

GRAND CHALLENGES FOR ENGINEERING: HEALTH

Brain. Medicine. Informatics. Water.



Message from Interim Dean Larry Holloway

On behalf of the faculty of the University of Kentucky College of Engineering, welcome to our annual publication where we shine the spotlight on research initiatives in the college.

In our First-Year Engineering program, we emphasize the National Academy of Engineering's Grand Challenges for Engineering. We want our new engineering students to understand the complex problems facing our world, identify opportunities where engineers can make a crucial difference and inspire each other to persevere until the challenges are solved.

Because of our proximity to the Colleges of Medicine, Pharmacy and Dentistry, as well as the UK Albert B. Chandler Hospital—the top-ranked hospital in Kentucky—we are uniquely positioned to address Grand Challenges related to improving human health. In this publication, we highlight how UK faculty research benefits heart attack victims, children with autism, individuals with muscle wounds, smokers wanting to quit and more. Whether it is using data mining to lower the epilepsy mortality rate or developing 3-D printable hand orthotics to assist in the rehabilitation of stroke patients, our researchers are fully committed to leveraging their intelligence, creativity and years of training and experience to create novel solutions to these Grand Challenges.

We are committed to building a world that works, and we hope that in the pages that follow you see what motivates us, and the students we teach, every day.



Larry Holloway
Interim Dean



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MEETING THE GRAND CHALLENGES

Grand.

Grand is a striking word. It suggests an awesome, sweeping scope. When connected to “Challenges for Engineering,” it points to monumental difficulties far beyond any individual researcher. It calls for creative collaborative efforts across diverse disciplines. It demands that engineering faculty apply their talents and resources to research that matters. And it compels. After all, who doesn’t want to be part of something grand?

In the pages that follow, you will see the impressive collective work UK researchers are doing to reverse-engineer the brain, engineer better medicine, advance health informatics and create better access to clean water.

REVERSE-ENGINEER THE BRAIN

TARGET AREAS:

- Biotech solutions to brain disorders, such as drugs or neural implants
- AI systems to replicate human abilities, e.g., vision, speech recognition
- AI to guide devices for medical diagnoses and treatments
- Repair of broken brains due to injury or disease by signal rerouting, e.g., cochlear implants, electrode stimulation for Parkinson's disease
- Control of artificial limbs, mind reading of people unable to speak

Sen-ching Cheung, Department of Electrical and Computer Engineering: Engineering autism therapies

Working with researchers in the Colleges of Education, Arts & Sciences and Medicine, Cheung is using NSF-funded, multi-year research to enhance the delivery of behavior therapy to individuals with autism and related disorders. The training mechanisms Cheung and his group have produced employ interactive gaming, wearable technology and even new approaches to surveillance. Using Google Glass, Microsoft Kinect and other well-known devices, Cheung is making substantial contributions to social skills training for autistic individuals.

Michael Johnson, Department of Electrical and Computer Engineering: Advancing computer-aided pronunciation training

To support effective learning and provide specific, useful pronunciation feedback to users, Computer Aided Language Learning (CALL) systems for pronunciation correction must be able to capture pronunciation errors and accurately identify and describe errors in articulation. Johnson's NSF-funded project addresses key limitations through the collection of a matched acoustic and five degree of freedom electromagnetic articulograph (EMA) data corpus for both native American English (L1) speakers and native Mandarin Chinese (L2) speakers who speak English as a second language.

Scott Stephens, Department of Mechanical Engineering: Helping stroke victims through 3-D printing

In a collaborative effort with doctors in the UK College of Medicine, Stephens is developing 3-D printable hand orthotics to assist in the rehabilitation of stroke patients. By scanning each patient's hand to create a virtual model, Stephens aims to design a 3-D printed mobility assist glove that is personalized to each patient's unique anatomy and tailored to his or her therapeutic goals.

Sridhar Sunderam, F. Joseph Halcomb III, M.D. Department of Biomedical Engineering: Imaging brain rhythms

Sunderam's research concerns the use of brain-machine interfaces to model, track and modulate brain rhythms and function specifically related to sleep and movement. These efforts are directed toward the treatment of disorders of sleep and epilepsy as well as neural injuries that impair motor function. His collaborative work is supported by federal grants from the NIH and NSF. He is a PI on a \$6 million NSF consortium grant to develop innovative brain imaging and modulation technologies that will provide insight into how the nervous system functions in health and disease.

ENGINEER BETTER MEDICINE

TARGET AREAS:

- *New systems to use genetic information to sense small changes in the body, assess new drugs and deliver vaccines*
- *Personalized medicine for preventing, diagnosing, treating and monitoring disease*
- *Synthetic biology – novel biomaterials to replace or aid in repair of damaged tissue*
- *Engineering new strategies to overcome multiple drug resistances*

Brad Berron, Department of Chemical and Materials Engineering: Isolating cells for heart regeneration

Following a heart attack, damaged tissue has poor access to blood flow and a reduced ability to pump blood. While therapies based on rare stem cells effectively aid in the formation of new blood vessels, it takes days to isolate these rare cells from bone marrow. Berron's lab has developed protective coatings that make these rare cells easier to isolate. His goal is to withdraw bone marrow from a patient, isolate the therapeutic cells and administer the cell therapy in the same surgery, lowering the risk of infection and the cost of the therapy. Berron's research is funded by NIH and NSF.

Zach Hilt and Tom Dziubla, Department of Chemical and Materials Engineering: Binding and capturing PCBs

Despite a production ban in 1979 and decades of remediation efforts, polychlorinated biphenyls (PCBs) remain a persistent environmental contaminant. Their continued presence in the environment has resulted in multiple potential human exposure routes, such as soil, riverbeds, groundwater and milk. There remains a need for a stable system that selectively binds and captures PCBs for sensing and remediation technologies. Hilt and Dziubla have developed a novel strategy to synthesize polymeric networks that incorporate phenolic moieties, with the capability of binding PCBs from environmental sources.

Martha E. Grady, Department of Mechanical Engineering: Saving dental implants from disease

Peri-implantitis, initiated by bacterial infections around implants, poses a threat to an indispensable therapy in dentistry used to replace missing teeth. Approximately 3 million individuals have dental implants, and that number is growing by 500,000 a year. Grady is exploring new ways to overcome current limitations in bacterial adhesion measurement techniques at the implant interface. Successful development of such techniques will lead to the discovery of parameters that govern pathogenic biofilm-implant adhesion. Control of these parameters by engineering new implants could reduce the likelihood of the onset of peri-implantitis.

Tom Hedman, F. Joseph Halcomb III, M.D. Department of Biomedical Engineering: A faster, cheaper, better solution to lower back pain

Millions of Americans suffering from low back pain could soon have a quick, cost-effective and permanent solution for the debilitating ailment. Hedman's solution, an injectable liquid called Réjuve, has received promising early results from a recent clinical study. Réjuve is an injectable orthopaedic device that mechanically strengthens the spinal disc and stabilizes the spinal joint. The procedure takes 15-20 minutes to administer and costs considerably less than current and emerging treatments. Hedman is Intralink-Spine's chief scientific officer.

Daniel Pack, Department of Chemical and Materials Engineering: Improving human gene therapy

Human gene therapy holds tremendous promise for treatment of a wide range of diseases, but clinical implementation has been hindered by the lack of safe and efficient methods for delivery of genetic material. Pack is developing microfluidic systems for construction of multilayered, multifunctional non-viral vectors. The devices will bring solutions of plasmid DNA and polymer(s) into contact under laminar flow, providing enhanced reproducibility and control of polymer/DNA stoichiometry and interaction times and allowing introduction of multiple materials in a sequential fashion and defined spatial arrangement.

Dave Puleo, F. Joseph Halcomb III, M.D. Department of Biomedical Engineering: Controlling scarring in muscle wounds

Muscle injuries are among the most common musculoskeletal conditions in the United States. While satellite cells provide muscle with the potential for regeneration, large wounds often suffer an excessive proliferation of fibroblasts that frequently results in fibrosis and scarring. In light of the multiple demands needed for preventing fibrotic scarring, Puleo's multidisciplinary team is delivering multiple biomolecules in a site-specific and temporally orchestrated manner to treat different aspects of the inflammatory and wound healing processes.



ADVANCE HEALTH INFORMATICS

TARGET AREAS:

- *Data sharing between governments and global health organizations about disease outbreaks*
- *Systems engineering to redesign care practices and integrate health informatics networks*
- *Security of systems and confidentiality of patient records*
- *Wearable devices to gather medical data or monitor medical conditions*

Greg Erhardt, Department of Civil Engineering: Utilizing GPS to strengthen smoking cessation research

Erhardt's research focuses on capturing and understanding individuals' daily travel through their local environment. While these methods are commonly applied to evaluate transportation infrastructure investments, they can be extended to health-related applications. His collaborative research will use global positioning system (GPS) tracking devices to monitor people's travel patterns and compare them to retail tobacco locations in southeastern Kentucky. With this information, researchers will gain a better understanding of the influence of access to tobacco on an individual's ability to quit smoking.

Licong Cui, Department of Computer Science: Lowering the epilepsy mortality rate

Cui's NIH-funded research looks to expand and broaden research resources across centers to accelerate the understanding of biological mechanisms responsible for Sudden Unexpected Death from Epilepsy (SUDEP) and to develop intervention and prevention measures to reduce SUDEP mortality. Current efforts include expanding an integrated clinical and translation data resource for epilepsy, providing coordinated services and support for Center for SUDEP Research members, empowering investigators with web-based cohort search interface for data mining and hypothesis generation, among other initiatives.

Licong Cui, Department of Computer Science: Debugging large biological ontologies

To fully capitalize on the transformative opportunities of the increasingly large amounts of digital data produced by the biological research community, a need persists to systematically adopt data and metadata standards, such as the Gene Ontology (GO). Quality issues, if not addressed, can cause misleading results or missed biological discoveries. Cui's research proposes a Subsumption-based Sub-term Inference Framework (SSIF), which can automatically detect semantic inconsistencies and generate change suggestions for future versions.

Himanshu Thapliyal, Department of Electrical and Computer Engineering: Biofeedback-based stress reduction in older adults

Stress has been linked to a plethora of emotional and physical conditions and immune system disturbances that increase susceptibility to infections and may make older adults vulnerable to cognitive difficulties. Tools that assist individuals in monitoring and managing their emotional dysregulation could be of tremendous benefit to their health, well-being and quality of life. Thapliyal is investigating the utility of portable mobile computing-based biofeedback for stress reduction. Although biofeedback has been used to treat chronic pain and improve agility, it has not yet been explored for measuring stress in older adults.

ACCESS TO CLEAN WATER

TARGET AREA: *Disease prevention*

**Gail Brion, Department of Civil Engineering:
Tracking untreated human sewage**

Almost 50 percent of our nation's waters do not meet pathogen standards set by the Clean Water Act because untreated human sewage is entering our surface waters through leaky pipes, overflows and unintended cross connections. Brion is evaluating the potential of a new indicator based on personal care products (PCPs), acetaminophen and sucralose in sewage to develop a new fecal source and age indicator by analyzing the ratios of one persistent and one biodegradable compound.

**Isabel Escobar, Department of Chemical and
Materials Engineering: Removing algal toxins
from water**

The incidence of cyanobacteria in harmful algal blooms and concentrations of cyanotoxins in surface waters used for potable water sources is increasing. Unfortunately, existing traditional water treatment technologies are not able to remove cyanotoxins to safe levels. Funded by the Ohio Department of Higher Education, Escobar is investigating the benefits of membrane filtration to contain algal toxins at basic pH values.

**Lindell Ormsbee, Department of Civil
Engineering: Clean water for spirit distillation**

Ormsbee has been working with Beam Suntory to develop watershed sustainability plans associated with its Jim Beam and Makers Mark distilleries in central Kentucky. Water is an integral part of spirit distillation, and to sustain and grow this industry, it is important that existing water sources be preserved and protected. Under Ormsbee's direction, students have sampled local streams to assess the ambient water quality conditions and identified local stakeholders and other industries that exist within those watersheds.

**Lindell Ormsbee, Department of Civil
Engineering: Workshops for utilities in rural areas**

Many systems in eastern Kentucky are plagued by a lack of funds for needed system improvements, partially as a result of a loss of revenue associated with decreased coal mining. Delayed maintenance and other infrastructure problems have resulted in some systems experiencing system leakage rates as high as 50 percent. Ormsbee is helping small water and wastewater utilities in the Appalachian regions of Kentucky and West Virginia through a series of workshops that focus on the technical, financial and managerial aspects of utility management, as well as more personalized technical assistance for individual utilities.

**Kelly Pennell, Department of Civil
Engineering: The impact of aging
infrastructure upon clean water**

Through funding provided by NIEHS University of Kentucky Superfund Research Program, NSF CAREER and the National Institutes for Water Resources, Pennell has investigated and continues to investigate a range of challenges related to clean water, including disinfection byproducts, the efficacy of water disinfection processes, and water and sewer pipe networks. Most recently, her research has been drawing important connections between clean water and the issue of aging infrastructure.

\$48M

**CURRENT TOTAL OF ACTIVE AWARDS FOR
COLLEGE OF ENGINEERING INVESTIGATORS**

The University of Kentucky College of Engineering is proud to bear the Carnegie Classification of “R1: Highest Research Activity.” The designation reflects our faculty’s commitment to forming collaborative networks, tackling big problems and changing the world. Our active award total has never been higher, and our faculty continues to get stronger at the junior and senior levels.

In the next five years, through the support of the university’s comprehensive campaign, we intend to expand the number of tenured or tenure-track faculty members from 148 to at least 217 and focus these new faculty hires in strategic research clusters that advance the college, the Commonwealth and society. Our goal is to increase the college’s total active awards to \$80 million. These are, indeed, exciting times in the UK College of Engineering.
