and free of blocks of rock to be safe for the first landing.

We can now do a basic form of remote sensing from home with Google Earth (or Google Moon). What has been the biggest technical leap as far as remote sensing is concerned since the formation of the Boston University Center for Remote Sensing?

Actually Google is it, because it has allowed people worldwide to enjoy the marvels of the Earth and the moon (and soon other planets and stars and galaxies of the universe). It is wonderful to see that these hard-to-obtain images are now in the hands of the young everywhere.

The center uses space technology to better understand archaeology, geography and geology. Give us an example of an archaeological finding you've been involved with.

An example of allying remote sensing to archaeology was done at the base of the Great Pyramid in Egypt. A sealed chamber containing a disassembled boat was mapped by ground-penetrating radar and thoroughly photographed. Its air was sampled and the temperature, air pressure, etc., were measured. This was all done in a nondestructive way by applying remote sensing techniques in order to preserve the wood of the 4,600-year-old boat.

Do you worry about any privacy issues with respect to remote sensing technology?

Remote sensing technology is just like any other tool that science discovers and engineering puts into human use. It can be applied to help people find water beneath a desert, or to select a site for bombing that would do the most damage. So, it is the criminal mind that can misuse the wonderful inventions of humanity.

Are you driven more by humanitarian concerns than in the past? Explain how the plan for Darfur (the wells) would help promote peace.

I feel most accomplished when my work results in the location of water for people that need it most – particularly in dry desert regions. For this reason, the work that culminated in the mapping of the boundaries of a major lake in Darfur is most significant. The provision of water to all who need it in this troubled region would ameliorate the human crisis.

You have helped to dispel the notion that deserts are created by humans. Your center also monitors environmental changes that could be caused by human activities. Do you find yourself in the middle of global warming debates? Do you have political views or only scientific views about this?

Scientific data shows us that nothing is constant on the Earth except change – climate is particularly changing. There is also proof that it changed more vigorously in the past. Having said that, we know for certain that CO_2 is increasing in the atmosphere, and this is most probably due to the burning of fossil fuels. We need to do our best not to exacerbate the present rate of change.

re:NEWABLE vehicles

by Mindy Limback (limbackm@mst.edu)

Charged up about the future of vehicles

Two energy researchers at Missouri S&T are revved up about the future of plug-in hybrid vehicles, what they see as the next generation of electrically driven automobiles.

"I would compare my excitement about plug-in hybrid technology to where we were with the Internet in the 1980s," says **Mariesa Crow**, the Fred W. Finley Distinguished Professor of Electrical and Computer Engineering and director of the Energy Research and Development Center. "The utility industry should be going gung-ho about plug-in hybrids."

Crow and **Mehdi Ferdowsi**, assistant professor of electrical and computer engineering at Missouri S&T, are joined by automakers, businesses and politicians alike in a desire to accelerate the development of plug-in technology. Even Internet giant Google has joined the mix, with its philanthropic arm planning to invest $11 million in the initiative.

Although plug-in hybrids aren't currently in production, existing hybrid vehicles, such as the Toyota Prius, can be modified into a "plug-in" hybrid for a few thousand dollars. The modification, which allows the vehicle to be plugged into a regular electrical outlet to recharge, includes adding batteries and an onboard AC-to-DC charger. Unlike all-electric vehicles, hybrid vehicles are powered by both a traditional internal combustion engine and batteries.

Hybrid vehicles get better fuel economy than their solely gas-powered cousins and don't face driving range restrictions, like the EV1, an all-electric vehicle developed by GM in the late 1990s. In the future Ferdowsi and

(*continued on the next page*)

Reducing carbon footprints

by Lance Feyh (lfeyh@mst.edu)

The housing market may be soft, but one neighborhood in Rolla is seeing a building boom. Okay, so it's really just a little village on campus property with a current population of two. But this is a village of the future, and the site developers are thinking long-term.

Later this year, students will begin construction on the fourth solar home in the village. Missouri S&T is one of 20 universities picked by the Department of Energy to receive $100,000 to support the construction of new solar homes. Ultimately, those homes will be entered in the 2009 Solar Decathlon, an event held every-other-year in Washington, D.C.

Three compact houses built for previous Solar Decathlons are currently situated on foundations in Missouri S&T's Solar Village. Two of the houses are available for rent to students and faculty members. This semester, **Rachel Swearingin**, a senior in environmental engineering, and **Bonnie Bachman**, the new chair of interdisciplinary engineering, are renting solar homes from the university.

"I have reduced my carbon footprint considerably," says Bachman. "What I like about the house is the sun room. I open the windows and doors and the whole house heats up just from the sun exposure as the day proceeds."

The houses are highly energy efficient. In the summer, the Solar Village generates extra energy that Missouri S&T sells to a utility company.

The new home will be built in the village, but it will be carefully dismantled and trucked to Washington in the fall of 2009. The houses are reconstructed on the National Mall and judged in 10 categories, including architecture, engineering and energy balance. After the competition is over, the Missouri S&T house will be trucked back to Rolla and placed on its original foundation in the village.

Renewable vehicles continued...

Crow envision, at least 10 percent of the vehicles on the road in the year 2020 will be in the form of a hybrid car that has an onboard energy storage unit. While the owner is at work, the vehicle would be plugged into the power grid, and its storage units would be used for grid regulation and peak-load shaving, a technique that helps stabilize energy prices.

"While the vehicle is plugged in, the state of the charge of the onboard energy storage unit would be optimized based on several factors, such as the driver's previous driving patterns and the forecasted daily power demand of the grid," Ferdowsi explains.

When the owner returns home, the vehicle would be plugged into a regular electrical outlet to recharge. A 2006 California study found that the cost to plug in the vehicle overnight would have been equivalent to less than 80 cents a gallon, at a time when gasoline was selling for more than $3 a gallon.

"It has been proven that employing energy storage systems improves the efficiency and reliability of the electric power generation as well as the power train of the vehicles," Ferdowsi explains. "If both the transportation and electric power generation sectors used the same energy storage systems, we could integrate the two and improve the efficiency, fuel economy and reliability of both systems."

That's the concept behind the $1.7 million demonstration project involving Kokam America Inc., the city of Kansas City, Mo., and the Missouri Transportation Institute. Funding for the project was secured by Sen. Kit Bond in the omnibus appropriations bill, which was signed by President George W. Bush in late December.

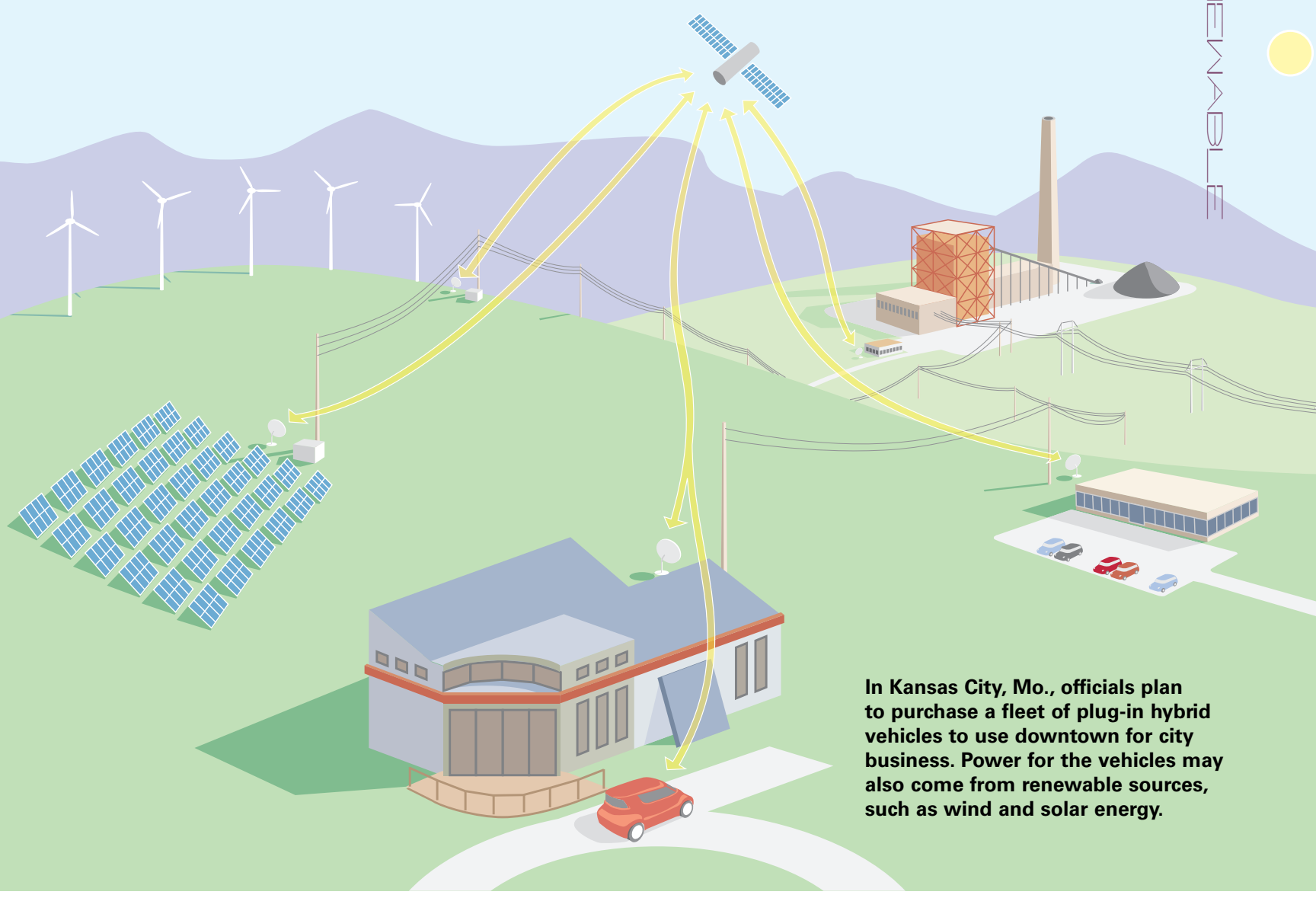
"We are currently partnering with the city of Kansas City in demonstrating the viability of electric and plug-in electric vehicles within the city's vehicle fleet," says Don Nissanka, president of Kokam America. "The project will include the use of alternative energy sources for recharging the lithium batteries that will be utilized by the fleet vehicles and the ability to return energy to the city's power grid."

Kansas City plans to purchase roughly a dozen small to mid-size plug-in hybrid sedans for employees to drive while they serve community needs. The vehicles, using Kokam batteries, would be used in downtown Kansas City. "We think it's a good way to address self-sustaining transportation in urban areas," says Robert Rives, manager of facilities management for Kansas City.

Crow and Ferdowsi say it's important to note that although plug-in hybrids are low emission, they aren't emission free. The group wants to reduce emissions even further by introducing renewable energy, such as wind and solar power, into the equation and creating a zero carbon footprint for drivers.

"The concept of zero emissions is one of the main aspects that sets our project apart from others," says Rives. "Our goal is to charge the vehicles through renewable resources."

Renewable sources of energy, such as wind and solar, generate electric power that can be delivered to the power grid. Plug-in



In Kansas City, Mo., officials plan to purchase a fleet of plug-in hybrid vehicles to use downtown for city business. Power for the vehicles may also come from renewable sources, such as wind and solar energy.

"A plug-in hybrid fleet that's powered purely off renewable energy results means we'll have emission-free energy that can be dispatched at the request of power grid operators."

- Mariesa Crow

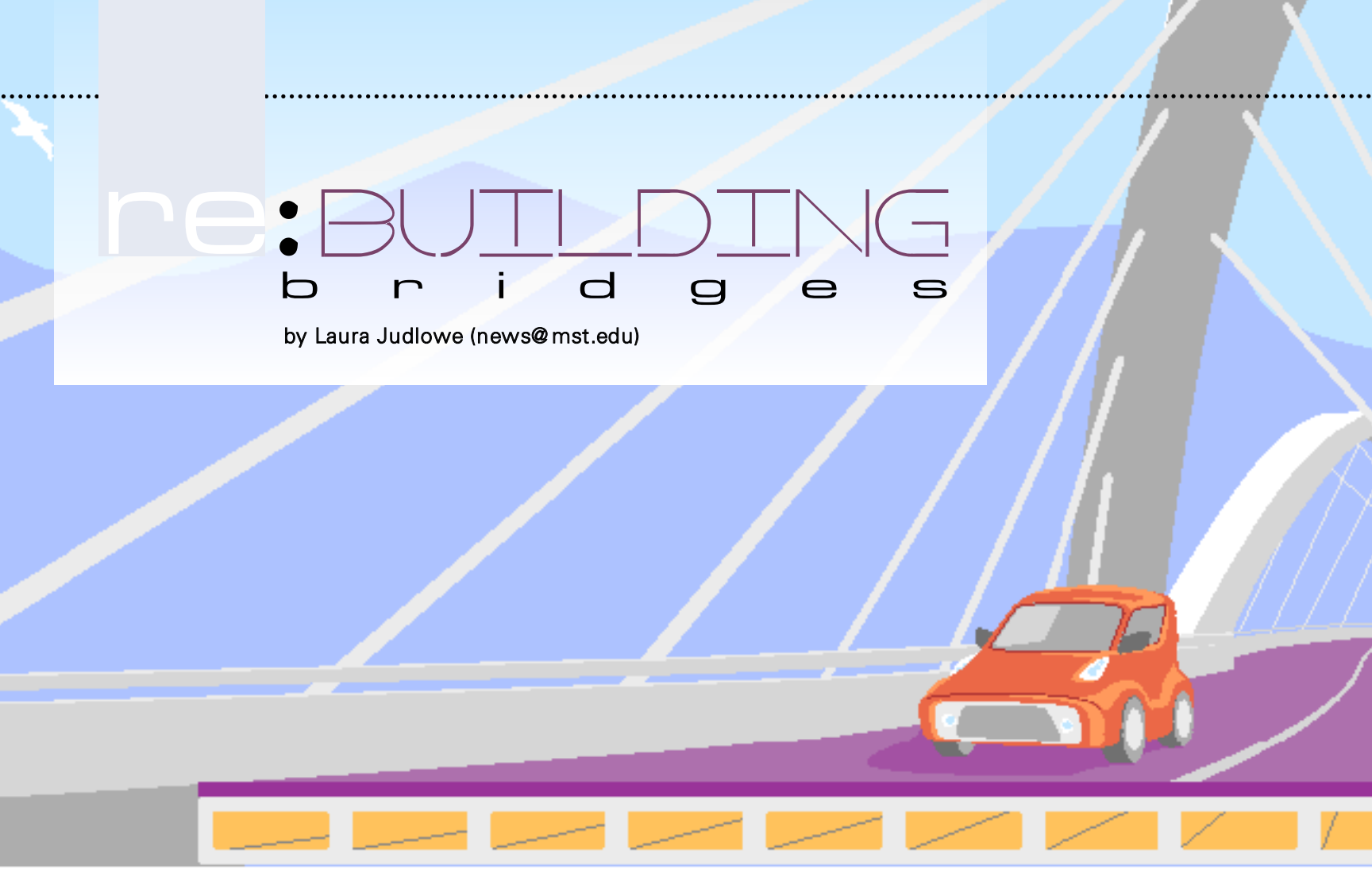
hybrid vehicles can then use that power once they are connected to the grid.

"The power grid will be like an interface between renewables and plug-in hybrids," Ferdowsi explains. "In an ideal case, you can always sell energy back to utility companies; however, it depends on the regulations of the particular state."

The future envisioned by Missouri S&T researchers includes millions of hybrid electric vehicles plugged in to the power grid. Each vehicle would have an onboard, embedded system that intelligently manages power generation and would interact wirelessly with energy management centers. The efficiency, fuel economy and reliability of both the transportation and electric power generation sectors would be improved because of this integration.

The carbon footprint of plug-in hybrids will be lowered once renewable energy sources are incorporated, which will also reduce their contribution to global warming.

"A plug-in hybrid fleet that's powered purely off renewable energy results means we'll have emission-free energy that can be dispatched at the request of power grid operators," Crow says. "This will happen, and it will start in forward-thinking cities like Kansas City."



re:BUILDING bridges

by Laura Judlowe (news@mst.edu)

Last summer's collapse of the Interstate 35W bridge in Minneapolis served as a stark reminder that the nation's infrastructure is aging, and was a dramatic example of the type of disaster researchers at Missouri S&T are working to prevent.

"We are unique because we are one of only about 10 schools in the nation that can take the entire body of a bridge and test it."

-Abdeldjelil Belarbi

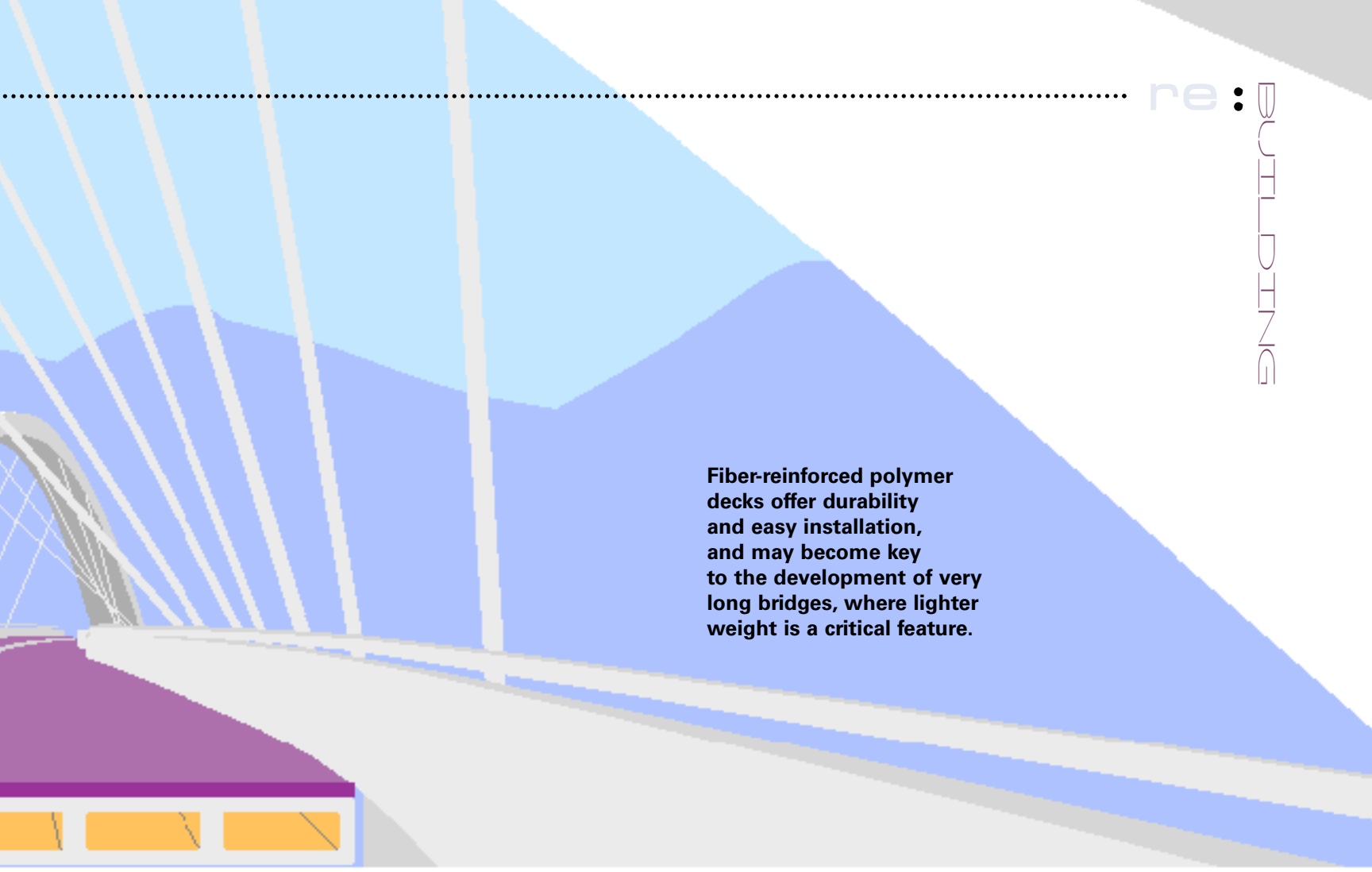
Long before the collapse occurred, Missouri S&T researchers were busy developing new materials and testing methods to preserve and protect the nation's roads, bridges and buildings. As one of only 10 national university transportation centers in the United States, Missouri S&T's Center for Transportation and Infrastructure Safety is bringing together researchers from a variety of disciplines to address some of the nation's most pressing transportation issues.

As a result of their research, we may one day find ourselves driving across bridges made from soybeans and reinforced with glass, carbon or steel fibers. While we travel across these cutting-edge structures, sensors will monitor the impact of our vehicles and warn technicians at the first signs of trouble.

Nearly 30 percent of the country's bridges are structurally deficient or functionally obsolete, according to a 2006 report from the U.S. Department of Transportation. Developments at Missouri S&T in alternative building materials and methods of monitoring the structural "health" of roads and bridges could be the keys to safer and stronger transportation systems. In addition, faculty members are training today's students for a world in which these new approaches to bridge- and road-building will become commonplace.

"We want to educate the next generation of transportation engineers," says **John Myers**, associate professor of civil, architectural and environmental engineering and director of Missouri S&T's transportation center.

Myers and his colleagues are creating and testing alternatives to traditional building materials like steel and concrete. Polymers reinforced with carbon, glass and steel fibers already have been tested on 26 bridges in Missouri



Fiber-reinforced polymer decks offer durability and easy installation, and may become key to the development of very long bridges, where lighter weight is a critical feature.

and surrounding states. A polymer made from soybeans is even being developed, and **K. Chandrashekhara**, Curators' Professor of mechanical and aerospace engineering and director of Missouri S&T's Composite Manufacturing Laboratory, said the material could be used to build bridge decks that are strong, corrosive-resistant and environmentally friendly.

Many of the bridges where new materials are tested are also being monitored by devices invented by Missouri S&T faculty. One such device is a sensor developed by **Genda Chen**, professor of civil, architectural and environmental engineering. The sensor can provide a three-dimensional model of cracks in a structure, as well as information about where and when the crack occurred.

Another device developed at Missouri S&T, called a Flood Frog, is being used to test bridges for health indicators such as strain, humidity, water level and vibration. The "frog" is an inexpensive, battery-powered device inside a waterproof case. It can easily be fixed to the outside of a structure.

"The Flood Frog can measure pretty much any quantity," says its developer **Sahra Sedigh**, assistant professor of electrical and computer engineering. By exposing a bridge's weaknesses in their early stages, "it opens a lot more doors to securing bridges than any other technology around."

Although it might seem like something straight out of science fiction, Missouri S&T researchers have even invented an inspection method that uses microwaves to see through sheets of reinforced polymer.

When researchers aren't working in the field, they can still conduct large-scale tests at Missouri S&T's high-bay lab, where it's possible to simulate the stress an earthquake puts on a bridge. Much of the testing is part of a larger project for the Network of Earthquake and Engineering Simulation.

"We are unique because we are one of only about 10 schools in the nation that can take the entire body of a bridge and test it," says **Abdeldjelil Belarbi**, Curators' Teaching Professor of civil, architectural and environmental engineering. "We are trying to duplicate exactly what happens to a bridge in the real world."

Belarbi and his colleagues hope their work will lead to the development of a new design code for transportation infrastructure that will aid engineers in building bridges with life spans of up to 100 years.

re:GROWING bones

by Lance Feyh (lfeyh@mst.edu)

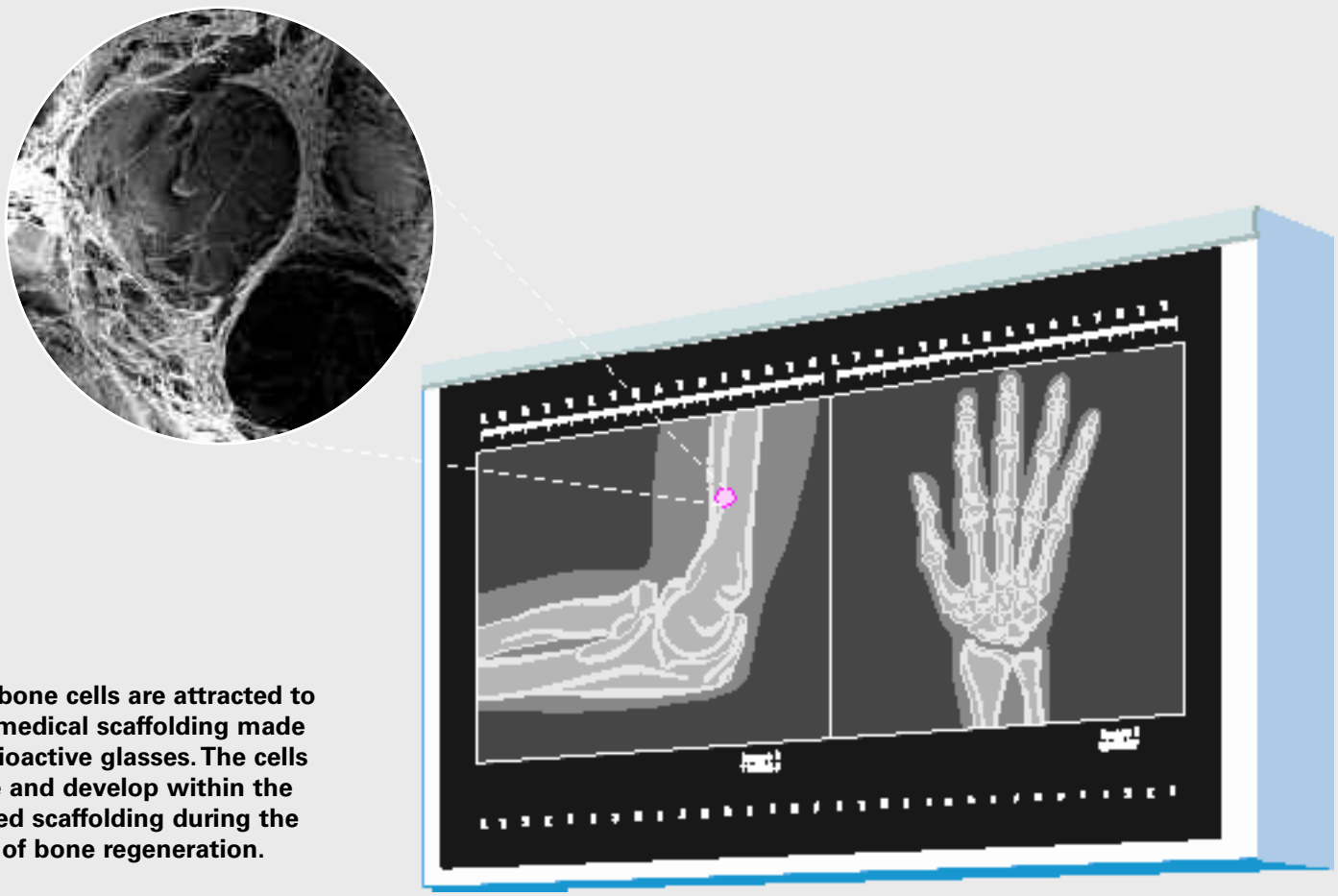
Delbert Day, CerE'58, MS CerE'60, says it's like seeding a fishing environment by throwing an old Christmas tree into the water. The submerged tree provides good pockets of cover for all kinds of fish. But this isn't really a discussion about aquatic habitats. Day is trying to explain why human bone cells would want to colonize medical scaffolding made out of glass fibers.

"Nature abhors a void," he says. "And the body likes certain kinds of glass."

A Curators' Professor emeritus of ceramic engineering, Day has developed a number of new applications for glass, including the treatment of liver cancer with tiny, radioactive glass spheres. In 1985, he co-founded Mo-Sci Corp., a world leader in glass precision technology. Currently, Day and a group of Missouri S&T researchers are developing 3-D scaffolds made out of bioactive glasses. And, yes, they plan to use the scaffolds for bone regeneration.

"Cells can get inside the scaffolding, grow, and develop in the pores," Day says, "just like the fish colonize the Christmas tree."

But here's where the analogy departs. Unlike the tree, which never becomes one with the fish, the scaffolding eventually does become part of the bone.



Human bone cells are attracted to porous medical scaffolding made out of bioactive glasses. The cells colonize and develop within the implanted scaffolding during the process of bone regeneration.

Right now, titanium rods are often used to repair badly damaged bones. But Day and his colleagues say the glass scaffolding is, mechanically, much closer to the composition of real bone. Compared to metal implants, which are smooth and rigid, the scaffolding is porous and downright hospitable. "Over time, the scaffolding would become indistinguishable from bone," says **Roger Brown**, a professor of biological sciences who is working on the project. "It becomes part of the bone structure."

"Cells can get inside the scaffolding, grow, and develop in the pores, just like the fish colonize the Christmas tree."

- Delbert Day, CerE'58, MS CerE'60

The Missouri S&T researchers have formed a partnership – officially called the Consortium for Bone and Tissue Repair and Regeneration – with researchers at the University of Missouri-Kansas City. "We do the materials work here," explains **Len Rahaman**, a professor of materials science and engineering at Missouri S&T who is working with Day and Brown. "They do the clinical work at UMKC."

Four bioactive glasses selected by the Missouri S&T researchers are being evaluated in Kansas City. Once the best glasses are identified, Rahaman will lead the effort to build new scaffolds in Rolla. Prototypes will then be placed in animals, and, if everything goes according to plan, the method will ultimately be tested in humans.

In addition to mending arm and leg bones, the glass scaffolding could be used to repair damaged joints and make some dental surgeries more efficient.

If the scaffolding works like they think it will, the Missouri S&T team will have played a big role in changing the way medical professionals treat bone trauma (just as Day was a pioneer in finding a new way to treat liver cancer). But Day, Brown and Rahaman don't want to stop there. They hope to develop something that really speeds up the process of regeneration – something even better that could be quickly employed in emergency rooms and on the battlefield.

"Bone regeneration takes a number of weeks," says Brown, not satisfied with how far the cutting-edge research has already come. "We eventually need something we can implant that provides load-bearing strength much faster."

Wayne Huebner, CerE'82, PhD CerE'87, chair of the materials science and engineering department, envisions a future where information on human bones is catalogued like fingerprints are today. "In the future, humans may have a computer-aided design file of their entire skeleton made by magnetic resonance imaging," Huebner says. "Then, if someone needed a new bone, a rapid-prototyping machine could make one out of the bioactive glass.

"A surgeon would simply install it and your body would do the rest, converting the glass into an entirely new bone."

Reliable glucose testing

by Laura Judlowe (news@mst.edu)

Thanks to **Chang-Soo Kim**, assistant professor of electrical and computer engineering at Missouri S&T, people living with diabetes may one day have an alternative to the daily routine of pricking their fingers to monitor their blood sugar.

Kim is developing a minimally-invasive "smart" sensor that provides continuous blood sugar monitoring and can be worn on the wrist like a watch, or on the hip like a pedometer.

Several sensor-based monitors already are on the commercial market. These sensors are implanted just under the skin and record glucose levels every few minutes. However, the monitors must be replaced every few days as they degrade and lose sensitivity.

Kim's monitor could be worn for weeks at a time because of its unique ability to self-calibrate and correct itself.

"We believe we can figure out a way in the near future for automatic self-calibration of glucose biosensors during continuous monitoring," Kim says. "This is expected to help develop a more stable and reliable continuous glucose monitoring technology in the future to minimize human intervention, such as periodic and cumbersome sensor withdraw and placement procedures."

Kim's research first was funded in 2004 by a grant from the National Science Foundation. In 2007, based on preliminary results from the NSF grant, Kim was awarded funding from the National Institutes of Health and now is working on a new method of one-point self-calibration in collaboration with **David Henthorn**, assistant professor of chemical and biological engineering, and **Matthew O'Keefe**, MetE'85, professor of materials science and engineering. Kim says the same techniques also are being applied to other biosensors used to monitor metabolites such as lactate and creatinine.

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Pictured is the historic Rolla Building on the Missouri S&T campus. Photo taken by B.A. Rupert. Interior illustrations by Jeff Harper.

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