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re:search

An inside look at innovation and discovery at Missouri University of Science and Technology /// Fall 2012

Turning over a new leaf in manufacturing

Missouri S&T researchers look to nature for inspiration.

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Missouri S&T University of Science & Technology

Fiscal Year 2012 Summary

Proposals submitted

493

Dollars requested

$ 151.4 M

Proposals awarded and amendments

270

Dollars awarded

$ 24.7 M

Total expenditures

$ 41.4 M

Faculty involved with sponsored activities

214

Invention disclosures

46

Patent applications filed

22

Patents issued

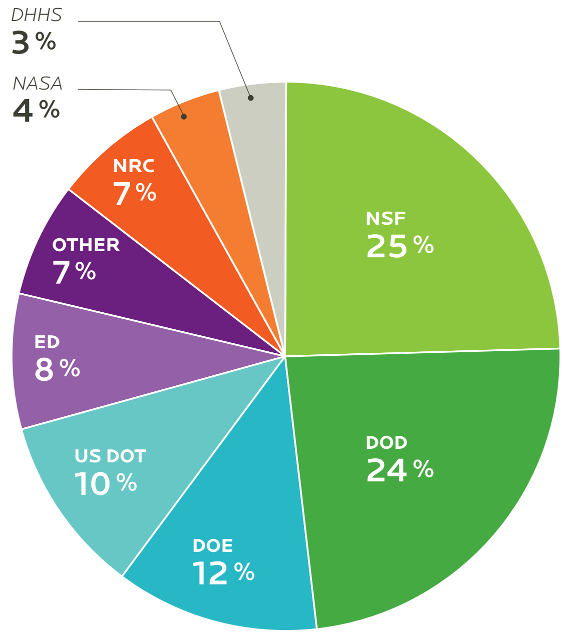
13

Licenses/Options signed

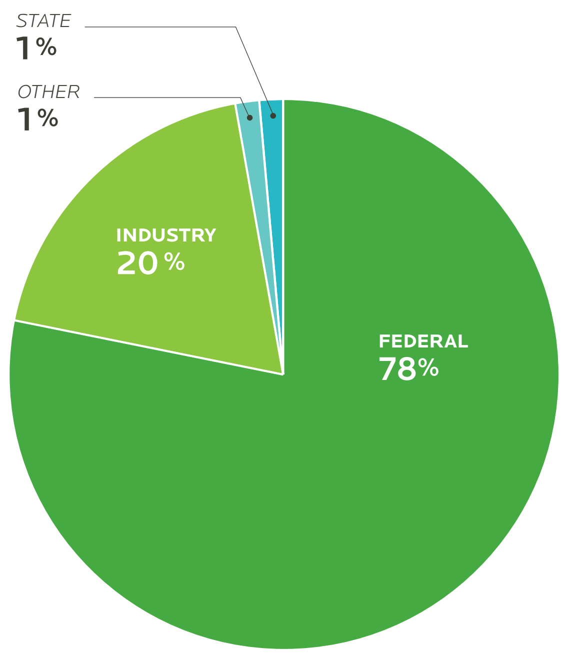
6

Licensing income

$ 265 K



FY12 federal awards by source (total amount: $19.3 M)



FY12 sponsored awards by source (total amount: $24.7 M)

K. Krishnamurthy
Vice Provost for Research

Dear Colleague,

I am excited to share with you some of Missouri S&T's cutting-edge research in this Fall 2012 issue of *re:search* magazine. You will read about the advanced technologies being developed by Ming Leu and his colleagues to manufacture new products and make existing manufacturing processes more efficient, and how faculty in nuclear engineering and chemical and biological engineering are contributing to the nuclear renaissance. You will learn more about Bill Fahrenholtz's and Greg Hilmas' work to develop ceramics for ultra-high temperature applications, Daniel Forciniti's research to understand formation of plaques involving different proteins, Yew San Hor's pioneering efforts to grow perfect crystals of topological insulators that are necessary for future electronic materials, and Julia Medvedeva's focus on the fundamental materials science of amorphous oxide semiconductors for developing novel transparent conductors.

You will also read about Martin Bohner's work to model insect population using time scales calculus, an area that he was instrumental in developing. The book he co-authored with A.C. Peterson, the other leader in this field, has been heavily cited and is the definitive reference in the area. This brings up the subject of scholarship, which also needs to be recognized and celebrated. John McManus is one of Missouri S&T's most prolific faculty members, having written 10 books on military history. His latest work, *September Hope: The American Side of a Bridge Too Far*, was published in June 2012. Earlier this year, he was named the 2012 Research Fellow by the First Division Museum at Cantigny Park in Wheaton, Ill.

I am also pleased to note that we now have four National Science Foundation Industry/University Cooperative Research Centers (I/UCRCs) at Missouri S&T. Working to solve network computing security and energy efficiency problems, the latest center is one of the sites of the Net-Centric Software Systems Center I/UCRC led by the University of North Texas.

Discovery, creativity and innovation are essential to expand the frontiers of human knowledge to maintain our national security, improve our quality of life and build a sustainable future. I hope you will take some time to learn more about what we are doing at Missouri S&T to address the grand challenges facing us.

Sincerely,

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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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Turning over a new leaf in manufacturing

Proton exchange membrane fuel cells, or PEMs, hold promise as a clean energy source for transportation vehicles — from hybrid cars to future hypersonic spacecraft. But they aren't yet as efficient at transferring energy as engineers would like.

Some Missouri S&T researchers are looking to nature for inspiration.

By studying how the veins of a leaf carry nutrients from the stalk to the blade, these researchers hope to improve the way hydrogen flows through the PEMs. Analyzing leaf patterns from a variety of flora, the researchers are developing flow patterns to improve power density within the PEM cells.

This "bio-inspired" approach to manufacturing components is one example of the kind of advanced manufacturing research under way at S&T.

"We're working to come up with new technologies, or to improve or optimize existing technologies," says **Ming C. Leu**, the **Keith** and **Pat Bailey** Missouri Distinguished Professor of Integrated Product Manufacturing and director of S&T's Center for Aerospace Manufacturing Technologies and the Intelligent Systems Center.

With the PEM fuel cell research, Leu and **Umit Koylu**, a professor of mechanical and aerospace engineering, are trying to improve an alternative energy technology. They're using an additive manufacturing approach known as selective laser sintering, which uses a high-powered laser to fuse small particles of powdered materials — graphite composites, in the case of PEMs — to create 3-D shapes, layer by layer.

S&T researchers can apply this high-tech sintering technique to other materials for different purposes. For instance, Leu and **Greg Hilmas**, Curators' Professor of ceramic engineering, are selectively sintering special types of glass for biomedical applications and working with high-temperature ceramics that one day might be used to build hypersonic spacecraft.

As the White House pushes to create a National Network for Manufacturing Innovation to boost U.S. manufacturing competitiveness, Leu believes S&T is well-positioned for this new national agenda. He and his colleagues already work with industry partners to make manufacturing more efficient, less expensive and more innovative – all goals of the White House initiative.

For instance, Leu leads another additive manufacturing effort that holds promise for the nation's aerospace industry. Working with Hilmas and **Robert Landers**, an associate professor of mechanical engineering, Leu is developing a process that mixes tough metals like tungsten with ceramic materials like zirconium carbide in a water-based slurry, then deposits the mix, layer by layer, in a pre-programmed model with "functionally graded materials." The method could be used to create a nose cone that would allow spacecraft to withstand the extreme temperatures of high-speed space travel.

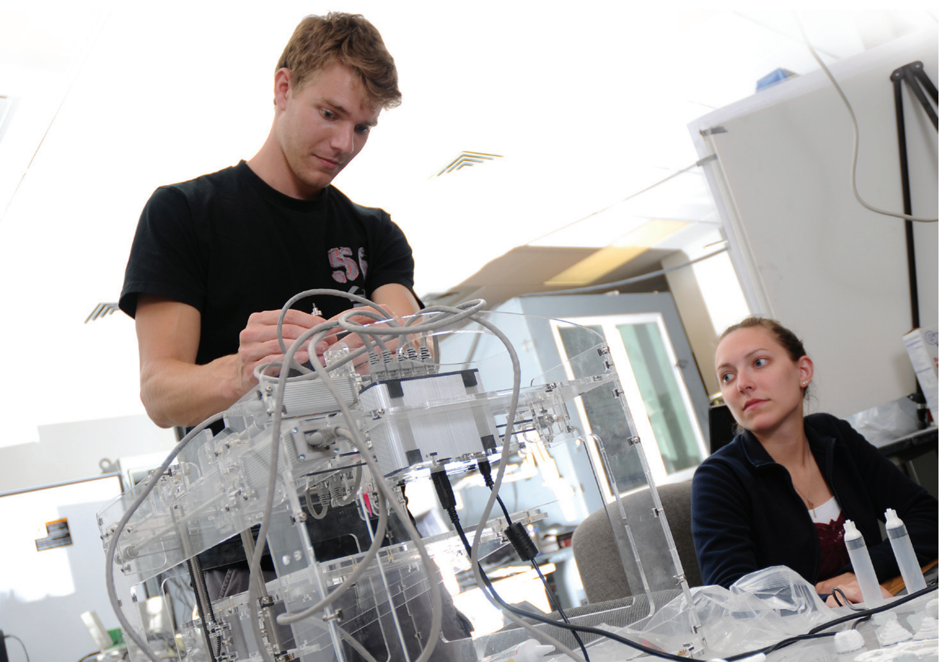
To carry out this research, Leu and his colleagues had to build a special computer-controlled machine with multiple extruders. They worked with the Boeing Research and Technology division to build the machine.

"This research is so new, there is no off-the-shelf equipment available for us to use," Leu says. ■

→

An efficient approach

Several S&T researchers are focused on advanced manufacturing, including Ming C. Leu (bottom, left).



Better ways to manufacture

/// You don't have to build a better mousetrap to succeed in manufacturing. As Missouri S&T researchers are showing, sometimes it's more important to make existing processes more efficient to save time, money and materials. Here are some examples of that research:

Frank Liou, the **Michael** and **Joyce Bytnar** Professor of Product Innovation and Creativity, is investigating how using a high-powered laser to melt metal particles as they exit a nozzle could make or repair specific parts in a layered fashion. This approach could allow companies to repair expensive components instead of scrapping them.

Grzegorz Galecki of S&T's High-Pressure Waterjet Laboratory and an associate professor of mining engineering uses abrasive waterjets to cut through titanium. This could save money for the aerospace industry by reducing waste.

K.C. Chandrashekhara, Curators' Professor of mechanical and aerospace engineering, is developing an "out-of-autoclave" manufacturing process. Conventional manufacturing of composite materials for aerospace, infrastructure and housing requires a high-temperature, high-pressure autoclave to cure the materials. By developing a way to manufacture composites without an autoclave, Chandrashekhara could help a company cut manufacturing costs and production time.

Robert Landers, associate professor, is working with **Doug Bristow**, an assistant professor, to make machine tooling more accurate. The mechanical and aerospace engineering reseachers are developing an approach that allows any machine tool's controller to compensate for the inherent errors that occur in machining due to dimensional issues, temperature changes and the like. Companies such as Boeing, one of the main sponsors of Leu's Center for Aerospace Manufacturing Technologies Industrial Consortium, could adapt this research to improve machining accuracy.

Growing nuclear

Nuclear energy has huge potential as an abundant source of clean power. The key is to unleash it in a controlled way.

Muthanna Al-Dahhan, chair of chemical and biological engineering and professor of nuclear engineering at S&T, is studying fourth-generation nuclear energy systems through two research grants.

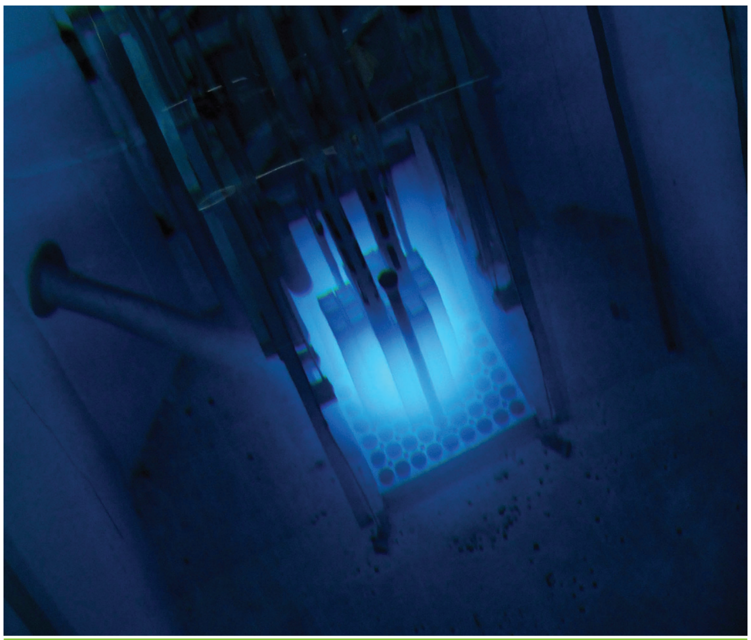
The first project examines the core of pebble-bed nuclear reactors, which are cooled by helium. Nuclear fuel particles are placed in graphite pebbles. Gravity pulls them down and then they are circulated back to the top of the core, Al-Dahhan says. His other project is to help advance the design, scale-up and performance of gas-solid spouted beds by coating nuclear fuel particles in all types of fourth-generation nuclear reactors.

While nuclear engineers strive to make clean energy more available, they also drive innovations in medicine. In addition to making standard X-rays and other treatments possible, nuclear technology is used to detect and treat various kinds of cancer and other diseases. Missouri S&T faculty members **Hyoung-Koo Lee**, an associate professor, and **Xin Liu**, an assistant professor, are both working on research related to nuclear medicine, including technologies that could improve mammograms and other procedures. Current research areas include digital mammography, computed tomography and digital tomosynthesis.

S&T houses one of the state's three nuclear reactors — the first one in Missouri. It is used for teaching and research.

"Using our reactor, Dr. Lee has been conducting research on a new imaging system that will produce clearer pictures of biomaterials," says **Arvind Kumar**, chair of the nuclear engineering program at S&T.

"The technology could also be used to examine the contents of shipping containers." ■



First in the state

The core of S&T's nuclear reactor, known as a "swimming pool" reactor, sits near the bottom of a large concrete pool of water.

Clean energy

Arvind Kumar leads S&T's nuclear engineering program. S&T is one of only 22 universities in the nation to offer bachelor's degrees in the subject.

re:search

Making proteins 'behave badly'

One of the hallmark traits of neurological diseases like Alzheimer's, Parkinson's and even Mad Cow is the presence of plaque. Understanding the formation of these plaques, each involving different proteins, is key to helping researchers diagnose, prevent or find a cure for these diseases, say Missouri S&T researchers.

Nearly 15 years ago, **Daniel Forciniti**, professor of chemical and biological engineering at S&T, began studying how proteins and peptides behave when they are near a solid surface — such as when a protein in blood adheres to the inner surface of a vein.

While the debate over what causes these diseases continues, it's commonly accepted that an abnormal buildup of protein deposits on the surface of the brain, also known as amyloid deposits or plaques, are found in people with Alzheimer's disease.

Scientists have been able to trick proteins into creating amyloid plaques, but only in extremely acidic and high-temperature environments. That situation is vastly different from what occurs in the human body, Forciniti says.

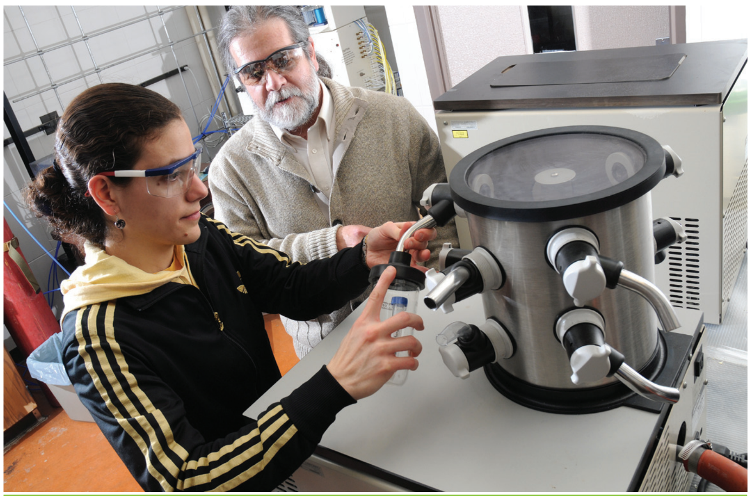
"They subject these proteins to harsh conditions at unrealistically high concentrations," Forciniti says. For example, these proteins may be immersed in a 3 pH solution, which is significantly more acidic than a human body's pH of 7.5. Instead of using nanomoles of peptides, as is found in the brain, researchers commonly use larger millimoles of peptides.

Forciniti's experimental and computational studies focus on making amyloid deposits at physiological conditions using model peptides. Under Forciniti's direction, a group of undergraduate and graduate students have synthesized tailored peptides from amyloid deposits at relatively mild conditions using solid surfaces as templates.

"Differences in the kinetics of plaque formation have been observed in bulk and interfacial conditions," he says. "Our group is working to better understand what types of peptide and surface encourage the formation of plaque." ■

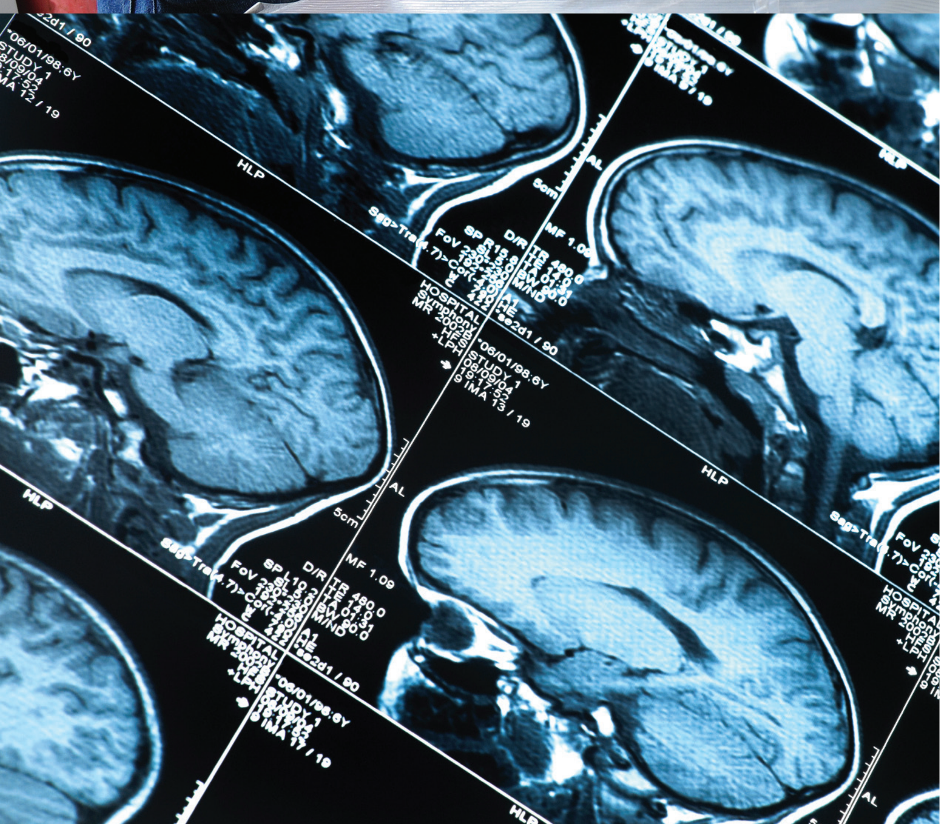
Bright ideas

Daniel Forciniti (right), professor of chemical and biological engineering at S&T, and his students are working to understand neurological diseases like Alzheimer's.



On my mind

Understanding how plaque forms may lead to ideas on how to intervene in the process.



The calculus of time scales

/// When the growing mosquito population in New York City led to an increase in West Nile Virus cases in both birds and humans in the early 2000s, researchers used a new mathematical model to improve eradication.

This method, known as time scale calculus, allowed the researchers to simultaneously study both differential equations (continuous time equations) and difference equations (discrete time equations). Instead of focusing only on the warm summer months, the researchers modeled the mosquito population over a period that included both warm and cold months. This allowed them to examine other variables, such as migratory bird patterns and the effects of temperature variation on mosquito lifecycles. As a result, New York health officials were able to limit the spread of the virus.

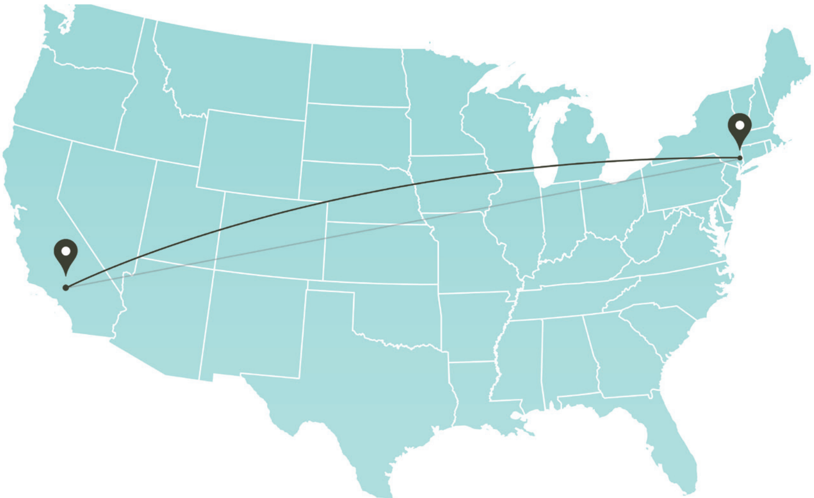
Missouri S&T mathematics and statistics professor **Martin Bohner** is an internationally recognized leader in the field of time scales calculus. His book, *Dynamic Equations on Time Scales: An Introduction with Application*, co-authored with Allan Peterson of the University of Nebraska-Lincoln, is the main textbook on the subject.

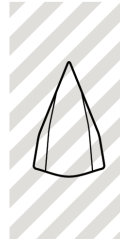
"In his book *Men of Mathematics*, Eric Temple Bell wrote: 'A major task of mathematics today is to harmonize the continuous and the discrete, to include them in one comprehensive mathematics and to eliminate obscurity from both.' Time scales analysis accomplishes exactly this," Bohner says. "It is also able to extend the study of differential and difference equations to a more general class of dynamic equations, which includes, for example, quantum-difference equations."

Most applications of time scale calculus so far are seen in biological systems — modeling the healing of wounds or the electrical activity of the human heart — but it could also be used to improve models of the stock market or to predict how students suffering from bulimia can be influenced by their college friends. ■

From Los Angeles to New York

The Falcon goes so fast it can make the commute from Los Angeles to New York in 12 minutes — more than 8 times faster than an F-18 and more than 33 times faster than a C-5.

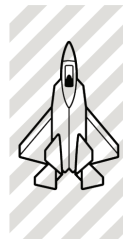




Falcon

Mach 20
SPEED

00:12
APPROXIMATE FLIGHT DURATION



F-18

Mach 1.5
SPEED

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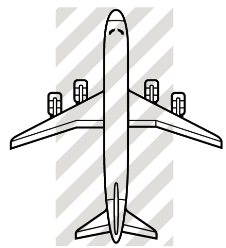
APPROXIMATE FLIGHT DURATION



C-5

Mach 0.6
SPEED

06:40
APPROXIMATE FLIGHT DURATION

If you can't stand the heat, get out of the laboratory

Last summer, the Defense Advanced Research Projects Agency (DARPA) tested a hypersonic cruise vehicle called Falcon, which is capable of reaching the upper levels of the atmosphere and delivering a military strike anywhere in the world in less than one hour. The test flight was aborted after nine minutes when portions of the vehicle's skin began to peel from heat hot enough to melt steel.

Meanwhile, at Missouri S&T, **Bill Fahrenholtz** and **Greg Hilmas** are studying zirconium-diboride-based ceramics that could be used to keep hypersonic vehicles from melting at temperatures above 3,000 degrees Celsius as they fly.

"Our work is applicable to the development of hypersonic aerospace vehicles with a global reach," says Fahrenholtz, professor of materials science and engineering. "The nose, the leading and trailing edges, and the propulsion section of hypersonic vehicles are exposed to the most heat."

Supersonic objects travel faster than the speed of sound, which is Mach 1. An object going five times that speed is considered hypersonic. The DARPA vehicle tested last year reached Mach 20, a speed that would enable it to get from Los Angeles to New York in 12 minutes – a very hot trip.

While ceramics are much more heat-resistant and oxidation-resistant than common metals, researchers must find the right elemental combinations to use for applications involving ultra-high temperatures. Hilmas, a Curators' Professor of materials science and engineering at S&T, says ceramic powders are heated to extreme temperatures in the laboratory while being compressed to make dense materials for the sleek vehicles — which reach high altitudes and then dive toward a target. According to Hilmas, these hypersonic vehicles need more heat protection over longer periods of time than the retired space shuttles or Apollo-style capsules. ■

Watch it

To see a video of the Falcon's test flight, scan the QR code above with your smart phone.

It’s a matter of spin

Recently discovered materials called topological insulators (TIs) may provide the key to the emerging technology of spin electronics or spintronics. Surfaces of TIs contain electrons with unusual spin properties that flow without dissipating, while the interior of the material prevents flow. Coupled with a superconductor, the TI could help create fault-tolerant quantum computers.

But before researchers can begin to tap TIs' potential, they must first create a perfect sample to test. Missouri S&T physicist **Yew San Hor** is a pioneer in growing TI crystals. He says research success hinges on growing a perfect TI specimen.

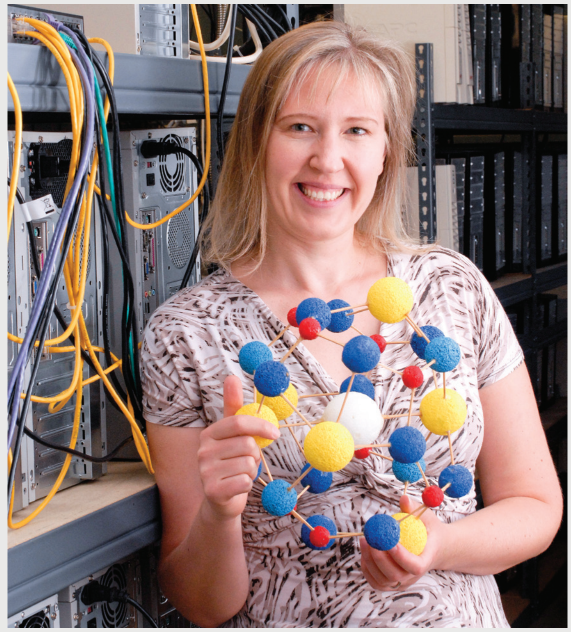
“Growing the crystal is a bit like baking a cake,” says Hor. “We have the correct ingredients, chemical elements in this case, and the perfect ‘recipe,’ but it’s a very delicate process that is affected by many factors."

Hor says many believe the study of TIs will help in the search for Majorana fermions, particles that contain both a positive and negative charge, which could be key to solving quantum computing applications. The research might also help confirm the existence of axions, hypothetical particles that may provide clues to the mystery of dark matter in the universe.

Once he has grown perfect crystals of TIs in his laboratory, Hor will study the TI crystal’s surface using ARPES (angle-resolved photoemission spectroscopy) to observe the electrons’ behavior. He'll also use a low-temperature electronic transport measurement system to “capture” the surface electrons. ■

Yew San Hor

Out of thin air



Julia Medvedeva

/// You’ve probably seen it in sci-fi movies — digital images that seem to appear out of thin air that can be manipulated by touch. Transparent materials that can transmit electronic images like that do exist — the problem is, they are really expensive to make.

An interdisciplinary team of researchers is working to find cheaper and more environmentally friendly materials to replace indium oxide, the best performing and most commercially used material that is both transparent like glass and conducting like metal.

The only theorist and physicist in the group, **Julia Medvedeva** represents Missouri S&T at the National Science Foundation-supported Center of Excellence for Materials Research and Innovation at Northwestern University.

“We’re looking for materials that are easy to grow and mass produce here in America,” she says. “My role is to calculate the properties of the materials before they are made in the lab, make suggestions as to what to grow, and predict the outcomes.”

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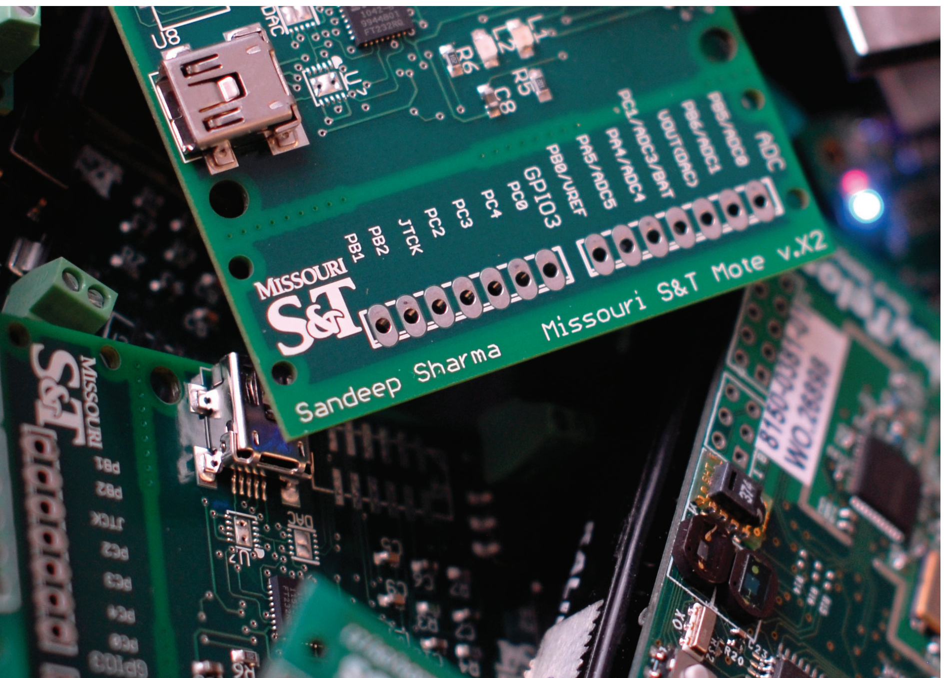

Speed + security

/// Researchers in Missouri S&T's Net-Centric Software Systems Center are working to solve two of the biggest problems with network computing – security and energy efficiency.

With funding from the National Science Foundation, the center is part of an Industry/University Cooperative Research Center (I/UCRC) with four universities and more than 20 industry partners, including the Air Force Research Lab. Its researchers work on both hardware and software issues in any application where systems are connected, like wireless networks, wired networks, mobile clouds and sensor networks.

"Our mission is to provide a platform for cutting-edge interdisciplinary research that brings faculty from many organizations together to collaborate," says **Sanjay Madria**, professor of computer science and director of the center. "We're applying our research to real-world applications in both industry and government agencies."

Working with Madria are **Sriram Chellappan**, assistant professor of computer science, and **Yiyu Shi**, assistant professor of electrical and computer engineering.

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.