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Research Edition 2016

J. Todd Hastings

Advancing nanotechnology research at UK and in the Commonwealth

ANNUAL RESEARCH EDITION

Message from Interim Dean Larry Holloway

In July, John Walz, who served as dean of the University of Kentucky College of Engineering for four years, became president of the Milwaukee School of Engineering. During his time as dean, John helped advance several areas within the college, specifically the quality and quantity of our research output. We are deeply appreciative of his service to the college and wish him well in his new post.

The signs for continued progress are positive. In the last three years, we have had five NSF CAREER Award winners. Our number of Ph.D. graduates has increased each of the last three years. We continue to participate in multidisciplinary and multi-institutional grants sponsored by the NSF, Department of Defense, Department of Energy and more. We believe we are poised to sustain our success and provide fertile ground for the next dean of the college.

In this issue, we are pleased to feature Todd Hastings, who holds the Reese S. Terry Professorship in Electrical Engineering and is director of UK's Center for Nanoscale Science and Engineering. After earning his master's degree at Purdue University and his Ph.D. at MIT, Todd has fostered a brilliant career in the area of nanotechnology. Having served as his department chair until recently becoming interim dean, I am thrilled that you will have a chance to read further about one of the college's top researchers.

Larry Holloway
Interim Dean

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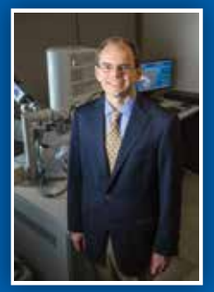

FRONT COVER
A Lexington native, Reese S. Terry Professor of Electrical Engineering J. Todd Hastings is the director of UK's Center for Nanoscale Science and Engineering.

College of Engineering

Marquette's Johnson Becomes Chair of the Department of Electrical and Computer Engineering

Michael T. Johnson, Ph.D., professor in the Marquette University Department of Electrical and Computer Engineering, has become the next chair of the University of Kentucky College of Engineering's Department of Electrical and Computer Engineering. Johnson began his duties August 1 with the rank of tenured full professor.

Johnson earned a Bachelor of Science in computer science and engineering from LeTourneau University in 1989 and followed it with a bachelor's degree in engineering with electrical concentration a year later. He received a Master of Science in electrical engineering from The University of Texas at San Antonio in 1994 and his doctoral degree in electrical and computer engineering from Purdue University in 2000. In addition to his academic background, Johnson has six years of industry experience as a design engineer and engineering manager.

After receiving his doctorate, Johnson began teaching at Marquette in 2000, achieving the rank of full professor in 2013. He served as director of his department's graduate studies for three years as well as on the University Board of Graduate Studies for seven years, two as chair. In both 2008-2009 and 2014-2015, he was a senior visiting faculty member at Tsinghua University in Beijing, China.

Johnson's research interests include speech and signal processing, machine learning and bioacoustics. He has received over $2.5 million in external funding, including multidisciplinary and multi-institutional grants. In addition, Johnson has authored 38 journal papers and more than 110 total refereed publications and presentations.

Johnson is a senior member of the Institute of Electrical and Electronics Engineers (IEEE) and a member of the IEEE Signal Processing Society. He is an area editor in the area of speech enhancement for the journal Speech Communication and is a member of the IEEE Signal Processing Society's Speech and Language Processing Technical Committee.

Johnson replaced Larry Holloway who became the interim dean of the UK College of Engineering on July 1.

UK Granted Permission to Conduct Drone-Based Research

Photo: Courtesy of Sean Bailey

The University of Kentucky has received permission from the Federal Aviation Administration (FAA) to conduct research with unmanned aerial systems (UAS), or drones, nationwide, following FAA regulations.

"UK is among the first universities in the country to receive this new FAA 'blanket' authorization," said Suzanne Smith, director of the UK Unmanned Systems Research Consortium and the Donald and Gertrude Lester Professor of Mechanical Engineering. "Now, UK faculty will be among the first to perform and publish their research on leading-edge autonomy technologies and applications and the new scientific discoveries that are sure to result."

The FAA's public Certificate of Authorization (CoA) allows UK researchers to fly drones that are less than 55 pounds up to 400 feet and less than 100 mph at sites across the U.S., away from airports and under other FAA procedures. UK is currently reviewing its guidelines with respect to drones on campus.

Procedures for those flying under the CoA include registering the UAS; issuing a NOTAM (Notice to Airmen) 24 hours prior to flights; having a certified pilot overseeing all flights along with trained visual observers; following safety procedures; maintaining a logbook and submitting monthly reports.

Researchers across a range of disciplines will now be allowed to conduct flights, including mining, precision agriculture, atmospheric science and transportation—all areas of significance for Kentucky and the nation—at their respective research sites.

"For example, researchers in transportation can conduct bridge inspection research for all but a handful of the 11,000 bridges in Kentucky at this altitude," Smith said.

UK researchers also continue to increase their UAS-based research collaborations across the nation. This summer, the three-state, four-university CLOUDMAP program, funded by the National Science Foundation to research atmospheric science and led at UK by Michael Sama, Jesse Hoagg, Sean Bailey, Marcelo Guzman and Smith, took place in Kentucky and Oklahoma. Other projects, such as elk research in Robinson Forest, as well as geological and transportation research across Kentucky, are in the planning stages.

To fly previously, UK researchers had to submit a separate application for each aircraft/location/flight-plan combination. Each application required multiple parts and could take three to nine months or more to process.

"This type of research could not be accomplished without the support of many individuals campuswide," Smith said, "and the researchers are very grateful."

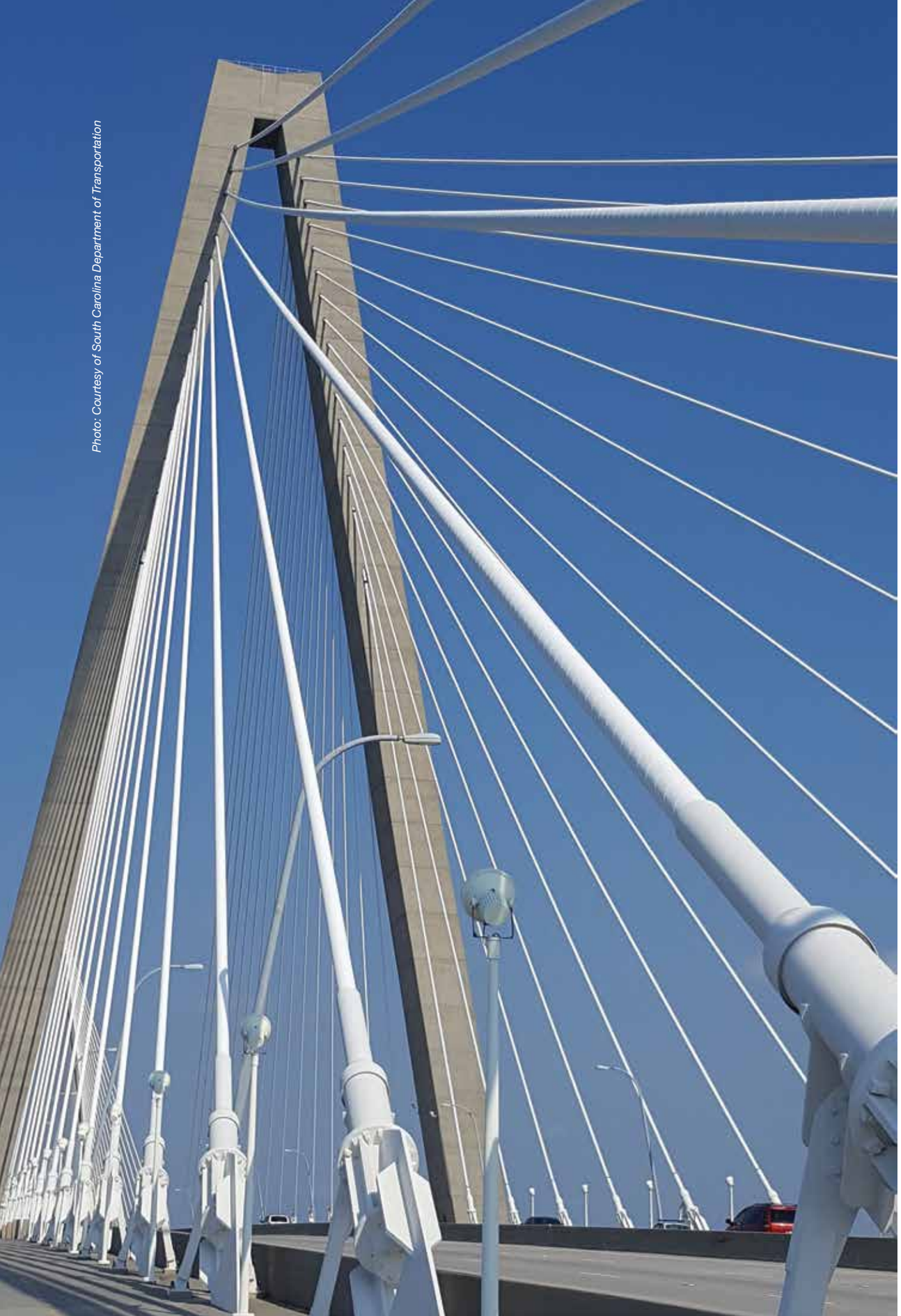

Photo: Courtesy of South Carolina Department of Transportation

ONE OF A KIND

*The University of Kentucky College of Engineering and the **Kentucky Transportation Center** Enjoy a Unique and Productive Relationship.*

In 1941, the Kentucky Department of Highways established a Materials Research Laboratory on the University of Kentucky campus. Over nearly 40 years, this single laboratory expanded its areas of expertise, eventually evolving into the Kentucky Department of Transportation's (DOT) Division of Research. In 1980, Governor John Y. Brown issued an executive order that dissolved the Division of Research and assigned the DOT's research functions to the University of Kentucky. Since that time, the Kentucky Transportation Center (KTC) has been located in the UK College of Engineering and has carried out the research program of the Kentucky DOT (now the Transportation Cabinet) under a master research agreement. This relationship is the only one of its kind in the United States.

Among research centers and consortia at UK, KTC is one of the most prolific when it comes to funding. In each of the last four years, KTC has tallied over $10 million in research expenditures. The $12 million in sponsored projects KTC received for the 2015-2016 fiscal year placed it third among non-medical research units at UK. The center conducts research for a variety of sponsors, including federal, state and local agencies as well as private companies.

"We are a large, multidisciplinary center, yet we reside within a college," says Director Joe Crabtree. "The arrangement gives us unique opportunities for collaboration. Seven faculty members from the Department of Civil Engineering routinely conduct KTC research, including three who serve as program managers."

KTC has eight dedicated research programs: construction management; structures; transportation planning; pavements, materials and geotechnology; bridge preservation; traffic safety and operations; ITS and traffic management and economics, finance and planning. KTC has 47 permanent employees, along with a substantial number of student and temporary workers, for a total employment well in excess of 100 people.

KTC's technology transfer group serves as the interface between the research arm of the center and the public officials who oversee Kentucky's transportation operations. In 2015, the technology transfer program conducted 333 training programs that reached 8,030 participants across the state. Sessions run throughout the year and range from best practices in asphalt paving or snow and ice removal to multicourse offerings in management.

Crabtree, who attended UK on a transportation scholarship in the mid-1970s, was a research engineer for the state DOT when Governor Brown transferred the research functions to KTC. He became KTC's director in 2010 and was recently reappointed for another six-year term.

"There has never been a more exciting time to be involved in transportation research," says Crabtree. "New technologies, such as connected and autonomous vehicles, have the potential to dramatically improve safety, efficiency and mobility, but those opportunities are accompanied by significant challenges. We also face major issues pertaining to our aging infrastructure, transportation funding mechanisms and how to design and construct roads and bridges that last longer and require less maintenance. There is important research to be done in these and many other areas, and I am confident that KTC has the expertise to address the most critical challenges facing Kentucky's transportation system." KEJ

SCALING UP

Reese S. Terry Professor in Electrical Engineering
***J. Todd Hastings** has put the Commonwealth of Kentucky in the upper echelon of nanotechnology research and development.*

Although Todd Hastings received his master's degree from Purdue University and his doctoral degree from MIT—two of the top 10 engineering schools in the country—his hope was that one day he would be a professor in the University of Kentucky College of Engineering. A Lexington native, Hastings was thrilled when he was offered a faculty position in UK's Department of Electrical and Computer Engineering in 2003. Now the Reese S. Terry Professor in Electrical Engineering, he has been the recipient of a National Science Foundation (NSF) CAREER Award as well as a Defense Advanced Research Projects Agency Young Faculty Award. In addition, Hastings has secured over $4.6 million dollars in funded projects as principal investigator, led 14 awards as principal investigator and collaborated on many others, including a National Nanotechnology Coordinated Infrastructure (NNCI) grant from the NSF.

In September 2015, UK and the University of Louisville announced the $3.76 million NNCI grant to create the Kentucky Multiscale Manufacturing and Nano Integration Node (MMNIN)—a national center of excellence in micro/nanotechnology. The highly competitive award was one of just 16 awarded to universities across the country and puts UK and UofL's eight combined research centers in a new national network that will make university facilities, tools and expertise in nanoscale science, engineering and technology more readily available to network institutions.

"Across the country, there have been significant achievements in nanotechnology over the last several years," says Hastings, co-PI and UK site director. "As a result, there is a need to incorporate those achievements into larger systems. From atomic scale creations to devices we can handle, this network allows us to collaborate for the sake of creating something bigger."

The award is for five years, with the opportunity to renew for another five years. Other notable institutions also receiving this grant were Georgia Tech, Stanford, Cornell, Harvard, Virginia Tech, The University of Texas at Austin and Wisconsin.

"No institution can house the infrastructure for everything," Hastings summarizes. "This network allows institutions to access others' specialized capabilities in the most efficient way possible."

Hastings also directs the highly multidisciplinary Center for Nanoscale Science and Engineering (CeNSE) which is part of the MMNIN and focuses on development of devices which exploit nanoscale phenomena. Using CeNSE resources, and in collaboration with FEI Company, an electronic microscope manufacturer based in Oregon, Hastings is exploring nanoscale 3-D printing thanks to an NSF Grant Opportunities for Academic Liaison with Industry Award.

"It is quite challenging to print something one thousandth the size of your hair, but there is a real need for it. Instead of developing a process from the ground up and using multiple pieces of equipment, our vision is to be able to go into the lab, and in one setting with one piece of equipment, quickly prototype small devices directly in real materials," Hastings explains.

Among Hastings' other research endeavors, he is working with electrical and computer engineering professor Daniel Lau on a new type of camera that can detect the full spectrum of light in an image, as opposed to simply red, blue and green. The camera can also give distance information. Lau and Hastings envision possible medical applications, such as fluorescence for guided surgery where visuals can be color-coded and differentiated. He is also engaged in a collaborative effort with UK physics professor Lance De Long in which the two are building magnetic nanostructures that might ultimately find application in magnetic computing or data storage. KEJ

GRANT ACTIVITY

CAER Part of $317 Million Venture to Accelerate Fabric and Fiber Innovation

Rodney Andrews
Director of CAER and Professor,
Department of Chemical and Materials Engineering

The University of Kentucky Center for Applied Energy Research (CAER) has been selected to participate in a five-year, $317 million public-private partnership announced in April by U.S. Secretary of Defense Ashton Carter.

The partnership, named the Advanced Functional Fabrics of America (AFFOA) Institute is the latest Manufacturing Innovation Institute and is designed to accelerate innovation in high-tech, U.S.-based manufacturing involving fibers and textiles. Matt Weisenberger, associate director of CAER's materials group, will be leading the UK efforts.

The partnership includes 32 universities, 16 industry members, 72 manufacturing entities and 26 startup incubators spread across 27 states and Puerto Rico.

The new initiative will receive $75 million in Department of Defense funding with $242 million in additional funding coming from industrial partners, venture capitalists, universities, nonprofits and states.

The partnership will focus on the development of new technologies through research and innovation. It also will include a network of community colleges and technical education experts to ensure necessary workforce development.

CAER's materials group is home to the center's fiber spinning and processing research. The center operates the largest solution spinline found in an academic setting in North America. CAER will receive $3.5 million over five years to fund advanced/smart fibers and textile research.

"We appreciate the opportunity to partner with some of the nation's leading fiber and textile manufacturers to advance the next generation of functional materials," said Rodney Andrews, director of the Center for Applied Energy Research. "This funding confirms what we have known at CAER for quite a while—that our fiber production capabilities are at the forefront in fiber research and development technology, helping advance manufacturing in Kentucky and across the nation."

CAER's unique 100-foot-long fiber spinning line produces multifilament, continuous tow yarns. The line was designed to help provide solutions to the complex issues facing the fiber spinning industry, especially carbon fiber and multifunctional fibers.

"Our spinline has made some very promising advances," Weisenberger said. "We have developed the capability to continuously process hollow and multicore fibers, which will pave the way for the future development of multifunctional fibers."

Weisenberger said that these capabilities support AFFOA's vision to develop fibers that, when processed into a fabric, will function as electronic devices or sensors. Such smart fibers hold great commercial promise.

Kunlei Liu
Associate Director of Research at CAER and
Associate Research Professor,
Department of Mechanical Engineering

Rick Honaker
Professor and Chair,
Department of Mining Engineering

The U.S. Department of Energy (DOE) has selected the University of Kentucky's Center for Applied Energy Research (CAER) for a five-year renewal of its United States-China Clean Energy Research Center (CERC) grant. CERC was created in 2009 by the DOE, the China Ministry of Science and Technology and the China National Energy Administration to facilitate joint research and development of clean energy by teams of scientists and engineers from the U.S. and China.

The DOE grant totals $2.4 million over five years and will support CAER efforts to develop advanced coal technologies. Kunlei Liu, associate director of research at CAER and associate research professor in the Department of Mechanical Engineering, will serve as UK's principal investigator, along with his co-investigators Mark Crocker and Don Challman. Liu, an advanced combustion and pollution control expert, and Crocker, a leader in utilizing algae to mitigate CO2, will each serve as technical leads for specific research areas, while Challman serves on the U.S. Steering Committee and on the bilateral U.S.-China Intellectual Property Experts Working Group.

"This grant will help maintain CAER's international leadership in developing and advancing carbon capture technologies," said Rodney Andrews, director of the CAER. "The development of proven and economical clean coal technologies is crucial to sustaining economic and community development and improved quality of life in Kentucky and in communities throughout the world."

The U.S. Department of Energy (DOE) National Energy Technology Laboratory has awarded nearly $1 million to Rick Honaker, professor and chair of the Department of Mining Engineering, to develop a mobile pilot-plant facility for the recovery of rare earth elements from coal.

Honaker and his team, which includes collaborators at Virginia Tech and West Virginia University, will develop and test a mobile processing facility that can efficiently recover the rare earth elements (REE) present in coal and coal byproducts in an environmentally friendly manner.

"Previous research conducted by UK scientists and others has found that the critical materials needed for renewable energy technologies, such as in cell phones and other electronics, are found in coal and coal byproducts at concentrations that may be economical to recover," Honaker said.

The U.S. has 10.9 million tons of rare earth resources in coal deposits located in just five western and four eastern states, including Kentucky, West Virginia and Virginia, according to the U.S. Geological Survey Coal Quality Database.

"If advanced separation technologies become available, the resource base will increase substantially," Honaker said.

With those technologies, the coal industry could potentially produce approximately 40,000 tons of REEs annually, which is more than twice the amount consumed in the U.S.

Thomas Novak
Professor and
Alliance Coal Chair,
Mining Engineering

Chad Wedding
Assistant Professor,
Mining Engineering

MINING ENGINEERING PROFESSORS COMBAT THE DANGERS OF DUST

According to Thomas Novak, professor and Alliance Coal Chair in Mining Engineering at the University of Kentucky, approximately 50% of all coal produced in underground mines in the U.S. comes from a particular kind of underground mine called a longwall mine. While such mines are quite productive, they are not effective at reducing the amount of dust generated by longwall shearers, which extract the coal. Whether respirable dust, which is harmful if breathed over a miner's career, or float dust, which carries the potential for an explosive dust cloud if the mine is subjected to an ignition of methane, dust is hazardous to safe and sustainable mining.

In an attempt to combat dust emissions, Novak and assistant professor Chad Wedding have created a full-scale model of a longwall shearer that features a fully functional scrubber system.

"Scrubbers aren't new to underground mining," explains Novak. "Continuous mining operations—which are different from longwall mining operations—have used what are called flooded bed scrubbers successfully for quite some time. Basically, we are trying to bring what we know works for one method of mining to another method that suffers from more difficult dust control."

While both Novak and Wedding are mining engineering professors at UK, they bring expertise in other fields to this project. Novak received his undergraduate degree in electrical engineering; Wedding earned his in mechanical engineering. Novak designed the electrical and computer-control system for the scrubber and Wedding fabricated all of the components with the help of the college's machine shop and used a 3-D printer to create a mold for the scrubber's 32 cutting picks.

Because longwall shearers face vertical-height restrictions, it is not possible to simply attach a scrubber onto an existing machine; therefore, Novak and Wedding have incorporated their scrubber into a new shearer design. Further, the placement of the scrubber is crucial. Because the dust must be captured before it is dispersed into the air and diluted, the scrubber inlet needs to be near the cutting drum, which cuts into the longwall face; however, if it is too close, large coal particles may clog the scrubber bed. Computational fluid dynamics (CFD) modeling played a critical role in helping the team place the scrubber's large centrifugal fan and ductwork.

Based on CFD modeling, Novak and Wedding 3-D printed a small-scale version of the new shearer design. Then they went to work on producing the full-scale model, which is approximately 65 feet in length when assembled. In June, they transported the shearer to the Pittsburgh Research Lab of The National Institute for Occupational Safety and Health (NIOSH), where they tested the scrubber's capabilities in NIOSH's longwall dust gallery.

"There wouldn't be any way to test this prototype due to its size and the disruption it would cause to a mining operation," says Wedding. "That is why it is important that we are able to use the longwall gallery at NIOSH, which closely simulates a longwall face. Currently, we are working on building a similar gallery for continuous mining in Georgetown, Ky."

Funding for the project came from the Alpha Foundation for the Improvement of Mine Safety and Health, Inc., with an in-kind donation of equipment from Joy Global and in-mine visits from Alliance Coal, LLC. KEJ

ENGINEERING STUDENTS AND ALUMNI WIN NSF RESEARCH FELLOWSHIPS

In April, 12 University of Kentucky students and alumni were selected to receive government-funded National Science Foundation (NSF) Graduate Research Fellowships—three times the number receiving fellowships in 2015. The fellowships award more than $100,000 to use toward research-based master's or doctoral degrees. Four College of Engineering students were chosen.

NSF fellows receive a three-year annual stipend of $34,000 along with a $12,000 cost of education allowance for tuition and fees. They also are given opportunities for international research and professional development, and the freedom to conduct their own research at any accredited U.S. institution of graduate education they choose. The 2016 fellowship recipients are:

- **Michael Scott Crocker**, a 2015 chemical engineering graduate from Bowling Green, Kentucky, now pursuing research in chemical synthesis at Vanderbilt University.
- **Matthew Fahrbach**, a 2015 computer science and mathematics graduate and Chellgren Fellow from Louisville, Kentucky, who is continuing his research in algorithms and theoretical foundations at Georgia Institute of Technology.
- **Marc Higginson-Rollins**, a 2015 electrical engineering graduate and former Honors Program member from Franklin, Tennessee, now pursuing research in electrical and electronic engineering at Georgia Institute of Technology.
- **Cassandra Jean Porter**, a 2016 chemical engineering graduate and former Honors Program member from Georgetown, Kentucky, now pursuing research in chemical engineering at Yale University.

"The NSF fellowship allows me to pursue my Ph.D. with my full focus on research and education, as opposed to needing to seek financial aid for living expenses," said Porter. "In addition, being part of this prestigious group of fellows opens up research and job opportunities for my future."

NEW FACULTY 2015-2016

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Chemical Engineering

Ph.D. University of Southern California

JACK MADDOX

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Mechanical Engineering

Ph.D. Auburn University

SERGIY MARKUTSYA

Assistant Professor
Mechanical Engineering

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Christina Payne
Assistant Professor
Chemical Engineering