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KENTUCKY ENGINEERING JOURNAL

Research Edition 2015

Suzanne Weaver Smith

leading UK's aerospace initiatives

ANNUAL RESEARCH EDITION

Message from Dean Walz

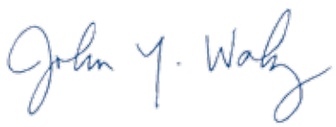
When I became dean in 2012, I began laying groundwork that I envisioned would move UK toward becoming a top 50 engineering school. Key hires, program changes, space reallocation and more initiated the process; however, it is not always easy to detect exactly when real progress is being made. As I review this annual research edition of our award-winning *Kentucky Engineering Journal*, I am proud to say there are several areas where we as a college are at a different level than we were just three years ago.

One area has to do with substantial federal funding for aerospace and energy research. Last year we received a $20 million award from the National Science Foundation with an additional $4 million supplied by the Commonwealth in matching funds for the project "Powering the Kentucky Bioeconomy for a Sustainable Future." It is a massive undertaking involving over 50 researchers throughout the state over five years. On the aerospace side, an interdisciplinary, multi-institution research team led by NASA Kentucky director and mechanical engineering professor Suzanne Weaver Smith has received a $6 million award to continue outstanding work unveiling applications for unmanned aircraft systems. These awards demonstrate that we have outstanding faculty who work collaboratively to address issues of national importance.

Additionally, we have added senior faculty members who have built excellent careers prior to arriving at UK. Dan Ionel, chief engineer with Regal Beloit Corp., who has taught at the University of Wisconsin-Milwaukee and Marquette University has joined our electrical engineering faculty as the inaugural L. Stanley Pigman Chair in Power. Michael Renfro has come to us from the University of Connecticut and is serving as our chair of the Department of Mechanical Engineering. Isabel Escobar has come from the University of Toledo to further our membrane science research efforts. Finally, biomedical informatics expert GQ Zhang, formerly of Case Western Reserve University, has joined the College of Medicine and will hold an appointment in the Department of Computer Science. Recruiting and promoting outstanding faculty is a major priority for our college and it is personally gratifying to see our progress in this area.

As you peruse this special research issue, it is my hope that you will understand why I am excited about the tangible results we are seeing.

Sincerely,



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FRONT COVER
Donald and Gertrude Lester Professor of Mechanical Engineering and NASA Kentucky director **Suzanne Weaver Smith** has played a leading role in the college's aerospace research efforts since joining UK in 1990.

UNIVERSITY OF KENTUCKY
College of Engineering

SENIOR FACULTY HIRES

Dan M. Ionel
L. Stanley Pigman Chair in Power
Department of Electrical and Computer Engineering

Michael W. Renfro
Chair
Department of Mechanical Engineering

Isabel C. Escobar
Professor
Department of Chemical and Materials Engineering

GQ Zhang
Director, Institute of Biomedical Informatics
Department of Computer Science

An expert in electric power engineering, as well as renewable and sustainable energy technology, Dan Ionel comes to UK with over 25 years of engineering experience. Prior to his arrival, Ionel was chief engineer at Regal Beloit Corp., a world leading manufacturer of electric motors, mechanical and electrical motion controls and power generation equipment. Previously, Ionel served as the chief scientist for Vestas, a world leading manufacturer of wind turbines.

Concurrently with his last industrial appointments, Ionel also served as visiting professor in the Department of Electrical Engineering and Computer Science at the University of Wisconsin-Milwaukee and research professor in the Department of Electrical and Computer Engineering at Marquette University. He is a Fellow of the Institute of Electrical and Electronic Engineers (IEEE) and is the 2017 general chair of the IEEE IEMDC Conference.

As the inaugural L. Stanley Pigman Chair in Power, Ionel will collaborate to develop internationally recognized research in areas related to power and contribute to the college's programs through research, teaching and service.

Mike Renfro comes to UK from the University of Connecticut, where he began teaching in 2002. During his tenure, he also served as both director of graduate studies and associate department head in the University of Connecticut Department of Mechanical Engineering. Renfro brings research, teaching and administrative experience to complement that of the department and college in energy and aerospace, areas important for UK and the Commonwealth. He received his Ph.D. in mechanical engineering from Purdue University in 2000.

Renfro's research is in the area of optical diagnostics applied to power production technology, particularly combustion, gas turbine and fuel cell systems. A National Science Foundation CAREER Award recipient, he has received extensive research support through various granting agencies and industry partners. Renfro is on the editorial board for *Progress in Energy and Combustion Science* and is an executive board member for the Eastern States Section of the Combustion Institute. He replaces Scott Stephens, who is returning to the faculty after serving as chair for the past six years.

Thanks to funding through a $20 million NSF EPSCoR grant, Isabel Escobar has joined the faculty of the Department of Chemical and Materials Engineering. Prior to joining UK, Escobar was professor of chemical and environmental engineering and associate dean for research, development and outreach at the University of Toledo. In addition to teaching, she will collaborate with researchers in the Center of Membrane Sciences, including center director and Alumni Professor Dibakar Bhattacharyya.

Escobar's primary research activity is in the area of polymeric membrane materials for water treatment and water reuse operations, focusing on the development of synthetic membrane materials with inherent anti-fouling characteristics. She has published over 50 peer-reviewed journal articles, presented approximately 180 conference talks and seminars and is co-editor of two books: *Sustainable Water for the Future—Water Recycling versus Desalination* and *Modern Applications in Membrane Science and Technology*. Escobar is currently the editor-in-chief of the *Journal of Desalination and Water Reuse* and is president-elect of the North American Membrane Society for 2016.

A new Institute of Biomedical Informatics at UK will integrate and leverage large data systems across the academic and medical enterprises to improve patient care, research and education. GQ Zhang, most recently the division chief of medical informatics and professor of computer science at Case Western Reserve University, has joined UK to direct the institute. Zhang will also serve as chief of the newly established biomedical informatics division in the UK College of Medicine, co-director of the biomedical informatics core of the UK Center for Clinical and Translational Science and hold an appointment in the College of Engineering's Department of Computer Science.

Zhang brings not only his extensive experience in integrating engineering, computer science and medicine, but also an expert research team actively working on two national center grants from the National Institutes of Health. Under his leadership, the UK Institute of Biomedical Informatics will facilitate interdisciplinary collaboration to integrate and utilize data that supports a learning health system and enhanced patient care.

TOP FLIGHT

Suzanne Weaver Smith Has Built a 35-Year Career in Aerospace Research by Bringing Academia and Industry into Innovative Partnerships

In 1980, Suzanne Weaver Smith's career ambitions were academia; however, she knew aerospace R&D experience would enable her to better educate students planning careers in industry or in research. So she went to work for Harris Corporation's Government Aerospace Systems Division. Her first assignment? Developing test-validated computer models for vibration of the fine guidance electronics of the Hubble Space Telescope to assess its launch survivability. From this work, themes in Smith's research career emerged: *unique test-validated analysis of dynamics for historic projects in collaboration with aerospace industry leaders.*

Validated analysis of the cross-country performance of the mobile ground communications station of the first U.S. unmanned aircraft followed before Smith returned for her doctorate in engineering mechanics from Virginia Tech. Her Ph.D. research was funded by NASA to determine the feasibility of using vibration measurements to locate damage in the backbone structure of the newly-announced International Space Station (ISS). Smith joined the faculty of the University of Kentucky College of Engineering in 1990 where she has held the Donald and Gertrude Lester Professorship in Mechanical Engineering since 2004.

In 1992, Smith received the prestigious National Science Foundation (NSF) Young Investigator Award—to partner with industry and research nonlinear vibration interactions in large flexible structures like the solar arrays on the ISS. Smith partnered with Boeing, which was building the ISS at the time. She and her students also joined the team led by Boeing that conducted on-orbit vibration tests of the Russian Mir Space Station.

Smith started the new century continuing her research with unique flexible structures and testing in extreme or unusual environments, working with both large and small companies. One project modeled the deployment of inflatable-boom spacecraft validated with microgravity experiments conducted by students—the Weightless Wildcats. From this and her early experience with unmanned aircraft systems (UAS), Smith and a multi-disciplinary team of faculty researchers began working on what would become the five-year BIG BLUE Mars Airplane program—to demonstrate the feasibility of inflatable wings for aircraft to explore Mars—while providing an amazing multi-disciplinary career-changing experience for over 300 engineering students. With ILC Dover, the team designed four different wings and deployment experiments, successfully conducting them at altitudes between 60,000 and 95,000 ft. These were cited for increasing the Technology Readiness Level (TRL) of inflatable wings for planetary exploration. The achievement led to industrial collaborations from 2009-2012 that advanced deployable-wing technologies for the Defense Advanced Research Projects Agency (DARPA) and other sponsors.

In 2010, Smith was selected to lead NASA's investments in workforce and seed research under the NASA Kentucky Space Grant and ESPCoR programs. These programs provide amazing experiences for students, along with key start-up support for early-career faculty across Kentucky.

Today, using unmanned aircraft and rotorcraft, Smith and researchers campus-wide collaborate on applications from bridge inspections to precision agriculture, working with industry via UK's Unmanned Systems Research Consortium, which launched in December 2013 and currently has five industry members.

Recently, Smith and a three-state multi-disciplinary team received a $6 million NSF grant to use unmanned aircraft to answer key scientific questions in atmospheric physics impacting severe weather formation and sustainable agriculture. For Smith, it's the next exciting exploration in her amazing career. KEJ

AEROSPACE RESEARCH AT UK

Autonomous Multi-Vehicle Control and Human-Assistive Control

Jesse Hoagg
Assistant Professor
Mechanical Engineering

Hoagg is leading an effort to develop multi-UAV cooperative control methods for flocking and swarming. His research is part of a multi-institution NSF award on studying atmospheric physics. With separate NSF support, Hoagg studies human learning and develops methods to enhance learning—work that has application to aerospace training.

Interpreting Dynamic Information in Videos

Nathan Jacobs
Assistant Professor
Computer Science

With over $3.4 million in federal funding, Jacobs is developing novel methods for interpreting imagery and video from a wide variety of sources, including unmanned aerial vehicles, surveillance cameras and social networks. His work will lead to more accurate measurements of environmental, behavioral and social changes across the globe.

Smart Materials and Structures with Environmental Response

Christine Trinkle
Associate Professor
Mechanical Engineering

With the support of NASA Kentucky, Trinkle is developing ways of creating new microscopic structures that have the ability to sense and respond to their environment. These microrobotic systems can be useful in a variety of applications, whether diagnosing and treating disease or making advances in low-cost space exploration efforts.

International Space Station and Small Satellite Experiments

Michael Seigler
Associate Professor
Mechanical Engineering

In cooperation with engineers from NASA Marshall and with funding from NASA Kentucky, Seigler is investigating a new approach to small-satellite orientation control. Seigler's research group has developed a piezoelectric-based attitude-control system prototype, which it is planning to test aboard a zero-G flight in 2016.

Multi-Physics Modeling and Experiments for Atmospheric Entry Spacecraft

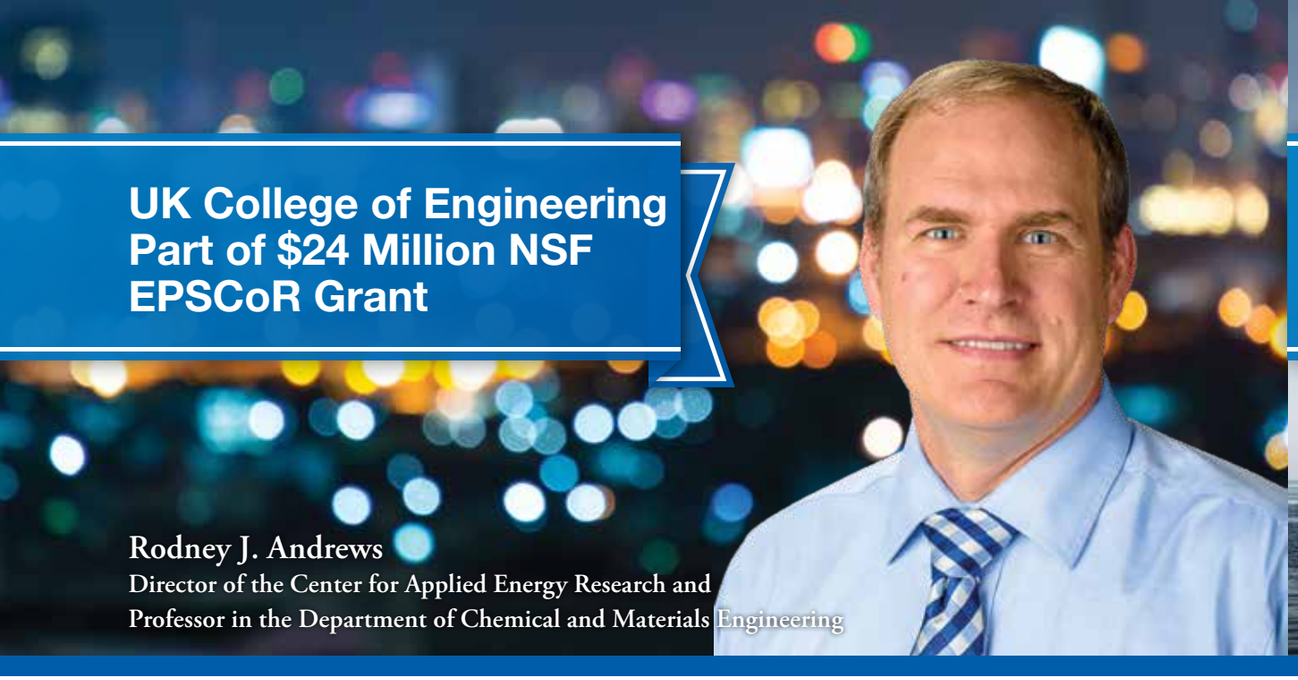
Alexandre Martin
Assistant Professor
Mechanical Engineering

Martin leads several multi-disciplinary, multi-institution teams of researchers that investigate the detailed physics of high temperature gases interacting with porous materials. This research will improve multiple fields of engineering, such as the heat shield of NASA's spacecraft and has already resulted in several publications in scientific journals.

Unmanned Aircraft Systems for Atmospheric Physics and Precision Agriculture

Michael Sama
Assistant Professor
Biomedical and Agricultural Engineering

Sama's contribution to a recently awarded $6 million NSF grant will include the development of low-cost crop and soil sensors for remotely estimating moisture variability across agricultural landscapes. The overall goal is to better understand a contributing factor to crop yield and develop sensor-based inputs for variable-rate irrigation systems.



UK College of Engineering Part of $24 Million NSF EPSCoR Grant

Rodney J. Andrews
Director of the Center for Applied Energy Research and
Professor in the Department of Chemical and Materials Engineering

In August 2014, six jurisdictions received Research Infrastructure Improvement (RII) Track-1 awards from the National Science Foundation's (NSF) Experimental Program to Stimulate Competitive Research (EPSCoR). The awards are intended to bolster science and engineering academic research infrastructure in the U.S. Virgin Islands and five states: Kentucky, Maine, Missouri, North Dakota and South Dakota. Each five-year award is supporting fundamental research in science, technology, engineering and mathematics (STEM) education and workforce development in areas relevant to the jurisdictions' economic and other vital interests.

Kentucky received a $20 million award with an additional $4 million supplied by the Commonwealth in matching funds. Rodney Andrews, director of the Center for Applied Energy Research and professor in the Department of Chemical and Materials Engineering, is the primary investigator for the grant. Over 50 faculty members from research institutions across Kentucky are involved in the project.

Kentucky faces significant challenges as the energy economy transitions from traditional coal mining to renewable resources. Kentucky's RII award, "Powering the Kentucky Bioeconomy for a Sustainable Future," will focus on bio-inspired nanocomposite membranes, biomass feedstocks and electrochemical energy storage. The project will drive and accelerate the growth of the emerging bioeconomy within Kentucky through statewide multi-institutional interdisciplinary collaborations that incorporate elements of chemistry, biology, physics and engineering. Strong ties between academic research and industry will confront the Green Grand Challenge, help train students and create jobs for an increasingly larger and diverse science, technology, engineering and mathematics educated workforce. The project provides a STEM-based educational framework that will encourage meaningful participation of under-represented and minority student populations in the emerging knowledge-based economy.

The funds also allowed the Department of Chemical and Materials Engineering to hire Isabel Escobar, professor and associate dean of research, development and outreach at the University of Toledo, as a senior faculty member. Escobar's research focuses on developing and/or improving polymeric membrane materials for water treatment and water reuse operations. In the field of membrane separations, Escobar has been the PI of numerous membrane research projects and her state-of-the-art membrane science laboratory will make significant contributions to the project's success. Escobar and her research group have published over 50 articles in peer-reviewed journals, and have made over 180 presentations at national/international conferences. She has also edited two books. In addition to teaching, Escobar will collaborate with researchers in the Center of Membrane Sciences, including center director and Alumni Professor Dibakar Bhattacharyya.

Cramer Receives 2015 Young Investigator Award from ONR

Aaron M. Cramer
Assistant Professor of Electrical and
Computer Engineering

This spring, the Office of Naval Research (ONR) named electrical and computer engineering assistant professor Aaron Cramer one of its 2015 Young Investigator Award recipients. Of the 383 research proposals aimed at "potential breakthrough advances for the Navy and Marine Corps" submitted to the ONR, Cramer's was one of 36 to earn funding from a pool of $18.8 million.

"This is fantastic news for Aaron and for the reputation of our college," confirmed Dean John Walz. "The winners of this award represent some of the best and brightest researchers in the country and it is gratifying when our faculty, who are doing truly outstanding work, receive such well-deserved recognition."

The focus of Cramer's work is part of the growing trend toward smarter modes of transportation—in his case, naval warships powered entirely by electricity. The Navy has been developing the DDG 1000 all-electric ship for over 20 years now and, according to Cramer, such ships are the future.

"The ships being built and that will be built will not have a mechanical powertrain, but a generator. The power systems will be very specialized; in fact, because these are warships that are expected to go into harm's way, the stakes are significantly raised. The power systems will have to be better than they have ever been."

Cramer notes that ships currently populating the naval fleet are hindered by an energy imbalance; that is, almost all of the ship's energy is directed toward enabling the ship to move. The energy that is left over is then used for the ship's lights, computers, radars, etc. With the transition to all-electric power, an abundance of options emerge.

"The next wave of ships will be more flexible in terms of what they can do. The extra electrical capacity will enable engineers to introduce new kinds of sensors, new types of weapons and more," Cramer explains.

Determining where the energy should go is the core of the proposal that made Cramer a Young Investigator. His project, titled "Market-Based Control of Shipboard Engineering Plants," combines electrical engineering with economic theory to develop value-based models for control.

Cramer clarifies, "On an electric ship, the system will allow us to use electricity for whatever we want. The same watt used toward propulsion can also be used for lights, air conditioning, computers, sensors and more. So the question becomes, 'What should I use it for?' The idea is to apply ideas from economics to evaluate the set of things I can do and what is optimal. We do that by assigning a price to various applications. The price value signals where to put more power in a given set of circumstances. The higher the price, the more I need power at that point."

UP TO THE CHALLENGE

The Center for Applied Energy Research: Engineering Renewable Energy Solutions

Energy has been described as one of the future's "Grand Challenges." The world employs a mix of energy resources—oil and gas, coal, sun, wind, hydro, geothermal, biomass and nuclear. We harness, burn and produce heat and electricity, liquid fuels, chemicals and gases from these energy resources. In turn, they contribute to our quality of life, health, nutrition, comfort, convenience, leisure, transportation, communication and productivity. But how will we satisfy our insatiable appetite for energy that fuels the global economy and our way of life?

The University of Kentucky Center for Applied Energy Research, led by director and chemical engineering professor Rodney Andrews, serves these higher purposes. Among its most important aims is to assure that the benefits of investigations, research and study are applied, made available to the public and brought into the widest possible use. The center, through its technology innovation and service to the community, contributes to improving the lives of Kentuckians by creating jobs and economic opportunities, sustaining vital industries and public services and improving energy efficiency and protecting the environment. Featuring 12 labs and centers on its campus, CAER's research is inventing new technologies that have the potential to:

- Position the coal and electric utilities industries to respond to a carbon-constrained economy and the technical challenges of capturing and utilizing carbon dioxide.
- Extend the life and improve the environmental performance of the state's fleet of coal-fired electric power plants, which provides some of the lowest-cost electricity found anywhere in America.
- Address problems associated with the accumulation of coal by-products and support a growing industry devoted to the use of these materials for sustainable construction.
- Develop processes that will enable a coal-to-liquids and coal-to-gas industry in Kentucky as an alternative to transportation fuels, chemicals and gases derived from imported petroleum.
- Enable a developing biofuels industry to benefit from the strength of Kentucky's agriculture and forest-product industries for cleaner, renewable fuels and chemicals.
- Advance distributed power generation and storage technologies to harness the sun and wind, which make for cleaner alternative fueled vehicles (fuel cells, batteries and capacitors).
- Develop higher value-added carbon materials derived from coal (pitch, coke, binders, fibers and composite materials) that serve the nation's defense, aerospace, automotive and manufacturing industries.
- Advance the monitoring, clean-up and remediation of legacy radioactive and chemical wastes associated with the nation's nuclear power and weapons industries. KEJ

STRESSFUL STUDIES

Michael Akenhead's Doctoral Studies Have Immersed Him in Cellular Mechanobiology

While finishing an undergraduate degree in biomedical engineering at Vanderbilt University, Michael Akenhead began looking for a graduate school where he could continue his interest in cell mechanics, immunology and cardiovascular biology. After applying to several schools, the University of Kentucky Department of Biomedical Engineering invited Michael for a visit. Upon learning that professor Hainsworth Shin's lab focused on mechanobiology—which entails studying cellular responses to mechanical forces—Michael was sold.

Michael's research involves studying how certain white blood cells, called neutrophils, respond to what is called shear stress—frictional stress imposed on the cell as it is flowing in the bloodstream. When neutrophils are exposed to shear stress, they become inactivated and are prevented from performing their normal defensive functions when they are not needed, such as when no infection is present. Michael is analyzing exactly how the shear stress response causes the neutrophil to inactivate and what kind of consequences could occur if neutrophils exposed to shear stress were to malfunction and remain active. Long-term, Michael hopes to determine if a dysregulated or malfunctioning neutrophil response can be connected to cardiovascular disease or pathology.

After completing his Ph.D. in late 2016, Michael plans to pursue post-doctoral studies and eventually become a professor of biomedical engineering at a research institution.

ZACHARIAS AGIOUTANTIS

Mining Engineering Foundation Professor
Mining Engineering

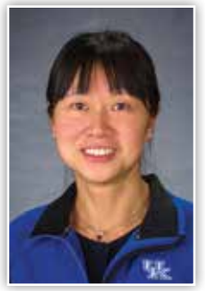
Ph.D. Virginia Tech

Mining Engineering Foundation Professor Zacharias Agioutantis came to the University of Kentucky from Athens, Greece, last fall after spending 25 years at the Technical University of Crete as a lecturer in the Minerals Engineering Department. During his tenure, he built a rock mechanics lab from scratch as well as a computer lab for graduate and undergraduate mining students. Over the years he has taught undergraduate and graduate classes in core mining engineering subjects such as drilling, blasting, mining methods, ventilation and rock mechanics. He also has a strong background in software development for mining and geotechnical applications, and has created commercially available and freely distributed software.

MONA SHIPOUR

Assistant Professor
Chemical Engineering

Ph.D. Max Planck Institute and University of Stuttgart



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2015 NSF CAREER AWARD RECIPIENT

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