re:search

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

Fall 2011

MISSOURI S&T
University of Science & Technology

Hydrokinetic energy

Shock and awe

Healing glass

Dear Colleague,

I AM PLEASED TO SHARE WITH you some of the exciting research being conducted at Missouri S&T in this Fall 2011 issue of *re:Search*. From solving the few-body problem of physics to developing new hydrokinetic systems, testing wound healing nanofibers and inventing a millimeter and microwave imaging camera, faculty are not only conducting fundamental research to create new knowledge, but also helping to move new discoveries from the laboratory to the marketplace.

Fiscal Year 2011, which ended on June 30, was another record year for sponsored program expenditures thanks to the hard work of Missouri S&T faculty and students. External funding has been critically important to developing core strengths in electrical and cyber systems, energy, the environment, civil infrastructure, manufacturing and materials. It also enables faculty to make significant contributions and develop new solutions that ultimately will improve the quality of our lives. Equally important are the opportunities these funds create for providing rich research experiences for undergraduate and graduate students, our future workforce.

Missouri S&T is part of the solution to create new jobs and help the State of Missouri and nation with economic recovery.

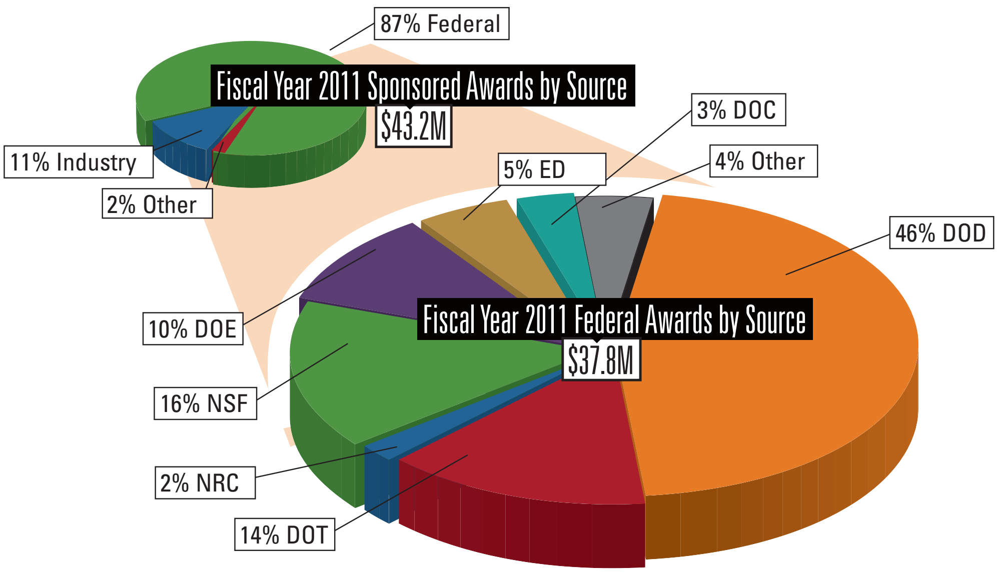
After several years of planning, the Technology Development Center — the first building in its newly designated research park, Innovation Park — was opened in January 2011. The park will expand Missouri S&T's strong connection with private industry and is a critical part of the economic development mission. Current efforts are focused on recruiting technology-oriented businesses, but the long-term objective is to develop industry clusters around the core strengths of Missouri S&T.

With about 90 percent of the students enrolled in engineering and science, Missouri S&T is in a unique position to address numerous challenges confronting us. As Norm Augustine, former CEO of Lockheed and chair of the National Academies panel that published the report "Rising Above the Gathering Storm" said, "In a global, knowledge-driven economy there is a direct correlation between engineering education and innovation. Our success or failure as a nation will be measured by how well we do with the innovation agenda, and by how well we can advance medical research, create game-changing devices and improve the world."

Sincerely,
K. Krishnamurthy, Vice Provost for Research

Fiscal Year 2011 Summary

Proposals Submitted	496
Dollars Requested	$149.5M
Proposals Awarded	292
Dollars Awarded	$43.2M
Total Expenditures	$45.9M
Faculty Involved with Sponsored Activities	219
Invention Disclosures	32
Patent Applications Filed	22
Patents Issued	6
License/Options Signed	10



re:Search is the annual report on research, innovation and discovery activities at Missouri University of Science and Technology, formerly the 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

Atlantis carried Sandra Magnus on both her first and last shuttle missions.
Photos by NASA

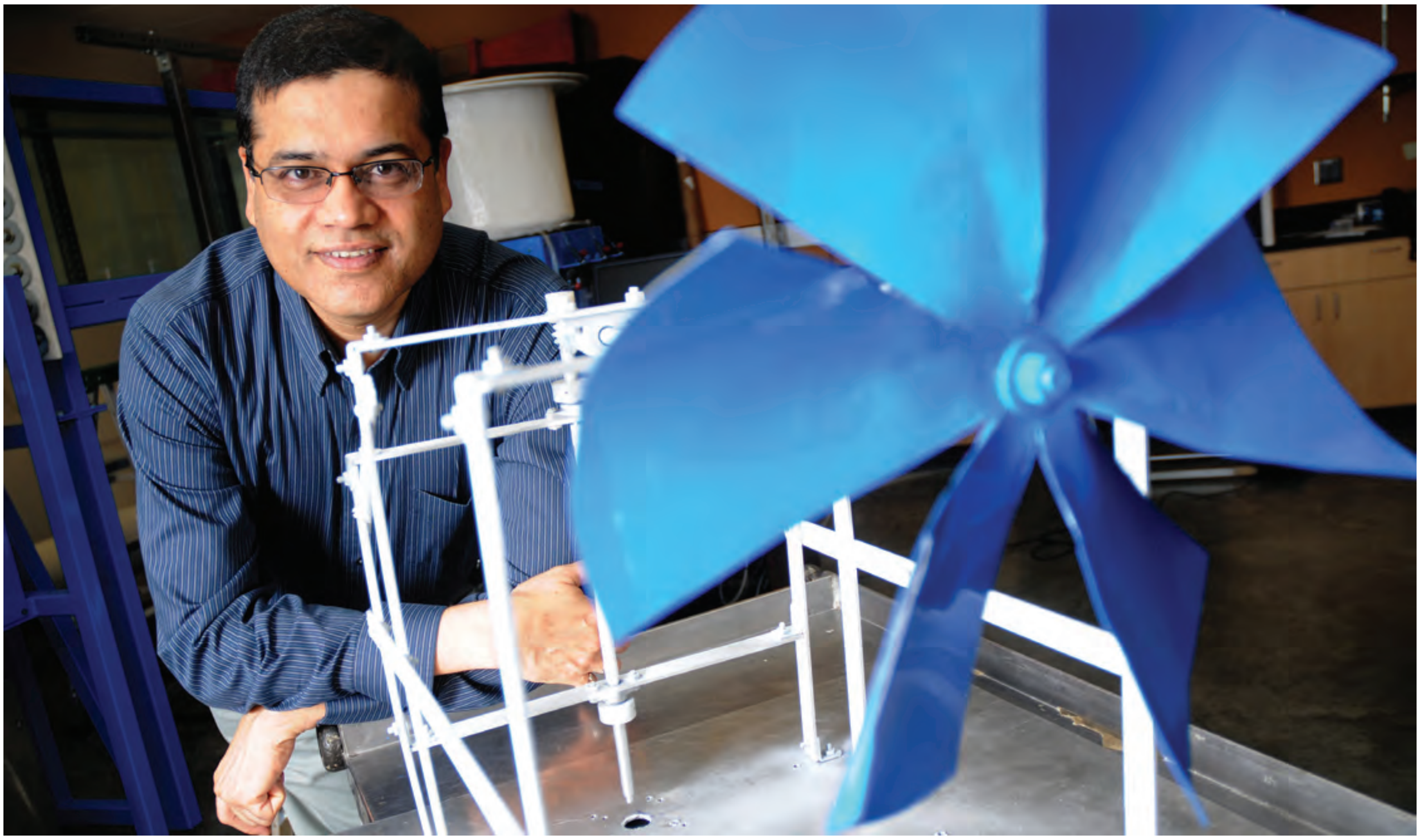
Missouri S&T graduate Sandra Magnus recently got to do what most of us only dream of — float in space.

Magnus, who had a four-month stay on the International Space Station in 2008-2009, was recently part of the crew of *Atlantis* and experienced the final flight of the space shuttle program. Magnus, along with Tom Akers and Janet Kavandi, make up the trio of space flight veterans who are also Missouri S&T graduates.

Now the question for NASA is: What's next? That same general question can be applied to grand challenges like energy and the environment. Well, as you'll see in the pages of this magazine, when it comes to the next big ideas, researchers at S&T are already working on them.

At S&T, we emphasize science and technology every day in an attempt to tackle the big problems in our state and around the world. Our students and researchers study everything from water to steel. They strive to promote advances in medicine and search for better ways to keep our soldiers safe. They scour the Earth for renewable energy options. And, yes, they also remain fascinated by space.

Unlocking potential water energy



Rajiv Mishra thinks the energy potential of Missouri's rivers is an untapped resource. Photo by B.A. Rupert/Missouri S&T

> "In the past, we prayed to the sun god, the wind god and the water god. Now we are back to that point."
>
> — Rajiv Mishra,
> Curators' Professor of materials science and engineering

RAJIV MISHRA THINKS THE ANCIENT PAST AND THE modern present are converging — at least in some ways. "In the past," Mishra says, "we prayed to the sun god, to the wind god and to the water god. Now we are back to that point."

Mishra, Curators' Professor of materials science and engineering at Missouri S&T, is talking about the three primary sources of renewable energy that Mother Nature produces naturally. Unfortunately, the state of Missouri can't really rely on getting as much wind and sun as some states. But what Missourians do have is plenty of water.

Missouri, though landlocked, has more than 3,000 miles of rivers. And the water in rivers flows predictably in one direction. "Water that is flowing constantly has much more energy potential than wind because of higher power density," Mishra says.

The idea is to put systems resembling wind turbines in running water to produce the energy. This is called hydrokinetic energy, not to be confused with hydro-electric dams, which rely on gravity to produce electricity via water and generators.

The energy produced kinetically could be used locally to decrease dependence on power currently derived from coal and

The state's major rivers include the Mississippi, the Missouri and the Osage.

nuclear plants. Many big cities in the U.S. are located on major rivers, including Kansas City, which is on the Missouri River, and St. Louis, which sits at the confluence of the Missouri and the Mississippi. Between the two cities, 90,000 cubic feet of Missouri River water is flowing per second on average. Mishra thinks hydrokinetic energy should be used to help power both metropolitan areas and other towns along the state's rivers.

Mishra says the locations of the turbines would be clearly marked. And, incidentally, one study shows that 98 percent of fish that come in contact with the turbines would be fine.

Several different designs for hydrokinetic systems are under development and being tested on campus. The sizes will eventually depend on the volumes of water in a particular river.

According to Joshua Rovey, an assistant professor of mechanical and aerospace engineering who is working with Mishra, gauges are being embedded in the turbine blades as part of a monitoring system. "With this technology, we can actively monitor the blade health as it evolves over time, significantly reducing operation and maintenance costs." Rovey's research is funded by the U.S. Department of Energy.

A post-doctoral fellow and 10 other S&T students, including two undergraduates, are also working on the research, which is being funded by the Office of Naval Research.

Eventually, Mishra and his team plan to have a prototype that can be licensed to Missouri companies. "Some companies in other states are already making hydrokinetic systems," he says. "But so far, nothing in Missouri."

Multitasking can be dangerous for military personnel, but Susan Murray — shown here performing three tasks at once — hopes to help them better manage interruptions. Photo by B.A. Rupert/Missouri S&T

Calculating the cost of interruptions

INTERRUPTIONS ARE A WAY OF LIFE — and unless we're trying to read email on our smart phones while driving, they're typically not life-threatening.

For military personnel monitoring unmanned aerial drones, however, interruptions could have deadly consequences. That's why the military has asked Missouri S&T researchers to study the impact of interruptions on such "human-in-the-loop systems." Researchers Susan Murray, professor of engineering management and systems engineering, and Muhammet Gulum, a Ph.D. student in engineering management, have set up a work station in S&T's Engineering Management Building to study how people react to interruptions. The subjects in Murray's study perform monitoring tasks on a computer but are also interrupted periodically to perform other tasks — each designed to engage subjects' motor skills, cognitive ability or visual ability.

"We're looking at different types of interruptions to see how people respond," Murray says. "We're looking at the impact on time and accuracy. The type of interruption can make a difference."

The results of this research — funded through a grant from the U.S. Army Research Lab through the Leonard Wood Institute — will be used by the military when designing new monitoring systems.

Tapping trees to detect pollution

TO DETECT THE PRESENCE OF CONTAMINANTS IN SOIL or groundwater, most environmental engineers require heavy equipment. But Missouri S&T's Joel Burken has come up with a less intrusive way: tapping into trees.

The process, called "phytoforensics," takes less time and costs much less than traditional detection methods, says Burken, a professor of civil and environmental engineering. Burken and his colleagues have tested their method at more than 30 sites in five countries and eight states in recent years.

> "Sampling is easy, fast and inexpensive for quickly identifying polluted areas or contamination patterns."
>
> — Joel Burken,
>
> Professor of civil and environmental engineering

The process involves coring trunks of trees to gather small samples. In past tests, Burken and his students collected those samples in vials to take back to a Missouri S&T laboratory for analysis. More recently, they've been using a specially designed, less intrusive approach that allows them to measure contamination on site. It involves the use of a thin filament called a solid-phase microextraction fiber, or SPME, to detect traces of chemicals at minute levels, down to parts per trillion or parts per quadrillion.

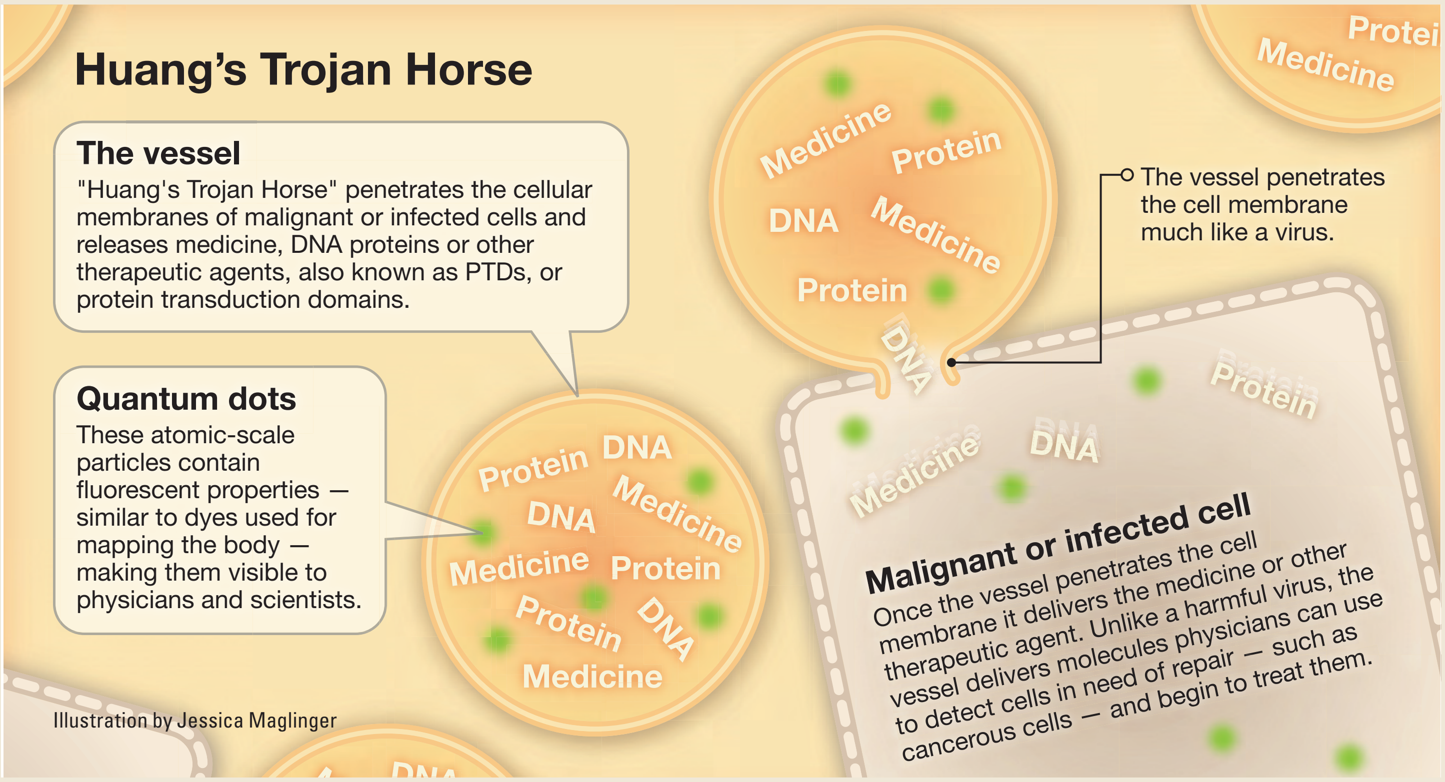
"The process of core-sampling plants has been around for a while," Burken says, "but we're taking a new approach that will improve the process on multiple levels. Sampling is easy, fast and inexpensive for quickly identifying polluted areas or contamination patterns."

Trees act as nature's solar-driven sump pumps, soaking up water from the ground by using the energy of the sun and the air around them, Burken says. Through a process known as "evaportranspiration," a tree's extensive root system absorbs all the water it needs. At the same time, the tree absorbs trace amounts of chemicals in that water and transports it above the ground.

Above: Joel Burken (left), Missouri S&T professor of civil and environmental engineering, works with S&T graduate student Matt Limmer and undergraduate student Amanda Holmes to test in Rolla's Schuman Park. Photos by B.A. Rupert/Missouri S&T.

Tapping into several trees in an area suspected of contamination can help engineers better and more rapidly delineate contaminants in the subsurface. "The only damage to the site is taking a piece of the tree about the size of a pencil and just an inch long," Burken says.

Connecting the quantum dots to advance medicine



HOPING TO FIND A NEW WAY TO TREAT DISEASE, Yue-Wern Huang is trying to mimic the way viruses operate.

But unlike a real virus, Huang's approach would spread healing instead of sickness.

Huang, an associate professor of biological sciences at Missouri S&T, studies the ways atomic-scale particles known as quantum dots can deliver and monitor proteins, medicine, DNA and other molecules at the cellular level. He's trying to create atomic-scale vessels of cell-penetrating proteins that would transport the quantum dots into cells.

Huang likens the process to the ancient story of the Trojan Horse, which according to Greek mythology was used to deliver Odysseus and his army into the enemy city of Troy. But in this instance, the vessel is a "protein transduction domain," the cargo consists of biomolecules or other therapeutic agents, and the walled city is the cell.

Essentially, the nontoxic protein transduction domain, or PTD, is derived from a virus that can penetrate the cellular membrane. But instead of spreading sickness, it would spread medicine or DNA.

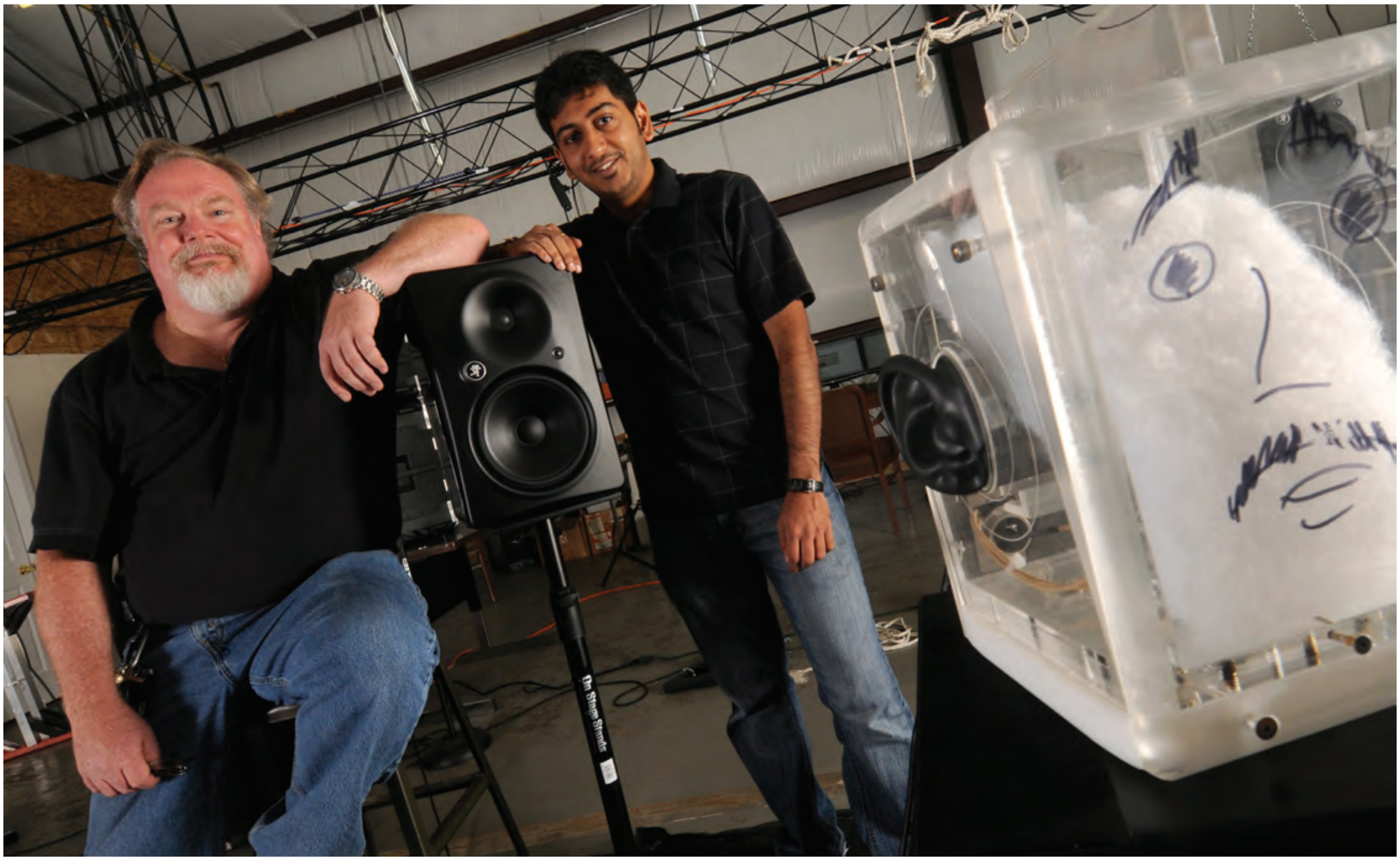
Quantum dots are fluorescent semiconductor nanocrystals — specks that are only a few nanometers in size. They possess unusual physical and chemical properties, making them attractive as tools for new approaches to medicine. For example, Huang says, the fluorescence of quantum dots does not fade as quickly as that of traditional fluorescent dyes used for tracing or mapping in the body. Quantum dots also have a longer half-life and are more resistant to degradation than traditional fluorescent dyes, making them more effective for detecting cancerous cells and other maladies, Huang says.

"Quantum dots are very photo-stable and they have a very high quantum yield. In other words, you don't need to use very much and they are very easy to detect under the microscope."

Huang projects "many potential long-term applications in biomedical areas" to come from this research, such as improvements in medical imaging and monitoring, as well as more efficient delivery of medicines and therapeutic agents.

The research is funded through a grant from the National Institutes of Health under the American Recovery and Reinvestment Act.

Shock and awe: in stereo



Steven Grant (left) and Ph.D. candidate Pratik Shah are helping prepare soldiers for the battlefield. Photo by B.A. Rupert

> "The difference between green and battle-hardened war-fighters is the ability to function effectively in stressful operational environments."
>
> — Steven Grant,
>
> Roy A. Wilkens Missouri Telecommunications Professor

SIXTY-FOUR LOUDSPEAKERS HANG FROM A TRUSS system and 80-hertz subwoofers shake the ground, blasting the sounds of combat inside a non-descript, soundproof building on the south side of Rolla.

The building is where Steven Grant and his fellow Missouri S&T researchers have built what is called an immersive audio environment, complete with the sounds of tanks, ordnance, gunfire, shouting and fighter jets, to help better prepare soldiers for combat.

"When soldiers train in a classroom and learn how to perform different tasks, that's very different than when they get on the battlefield and suddenly there's a cacophony of warfare going off all around them," explains Grant, the Roy A. Wilkens Missouri Telecommunications Professor. "By training soldiers in an immersive auditory experience, they will be better able to complete their tasks quickly and efficiently when they get into a combat situation."

Although the noise levels that troops are exposed to in battle far exceed those of a rock concert, the researchers must limit the immersive audio environment to a maximum of roughly 100 decibels.

"With our current implementation of battle sequences, you can stay in the immersive audio environment without any hearing loss for about two hours per day without using hearing protection," Grant says. "Of course, real battle sounds are much louder, but we conform to Occupational Safety and Health Administration guidelines."

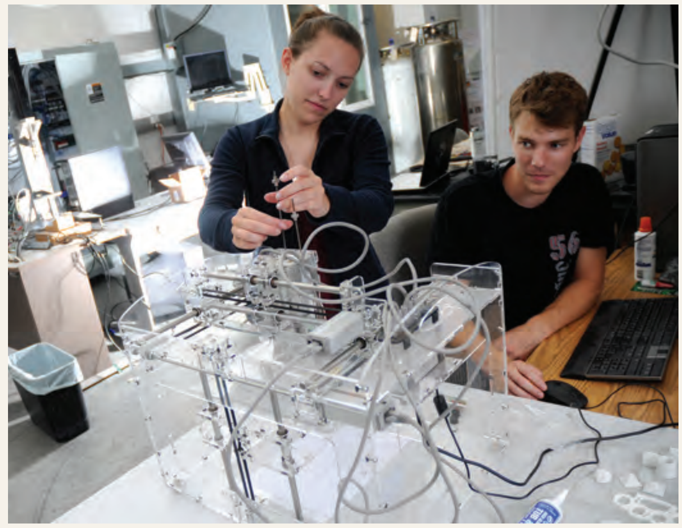
In the United States, very few immersive audio environments exist, and the ones that do are experimental in nature, expensive and inaccessible to the general military trainee. More commonly, military training ranges from detonating actual explosives in bombing ranges to relatively inexpensive video gaming facilities.

"The difference between green and battle-hardened war-fighters is the ability to function effectively in stressful operational environments," says Grant, whose research is funded by the U.S. Army Research Lab through the Leonard Wood Institute. "Our idea is for soldiers to get accustomed to an environment that they haven't been exposed to yet."

Grant is working with Robert Montgomery, professor of psychological science at Missouri S&T, to measure the benefits of the training simulator. Soon they'll begin working with student volunteers to test how effectively the audio-battlefield environment assists individuals in becoming habituated to a battle environment.

See the video
www.youtube.com/missourisandt

Army Capt. Chad Foster delivers a situation report over the radio during an air assault raid on a suspected insurgent sanctuary in Mushahda, Iraq, on June 23, 2006. Photo by U.S. Department of Defense



Maggie Bollinger and Brad Harris test a 3D printer. Photo by B.A. Rupert/Missouri S&T

Experiencing research, as an undergrad

CREATING NEW ADDITIVE MANUFACTURING processes is a Missouri S&T specialty, and students interested in the research now have an excellent opportunity through the university's Additive Manufacturing Research Experiences for Undergraduates (REU) Program.

Funded by the National Science Foundation, the program brings eight undergraduates from outside the university to Missouri S&T for 10 weeks. They work alongside faculty and student experts.

"Students work as a team designing and developing a new additive manufacturing process," says Robert Landers, associate professor of mechanical and aerospace engineering. "They also build and test products using these processes."

The program will run for two more summers on the heels of the Wireless Sensor Computing REU Program that recently wrapped up its four-year run. Sanjay Madria says its participants have published research papers at IEEE conferences, joined graduate programs at Missouri S&T and other top universities, and presented their findings at Osaka University in Japan.

"We trained students in the use of sensor networks and data security using a sensor network test bed," says Madria, associate professor of computer science. "They learned how to develop effective strategies for handling threats to civilian infrastructures."

Healing with glass

Glass-fiber work by Steve Jung (left) and Delbert Day may lead to a new method to heal open wounds. Photo by B.A. Rupert

WHAT IF ALL A BATTLEFIELD MEDIC HAD TO DO to treat a serious or lingering wound was to stuff it with a material that looks and feels like cotton candy? Sounds unlikely, but that is pretty close to what is happening in a clinical trial at Phelps County Regional Medical Center in Rolla, Mo.

The cotton candy-like fibrous material used in the trial was developed at Missouri S&T's Graduate Center for Materials Research and the Center for Bone and Tissue Repair and Regeneration by bioglass pioneer Delbert Day, Curators' Professor emeritus of ceramic engineering, and his former graduate student, Steve Jung, who earned bachelor's, master's and Ph.D. degrees from Missouri S&T. The material is produced at Mo-Sci Corp., a glass technology company Day co-founded.

In a recent clinical trial, the material, a nanofiber borate glass, was found to speed the healing of venous stasis wounds in eight of the 12 patients enrolled.

Other bioactive glass materials are formed from silicate glass compositions and have been used primarily for hard-tissue regeneration, such as bone repair. But Day and Jung say borate glass reacts with body fluids much faster than silicate glasses.

"The borate glass nanofibers (about 1/1000 the diameter of a human hair) react with the body fluids very quickly" when applied to an open wound, says Day. "They begin to dissolve and release elements into the body that stimulate the body to grow new blood vessels and new soft tissue. This improves the

> The borate glass nanofibers begin to dissolve and release elements into the body that stimulate the body to grow new blood vessels and new soft tissue. This improves the blood supply to the wound, allowing the body's normal healing process to take over.
>
> — Delbert Day
>
> Curators' Professor emeritus of ceramic engineering

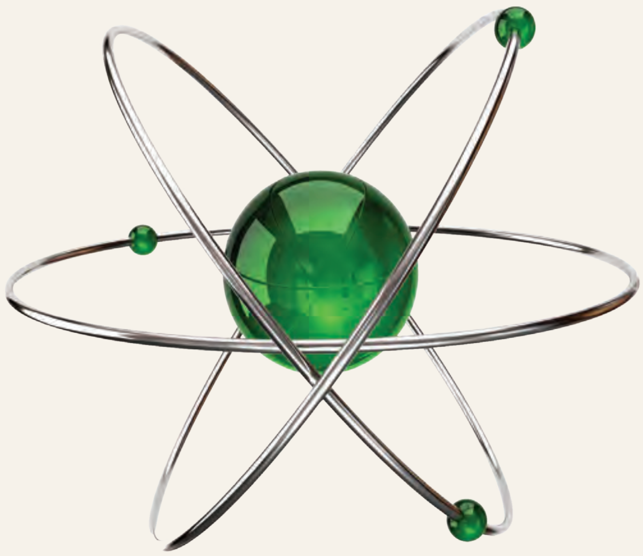
blood supply to the wound, allowing the body's normal healing processes to take over."

The treatment is simple. First the wound is washed with water, and then a pad of the dry nano fibers is applied to the wound. Every four to seven days, the wound is washed and a new pad of dry fiber is applied until the wound is healed. There is very little scarring.

Clinical trials at Phelps County Regional Medical Center in Rolla began in the fall of 2010 with 13 subjects, and now includes a total of 32 patients with many different types of non-healing wounds, including pressure ulcers, bed sores and surgical incisions. Many are diabetics with wounds that have not healed for up to a year.

Depending on the severity of the wound, Day says the wounds can heal within a few weeks to several months after the glass nanofiber material is applied. "Within a few days, most patients see an improvement," he says.

Day foresees expanding the clinical trials to include patients with other types of difficult-to-heal wounds, such as burn victims.



To solve the few-body problem

IT IS WELL ESTABLISHED THAT AT MOST four fundamental forces are required to describe nature. These forces can only act between two objects at a time. But what happens when there are more than two objects involved?

The equations to calculate the motion of all involved objects are then no longer exactly solvable. That is known as the "few-body problem" and it's one of the oldest and most important fundamental unsolved problems in physics.

For larger objects, like planets, the motion of two bodies is predictable. But in quantum mechanics, which deals with particles of atomic size, Newton's laws no longer apply. The wave-like nature of microscopic particles has a drastic consequence.

"Even if only two bodies are involved there is an inherent uncertainty to their motion that is not due to imperfections in our theories, but is provided by nature," says Missouri S&T experimental physicist Michael Schulz. "This makes the few-body problem even more challenging."

Schulz, Curators' Professor of physics, provides benchmark data essential to theoretical efforts to develop sophisticated models that will get closer to a solution.

He and his fellow researchers take 3-D snapshots of electrons that were ejected from an atom by a collision with a proton, then compare them to theoretical calculations to test their accuracy.

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Commercializing a new kind of camera

Reza Zoughi (second from left) and Mohammad Tayeb Ahmad Ghasr, assistant research professor of electrical and computer engineering, work on the hand-held camera with electrical engineering students Royce Bohnert (left), a senior, and Brice Hirst (second from right), a graduate student.

REZA ZOUGHI, THE SCHLUMBERGER DISTINGUISHED Professor of Electrical Engineering at Missouri S&T, invented a hand-held camera that uses millimeter and microwave signals to peek inside materials and structures. He holds three patents for related technologies, and three more are pending.

The Small Business and Technology Development Center at Missouri S&T has been working with Zoughi's team to commercialize its inventions. "There are multiple applications," says Keith Strassner, director of technology transfer and economic development at Missouri S&T. "That's why it's so attractive as a business."

Among the camera's applications are:

- **Infrastructure health**. See through walls and inside structures to monitor deterioration.
- **Airport security**. Screen airline passengers for dangerous materials.
- **Aircraft inspection**. See beyond the paint of an aircraft to evaluate the quality of the underlying material.
- **Burn victims**. Determine if a skin graft is working without taking off the dressing, which is a painful step.

See the video
www.youtube.com/missourisandt

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**.