ICRES

CAVS • CAVS-E • ISER • I2AT

INSTITUTE FOR COMPUTATIONAL RESEARCH IN ENGINEERING AND SCIENCE

2016 ANNUAL REPORT

MISSISSIPPI STATE UNIVERSITY

WORLD CLASS RESEARCH

MISSION

The Institute for Computational Research in Engineering and Science (ICRES) will be a global leader in interdisciplinary education and research of computational science and engineering for the local, state and national industrial base.

VISION

The Institute for Computational Research in Engineering and Science strives to be a world-class center of excellence for research, technology and education equipped to address engineering challenges facing the nation's industrial base. Utilizing high performance computational resources and state-of-the-art analytical tools for modeling, simulation and experimentation, ICRES will provide a distinctive, interdisciplinary environment that will support economic development and outreach activities throughout the State of Mississippi and beyond.

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ICRES

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DIRECTOR'S MESSAGE

In our mission statement, the Institute for Computational Research in Engineering and Science (ICRES) states that it strives to be a world-class center of excellence for research, technology and education equipped to address engineering challenges facing the nation's industrial base. This year's annual report highlights the international projects in Japan, South Korea and the United Kingdom to illustrate how we are achieving our stated mission. We believe these international relationships are key in helping us to discover the important ideas and how we can solve conflict or achieve cooperation.

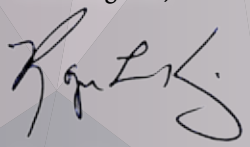
Science connects all of us. International partnerships show us that researchers in other countries face similar challenges and the collaboration of expertise and resources helps us to work smarter, faster and more efficiently rather than duplicating methods that has already previously been created or optimized by us or others. A point that, Rick Nader, MSU's associate vice president for International Programs and the executive director of the International Institute, makes in his article about how international research approaches and partnerships have greater global impact and benefits.

Our ICRES researchers practice this diverse philosophy and approach as we work in an environment of collaboration to solve complex research projects whether that is with our stateside colleagues or those who are abroad. This work culture thrives in each of the four research and economic development centers and institutes comprising ICRES:

- Center for Advanced Vehicular Systems (CAVS)
- Center for Advanced Vehicular Systems Extension (CAVS-E)
- Institute for Imaging and Analytical Technologies (I2AT)
- Institute for Systems Engineering Research (ISER)

These ICRES entities have continued to support the university missions of research and service to the state, region and world. In 2017, ICRES is working to expand its impact within Mississippi's industrial enterprise and continue to provide computational engineering and science research support to its domestic and global partners.

With Regards,



Roger King
Director of the Institute for Computational Research in Engineering and Science

INTERNATIONAL COLLABORATION IN RESEARCH: WORKING TOWARD A GLOBALLY AGILE UNIVERISTY

Richard H. Nader, Ph.D.
Associate Vice President for International Programs, Executive Director of the International Institute
Mississippi State University

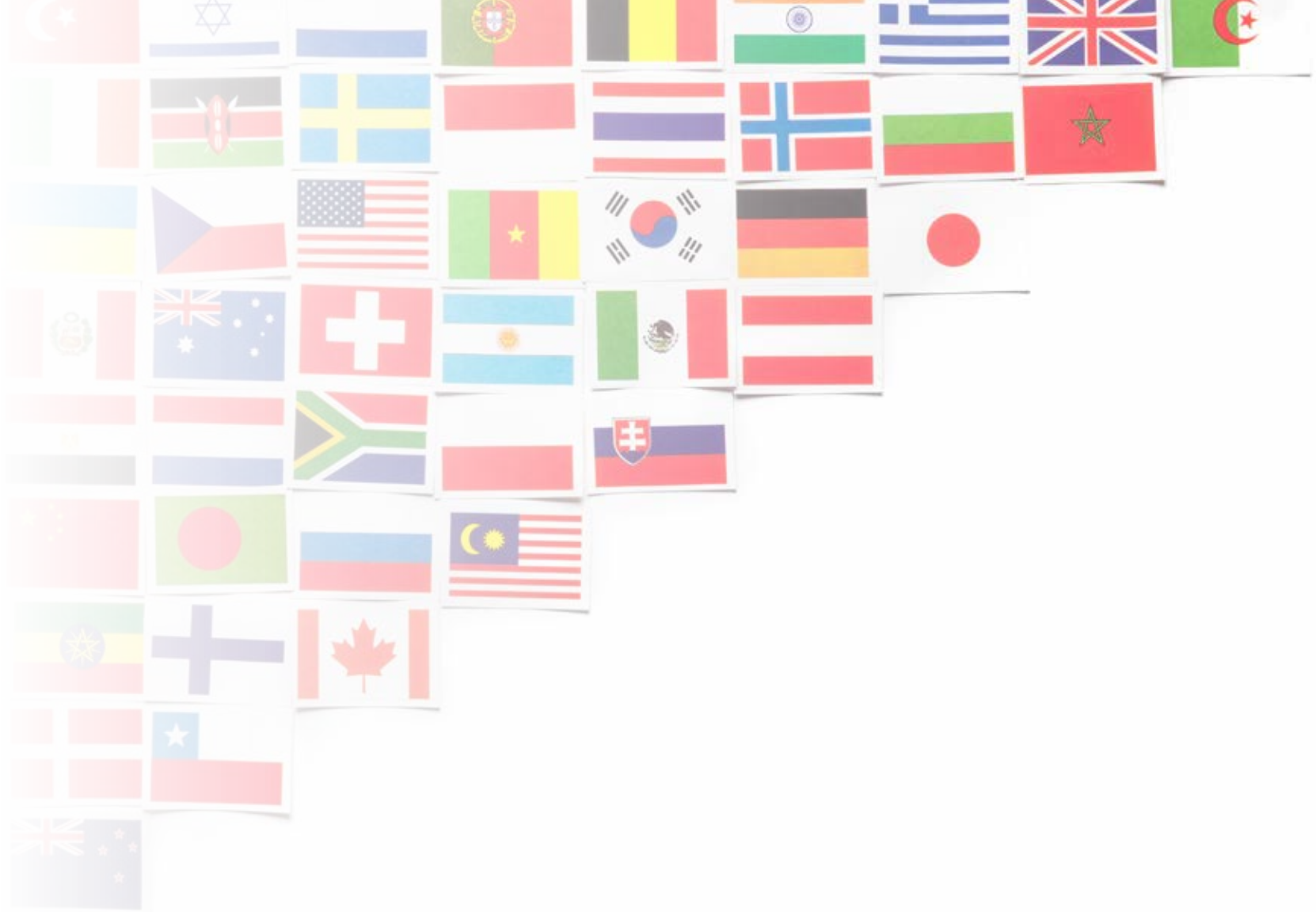
Globally, spending on research and development doubled from 1990-2000 (NSF, NCSES), and this trend continues with most of that growth occurring outside the United States and Western Europe. Research-active faculty are four times more likely to be internationally engaged, according to Martin Finkelstein (Seton Hall). More to the point, research has entered the fourth, *international*, stage of development, having cycled through research produced within one's institution, regional and national collaborative stages. Why? And what are the benefits of international R&D cooperation?

Questions of interest to science are interdisciplinary and global by nature, thus requiring international partnerships. Further, global "research families" are created by increasing numbers of students studying with mentors abroad. Advanced communications technology is bringing down barriers. Finally, as industry is highly global, so too are the questions that industry turns to universities to address, and employers expect universities to prepare a globally-competent workforce.

International students brought $65 million in economic impact across the State of Mississippi. More importantly, the presence of international students and scholars increases brain circulation, which escalates innovation and builds social and economic capital. NSF data for EPSCoR states (the bottom 25 states in terms of overall research funding of which Mississippi is one), points to the fact that 85% of Ph.D. grads stayed within 50 miles of the institutions from which they graduated. It is also true that internationally co-authored publications have higher citation impact factors (Elsevier Research Intelligence). More to the point, a study examining what correlates most with high impact articles was the *ethnic and national diversity* of the authors. (Freeman).

These facts point to an important lesson to compete in the 21st century: University leaders must create a *globally agile university* to ensure universities operate optimally abroad, and with cultural competence. In effect, universities that wish to remain in the top tier of research and development must remove barriers for international research cooperation as discussed in several National Academy of Science reports in recent years. See: http://sites.nationalacademies.org/PGA/guirr/PGA_050827

I applaud ICRES' globally engaged R&D and Mississippi State University's commitment to international collaboration. These global research partnerships will propel our faculty and students to new heights, while serving our State well into the future.



RESEARCH THAT DEMYSTIFIES THE CONTROVERSIAL TOPIC OF SHAKEN BABY SYNDROME

An international partnership between CAVS and Cardiff University is seeking to redefine the world's understanding of the decadeslong controversial topic, shaken baby syndrome.

Raj Prabhu, assistant professor of biological engineering at Mississippi State University and Wilburn Whittington, a research engineer, explains that proper testing of SBS is based on results that do not account for the full biomechanics of a baby's head trauma. In other words, the tests include a small handful of accurate measures that fail to contain the overall composition of the baby and the environment of the incident.

CAVS and Cardiff University (United Kingdom) researchers aim to change this problem by combining their different methods of research to enlighten the scientific and legal communities with never-before-seen data. Prabhu and Whittington have been working on a novel experimental device that will measure what they call intermediate strain rates. By using this device along with a surrogate pig brain (which has much of the same mechanical properties of the human brain) and supercomputer models, CAVS can test what happens to a baby's brain when medium forces of movement are applied.

Whittington explains the frightening lack of data in this field of study.

"Well here is how scary it is, whenever you throw the baby up and the head moves, there is no data in the world that has ever been recorded that any scientist anywhere in any drawer or any paper in the history of mankind that can tell you what is going on at all. No one even knows. There is no person in this world that you can call up and even knows what is going on."

A quote from a forensic pathologist and former chief medical examiner of Kentucky, George Nichols states, "Doctors, myself included, have accepted as true an unproven theory [SBS] about a potential cause of brain injury in children. My greatest worry is that I have deprived someone of justice because I have been overtly biased or just mistaken."

Dr. Mike Jones, a leading expert on infant head trauma with Cardiff University in the United Kingdom explains, "Lack of thorough data have made shaken baby syndrome one of the most controversial topics in modern history, especially in the judicial arena. An exhaustive study was done by The Washington Post which reviewed murder and abuse cases involving shaken babies since 2001. Of the 1800 resolved cases, 200 of these across 47 states had charges dropped or dismissed; defendants were found not guilty or convictions were overturned. Much of this happens as doctors now revise their opinions on SBS."

The data that is used now in the judicial system for crime scene investigations, for companies to design infant safety equipment, and for the government to set safety standards are collected from only a few infant post-mortem subjects. The issue is that it looks at the average response of the infant head trauma from a limited view that excludes particular injuries to the brain. Yet, what Prabhu and Whittington have discovered through data collected from the innovative device called the Polymeric Serpentine Bar, and through computer simulations, is that local injuries to an infant's brain are vastly different from the average response and impact of trauma on an infant's head.

According to Prabhu, “The issue of infant head traumas is that babies don’t get shaken at the rate of a blast wave. The impact rates are much lower, and it isn’t at a rate that is slow and methodical like a surgeon performing a surgical procedure, it is at a rate somewhere in between, and we call it intermediate strain rates.”

Again, on the Cardiff University side, one of Dr. Michael Jones’ key collaborators from the University of Leicester, Dr. Roger Malcomson, is one of the few in the entire UK who is a pediatric forensic pathologist. Malcomson conducts autopsies on deceased toddlers thanks to a UK law which classifies any baby death as a legal case automatically. This allows him to study the brains of the deceased if the cause of death is head trauma.

In speaking about what this connection does for the overall research, Prabhu said, “So what he brings to the plate now is forensic pathology from a clinical side, so we are now able to speak directly to our researchers from the clinical arena, which is one of the primary efforts.”

Moreover Prabhu says, “We’re {Cardiff and Mississippi State} are maximizing the impact of our research because not only are we providing some of the most useful data in understanding how the human body responds during impacts that cause harm, but we’re also providing information on how you might protect the human, how you might design components and things around a human and then how you might prosecute whenever those things happen.”

The CAVS and Cardiff research team are already uniquely tied and dependent on one another in investigating SBS to find life-changing solutions. For instance, laws in the U.S. prevent researchers from having immediate and easy access to study baby’s brains with infant head trauma. On the other hand, our neighbors in the U.K., scientists, and investigators are unable to test their data because they don’t have access to the innovative device or an avenue to supercomputers and engineers with the experience to model the research in a computational environment.

The international partnership also transforms how university research projects could be funded in the future. In the U.K., The Engineering and Physical Sciences Research Council (EPSRC), which is the U.K.’s equivalent of the U.S. National Science Foundation, has fully funded financial resources for a Ph.D. student to conduct joint research on the same topic.

It’s a win, win situation that Prabhu and Whittington believe will not only yield useful data in understanding the human body but will also provide new ways in thinking about protecting it and may revolutionize how the legal system handles such cases.

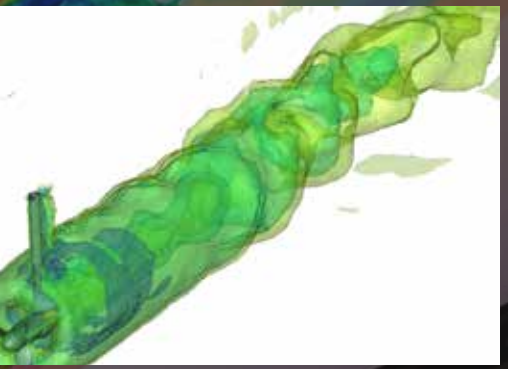
SIMULATION BASED DESIGN OF HYDROKINETIC FARMS

An untapped renewable energy source could help transition the country toward clean energy. Mississippi State University and a team of both domestic and international institutions in the United Kingdom are researching a design to transition in-stream hydrokinetic power from concept to mass commercialization.

In-stream hydrokinetic power is the electric power generated by extracting energy from the natural flow of water. In this case using the water to power turbines. The sites for gathering this power would be rivers, tidal streams and ocean currents. These are all naturally occurring phenomena that represent a clean, renewable energy source without the necessity of an impoundment, such as a dam.

According to a proposal submitted by Mississippi State University researchers to the National Science Foundation, the maximum combined theoretical resource available from these sources represents almost one-half of the total consumption of electricity in the U.S.

Shanti Bhushan, associate director of CAVS and a computational fluid dynamics researcher, said, "One of the key requirements for an energy source is reliability. In-stream hydrokinetic power can be significantly affected by the daily-to-seasonal changes in the flow rate and current pattern, free-surface roughness, bed topology, sedimentation behavior, etc. Understanding the effects of these factors on the power output using experiments is immensely expensive, if not infeasible. Simulation-based-design tools can play a significant role in this aspect. The proposed collaboration, which brings experts from different disciplines will help in the development of such a tool."

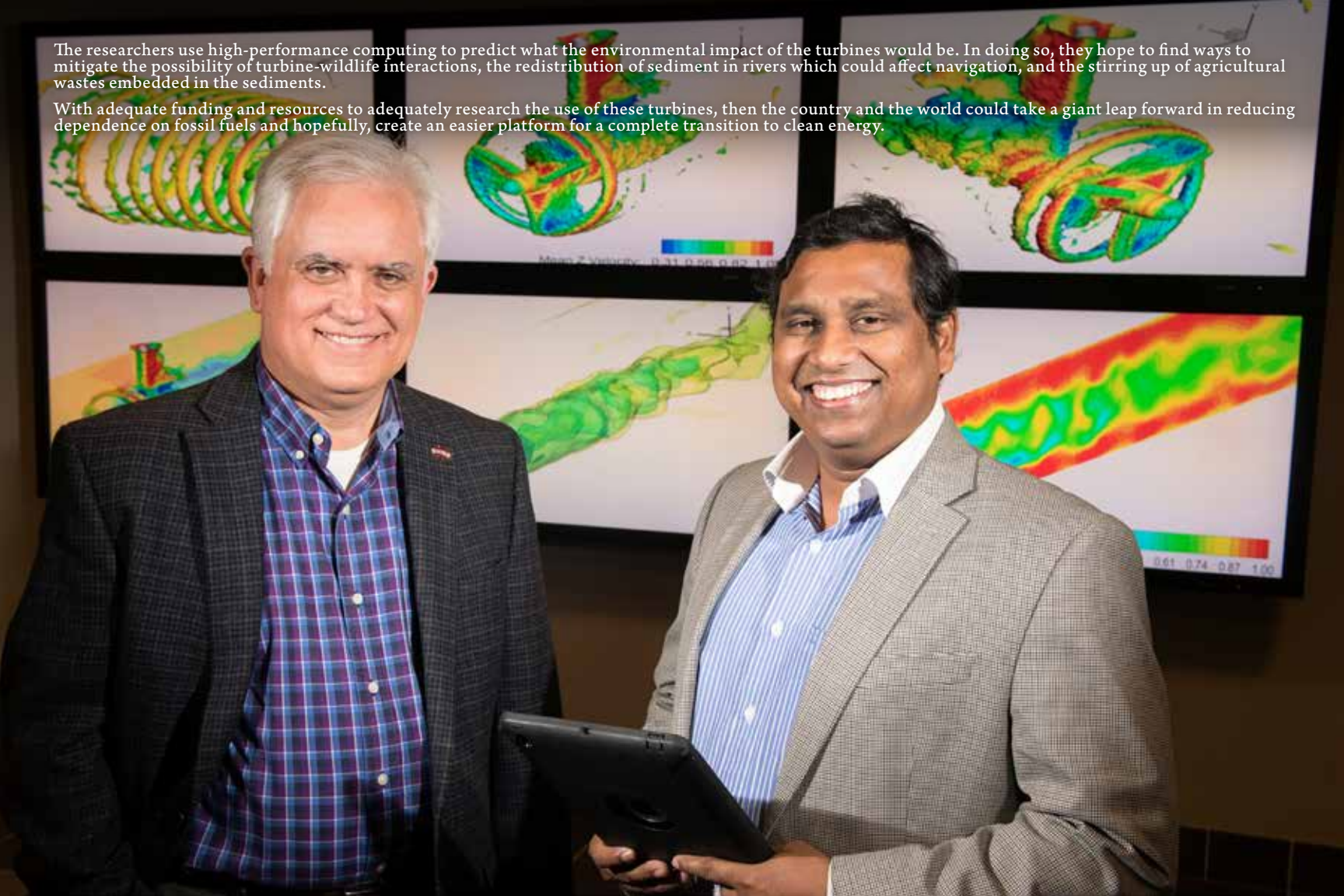


So why go with in-stream hydrokinetic power versus building another dam? The report made in 2000 by The World Commission on Dams found the following disadvantages of large dams:

- Power - more than half the hydropower dams reviewed generated less power than projected.
- Water supply -70 percent did not reach targets.
- Irrigation – almost half have underperformed.
- Flood control – dams have increased human vulnerability to floods.
- Multipurpose dams mainly fell short of targets.
- Average cost overrun equals 56 percent; if predicted cost was $1 billion, it ends up costing $1.56 billion. (Dams and Development: A New Framework for Decision-Making, 2000)

In-stream hydrokinetic power would not necessitate the development of additional impoundments, thereby foregoing the need for such significant investments monetarily, environmentally and socially. There are, however, obstacles that only the continued research of the international team can solve.

David Thompson, professor and Airbus Helicopters professor for the Department of Aerospace Engineering at Mississippi State University, explains one of the target goals of the research, "What we want to do is accurately predict the impact of the turbine installations on the environment, which can include the wildlife [or] how it affects the navigability of the river."



The researchers use high-performance computing to predict what the environmental impact of the turbines would be. In doing so, they hope to find ways to mitigate the possibility of turbine-wildlife interactions, the redistribution of sediment in rivers which could affect navigation, and the stirring up of agricultural wastes embedded in the sediments.

With adequate funding and resources to adequately research the use of these turbines, then the country and the world could take a giant leap forward in reducing dependence on fossil fuels and hopefully, create an easier platform for a complete transition to clean energy.

JAPAN UNIVERISITY TAPS CAVS FOR HUMAN FACTORS EXPERTISE

The Center for Advanced Vehicular Systems' (CAVS) virtual reality research and motion capture capability has caught the attention of some of Japan's top brass in autonomous vehicle technology. Professors Ichiro Kageyama and Masakazu Furuichi of Nihon University (Japan) are partnering with the CAVS' team of human factors experts to construct research scenarios that produce sound, pedestrian behavioral data to use to develop safe control systems for autonomous vehicles.

CAVS researchers Daniel Carruth, Lesley Strawderman and Ph.D. student, Shuchisnigda Deb, along with software developer Richard Sween, are collecting, in real time, pedestrian reactions as they cross a simulated busy intersection. The bad, unsafe, as well as good habits from the data will be used to create smart, autonomous, vehicle software that mimics operators' safe driving styles.

Researching pedestrian flow in the real world is chaotic in nature and complex. Those two factors alone make it nearly impossible to capture the same pedestrian behaviors over and over in order to study, validate and analyze in a cost-effective and realistic time frame.

"We've designed scenarios that mimic real-world pedestrian crossings at busy intersections. That means we can test hundreds of variations and the only cost is the time it takes a student to build a 3D model of a vehicle," Daniel Carruth, associate professor of human factors, and CAVS lab director said. "We are trying to understand pedestrian responses at a level where we can tell them this is the range of behaviors you can expect to see to make sure those autonomous vehicles maximize the safety of pedestrians."

Current autonomous vehicle research projects only consider the direction - crowd flow, and maybe the speed of pedestrians crossing a street. Carruth emphasized that professors Kageyama and Furuichi and the Japanese culture have a different philosophy. They believe that understanding the behaviors of the why, how, and the scenarios that cause pedestrian reaction will help them build autonomous vehicle technology that first saves lives and then it will transform the automotive industry.

"They understand they have to earn drivers' and pedestrians' trust and the way to do that is to understand pedestrian behavior to build autonomous vehicles that can accurately predict reactions in any scenario," Carruth explained. "And I think they are right. We see drivers communicate between each other and with pedestrians by swapping a look, a hand gesture or verbally. We look for signals while judging an automobile's speed and movement. We have to understand that behavior and the tiny communication pointers motorists and pedestrians pick up from one another to build safe systems."

Safety features like automatic braking systems, collision protection, roadside assistance and smart-car audio technology are getting the world closer to accepting driverless technology. However, Japan's research and automotive experts believe the world's drivers will not adopt the technology until software is designed around accurately predicting pedestrian behavior that will result in building reliable and trustworthy autonomous vehicles. The Japan autonomous vehicle experts from Nihon University are turning to the CAVS Human Factors' team for what they deem the most import element of the equation—integrity—to help their country reach the goal of having super-safe, state-of-the-art, self-driving cars on the road by the 2020 Olympics in Tokyo.

RESEARCHERS RELY ON MUTUAL EXCELLENCE FOR HIGH-TECH SOLUTIONS

An international partnership between CAVS and the Korea Institute of Industrial Technology (KITECH) has helped improve South Korea's power line efficiency and continues to research methods of making cars safer in the event of an accident. The international collaboration gives each institution the opportunity to scrutinize, debate and share experiences that help them generate scientific knowledge that can expedite the solution of problems on a global scale.

One such success story involves the delivery of electricity. Power lines must be able to carry an electrical current over long distances safely. The majority of overhead line conductors are made of heavy, expensive copper-based materials due to their excellent electrical conductivity, although mechanical properties of more cost-effective aluminum are typically better than copper.

Finding a lightweight material that can carry electricity efficiently was South Korea's challenge until Hong-joo Rhee, associate research professor at the Center for Advanced Vehicular Systems at Mississippi State, and his team designed novel composite materials and developed an innovative manufacturing technique for lightweight, overhead, line conductors with high strength and improved electrical conductivity. Based on their experimentation and simulation results, the team successfully arranged different aluminum alloys into annual rod shapes that extrude to the component shape.

CAVS and KITECH began working together by identifying each organization's strengths. In discussing each program's role, Rhee explains, "They [KITECH] are excellent at experimentation and CAVS is magnificent at modeling and computational simulations because we have supercomputers." This way of working allows KITECH to do initial tests, CAVS to run simulations and models based upon those tests, and then both to come together to design a solution for the given problem.

Another potential research target area generated from this cross-cultural university partnership is to share research and computational methods to make vehicles safer. A discovery that could easily save lives is finding the solution of how to reinforce the B-pillar, the support between the front and rear doors of a car. When a crash occurs, the B-pillar maintains the integrity of the cab, but if a passenger were to hit it, they could incur serious injury.

The challenge for researchers is how to keep the B-pillar robust enough to maintain cab integrity while also making it flexible and light-weight enough to lessen the chances of injury. Rhee explains a possible solution: "So in this project, what we're trying to do is redesign it to make specific parts of B-pillar stronger and the remaining parts a little bit ductile, not too stout but a little bit flexible."

The idea behind this method is that cars crash into each other in their midsections rather than their ceilings. By making the upper portion of the B-pillar ductile, passengers have a lesser chance of severe injury from striking the pillar. This method has its challenges, but the partnership is using their combined resources to find the best solution to making vehicles safer for society.

AEROACOUSTIC RESEARCH PROMISES TO REDUCE THE NOISE OF JETS AND PROPELLER POWERED AIRPLANES

Researchers from the Center for Advanced Vehicular Systems and Tohoku University (Japan) are conducting research in computational aeroacoustics with the ultimate objective of reducing the noise generated by aircraft.

Research in noise reduction involves two interrelated fields: fluid dynamics (a branch of fluid mechanics that deals with fluids in motion under the effect of various forces), and aeroacoustics (a subcomponent of acoustics dealing with noise generation via aerodynamic forces or turbulent fluid motion).

Each group has their expertise for undertaking the problem: CAVS researchers focus on applying highly-accurate computational methods to aeroacoustics while researchers from Japan's lab, called the Institute for Fluid Science, are very proficient in the use of direct numerical simulations aimed at obtaining a full characterization of the fluid dynamics. The collaboration allows CAVS researchers to run computational aeroacoustic simulations of jets. The team compares the model against numerical results from the Institute for Fluid Science. In other words, both research groups study the same problem by using different analysis tools.

In doing so, the joint project seeks to understand how aircraft generates noise and how the sound radiates to the far-field. Their findings will aid in the development of more efficient noise reduction technology and reduce the impact of noise on workers who must consistently be around aircraft, and on the public at large.

"You cannot shut it [noise] down entirely. We want to reduce it by 10 or 20 percent," explains Adrian Sescu, an assistant professor of Aerospace Engineering at MSU.

He adds, "We measure noise in decibels (dB). A typical jet engine noise level is around 140dB. So if we can reduce this level to 130db or even 120db, then that is a favorable result,"

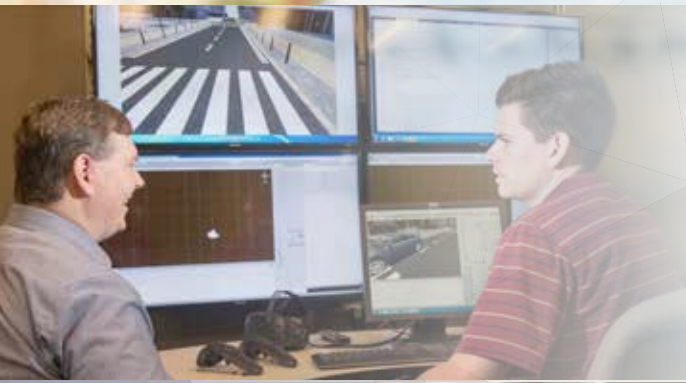
A healthy human ear can only tolerate sound up to 120 decibels (although the recommended limit is 110 decibels). By reducing the jet noise by 10 to 20 percent, researchers can bring aircraft into a more tolerable hearing range.

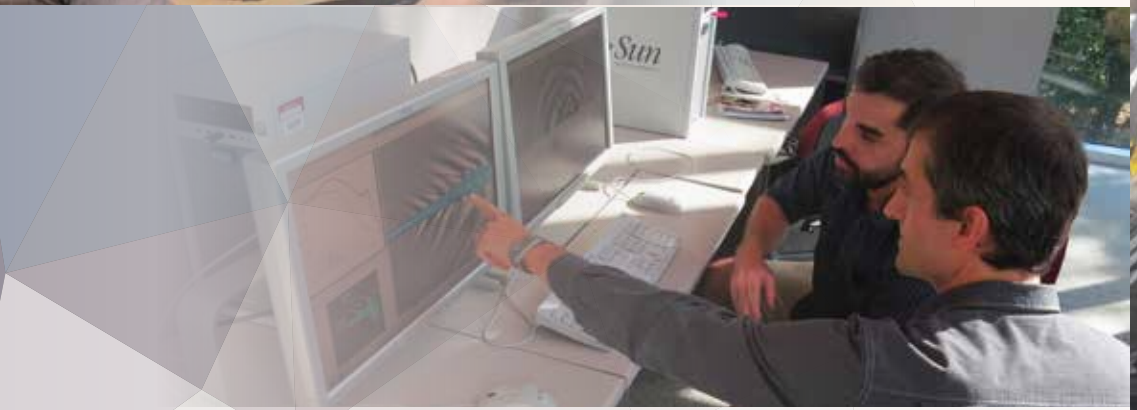
"When you do research in noise reduction, you think about people," Sescu adds. "You think about humans because it's all about the safety of our hearing system, and improving the quality of life. Jets and other aircraft sound impact society as a whole, and we're trying to create a more peaceful world by reducing the noise."

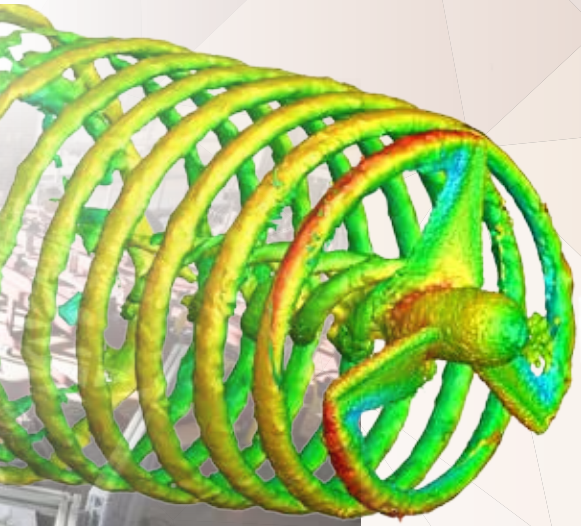
Despite the progress made over the last decade in understanding jet and aircraft noise, research in noise reduction is still a tumultuous topic, and there are a lot of gaps that are left to fill. The collaboration with Tohoku University from Japan is still too early to have yielded any substantial results, but researchers are confident that the exchange of cultures and ideas will lead to some very fascinating and game-changing results.

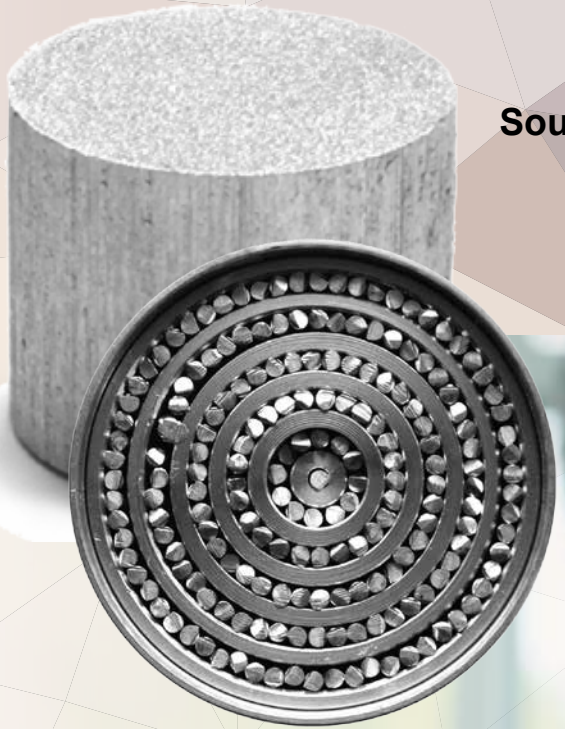

Sun
microsystems

IMAGES OF ICRES' INTELLECTUAL CAPITAL AND COLLABORATIONS CONTRIBUTING TO A GLOBAL KNOWLEDGE SOCIETY THAT HELPS BUILD A THRIVING KNOWLEDGE-BASED ECONOMY.









South Korea

UNITED KINGDOM

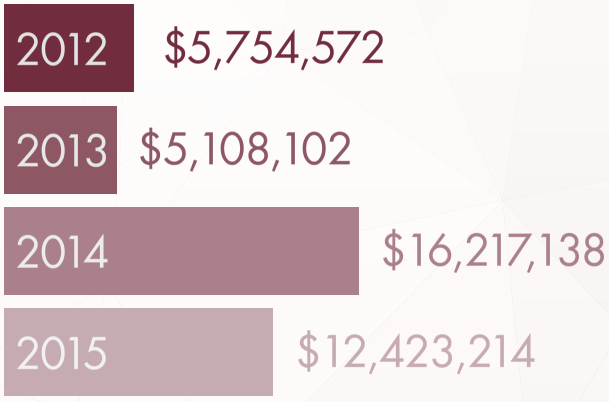
ICRES BY THE NUMBERS

ICRES Awards
(Established in FY2015)

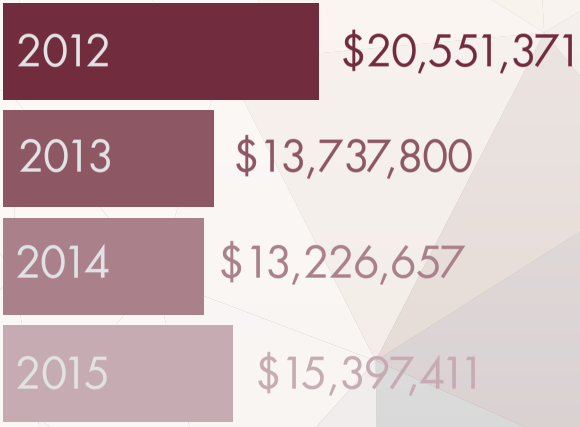
ICRES Expenditures
(Established in FY2015)

ICRES Proposals Submitted

CAVS Awards



CAVS Expenditures



MORE INFO

Interested in how your business, company or organization can partner with ICRES,

please contact:

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or visit www.icres.msstate.edu.

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