



CAVS • CAVS-E • ISER

**Institute for Computational
Research in Engineering
and Science**

2015 Annual Report



**MISSISSIPPI STATE
UNIVERSITY™**

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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Director's Message

Dear Colleagues and Friends,

This is the inaugural annual report for the Institute for Computational Research in Engineering and Science. ICRES was created to leverage and expand MSU research efforts in high performance computing, physics based modeling and simulation, and science/engineering related to manufacturing. The new research institute will provide a comprehensive vision and structure for two existing research/economic development centers: the Center for Advanced Vehicular Systems, CAVS Extension and the recently established Institute for Systems Engineering Research (ISER). In conjunction with this strategic undertaking, ICRES will also have a decidedly economic development mission through its facilities in Starkville, Canton and Vicksburg.

Over the last 25 years, Mississippi State University has garnered both national and international recognition for its applications-research related to modeling and simulation of various vehicle platforms of air, space, ground and sea, as well as acclaim for economic development support to the state of Mississippi. ICRES will now coordinate, facilitate, and expand research activities across academic and research units involved in the application of high performance computing for physics-based modeling and simulation and the verification and validation of newly developed codes. Another purpose for the institute is to serve the state by becoming an economic engine in the areas of systems engineering, manufacturing process control, and development of new designs and products for Mississippi manufacturers. In other words, ICRES will help maintain a leadership position for MSU and Mississippi in engineering applications of high performance computing.

This annual report highlights notable achievements from all three of the units comprising ICRES. The first story describes a project led by CAVS Extension that is focused on helping industry in better understanding the

manufacturability of a product before going into production. The results from this work can support new product development for Mississippi industry and for large federal acquisition projects.

The next three projects are led by faculty working at CAVS. One describes ongoing research in our foundry - MSU Steel Research Center - that is associated with CAVS. The SRC work is looking at new chemistries for advanced high strength steels. The following article describes a project for high performance modeling and simulation of turbulence. The results of this work are utilized by both NASA and the Department of Defense. The final CAVS piece describes research funded by the National Institute for Occupational Safety and Health that was performed in our driving simulator to ascertain the effectiveness of various road sign designs for communicating safety messages to drivers.

The Institute for Systems Engineering and Research, located at the Engineering Research and Development Center's campus in Vicksburg, rounds out the research reports. ISER's research vision is to revolutionize system engineering processes and virtual prototyping through computational science and engineering that leads to a dual use capacity of enhancing innovation in the DoD and the U.S. industrial base.

The constituents of ICRES have continued to support the state of Mississippi's industrial enterprise through multiple Manufacturing Extension Partnership projects. In 2016, ICRES looks to be able to expand its impact within Mississippi's industrial enterprise and continue to provide computational engineering and science research support to its sponsors.

With Regards,

A handwritten signature in black ink, appearing to read 'Roger King', written in a cursive style.

Roger King

Director of the Institute for Computational Research in Engineering and Science

Translating Product 'R and D' into Workable Manufacturing Processes

A manufacturability team that consists of engineers from the Center for Advanced Vehicle Systems Extension, CAVS-E and the Institute for Systems Engineer Research, ISER are progressing toward creating a formal assessment methodology for manufacturability. This long term project targets assisting product designers by addressing manufacturability concerns early in the development cycle. The goal is to assist companies by highlighting manufacturability concerns and developing recommendations for simplifying the manufacturing and assembly process. CAVS Extension works with a variety of approximately 50 companies in the time span of one year. The already established working relationships provide the perfect opportunity for CAVS-E to offer services that help these manufacturers and innovators reduce cost, reduce complexity, and create standardization of components.

Clay Walden, director of CAVS Extension, said, "Manufacturability measures how easy it is to manufacture and produce a certain product. It takes several aspects into account before determining if a product is ready for production. Studies have shown that around 80 percent of production cost are established initially in the design phase."

Walden further clarified that this is an applied research project, where case studies are performed by collaborating efforts with the design teams.



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“We are assisting local companies with developing more manufactureable products,” Tonya McCall, engineering project manager, stated, “while simultaneously using these experiences to improve our methodology.”

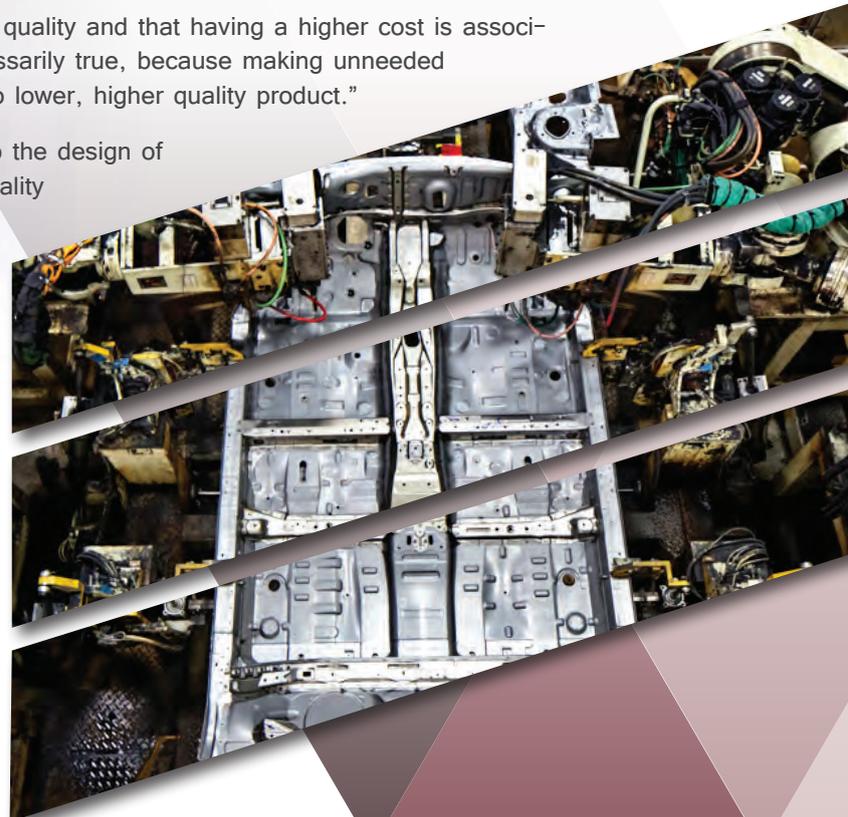
The outcome of the MSU research is to support activities at the Engineering and Research Development Center in their development of trade space tools, which are virtual tools that assist the working group and the designers with trade-off decisions. This virtual environment brings together various options that are evaluated by computer models and used by the product design team.

“Sometimes we think that lower cost is associated with having lower quality and that having a higher cost is associated with having higher quality,” Walden explained. “That’s not necessarily true, because making unneeded changes on the production line is expensive and usually translates to lower, higher quality product.”

Walden pointed out that if it can be fabricated without having to redo the design of the product then manufacturing will cost less. Therefore, a higher quality product simply requires no further modifications before and after production.

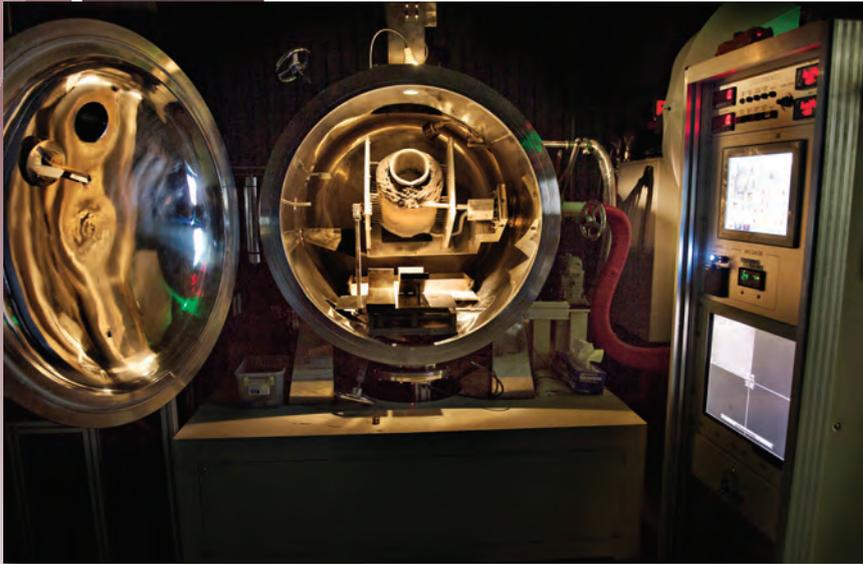
CAVS Extension, located in Canton, Mississippi, has assisted multiple companies like Nissan, several companies pertaining to the defense industry, and even local inventors to offer new products at extremely competitive costs. CAVS-E sister organization ISER, located on the ERDC campus in Vicksburg, Mississippi, plans to offer the same kind of opportunities to various entities located in that part of the state. This important research to commercialization project is funded by the U.S. Army Engineer Research and Development Center, ERDC.

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Researchers Get Real with Steel by Making Next Generation Advanced High Strength Steels Commercially Available

Researchers at the Center for Advanced Vehicular Systems (CAVS) are exploring ways to make steel stronger while sustaining its flexibility as lightweight components. Many researchers have come up with solutions to make next generation advanced high strength steels (AHSS) at the small lab-scale, but the issue is the means of converting the complex processes to the commercially viable mass production lines.



Hongjoo Rhee, a CAVS associate research professor, is using Mississippi State University's High Performance Computing Collaboratory's supercomputing capability to create algorithms that simulate the optimum AHSS alloy design and thermo-mechanical process in order to understand their process-structure-property-performance relationships. Once the alloy design and fabricating processes are refined in the supercomputer environment, Rhee transfers his theory and tests it at the MSU/CAVS Steel Research Center.

"Not only are the alloying elements expensive to replicate at the commercial scale, but steel manufacturers want to make minimal process modifications to production lines because of the costs involved," explained Rhee. "We've created the Steel Research Center layout to mimic the mass pro-

duction lines, and we're installing tailored equipment to fabricate and test the AHSS to figure out how to efficiently transition existing technology and next generation steels from laboratory to fabrication."

Most steel manufacturers' mass production lines lack the intricate thermal and mechanical processing steps required to make AHSS. Steel makers, end-users, and the automotive and defense industries are interested in Rhee's work because the outcomes could help develop cost- and time-effective design methodologies that will produce AHSS to make lighter weight, more fuel efficient, low-emission vehicles without sacrificing safety.

"We've created the Steel Research Center layout to mimic the mass production lines, and we're installing tailored equipment to fabricate and test the AHSS to figure out how to efficiently transition existing technology and next generation steels from laboratory to fabrication," Rhee stated.



Researchers Work to Improve Solutions for One of Physics 'Last Unsolved Problems'

Most people are familiar with the word turbulence, defined as “a fluid state that is random or unsteady,” because of their unforgettable experiences with it. Those who have racked up a lot of sky miles, and those who have not, describe similar experiences of gripping chair armrests and becoming semi-paralyzed in seats when an airliner suddenly drops altitude when flying through choppy air. Thanks to researchers like the computational turbulence modeling team at the Center for Advanced Vehicular Systems, airliners are built to withstand substantial amounts of turbulence. As a result of years of refining the computational models that simulate turbulence effects on structures, aircraft are designed to endure greater amounts of pressure, and the turbulent dynamics of aggressively maneuvering the plane when recovering from it. Although the designs of these air transportation vehicles are safe, according to Keith Walters, an associate director of CAVS, there is always room to improve the computational models that simulate turbulence around all moving things in order to make them safer and more cost effective.

“It is difficult to predict the flow of fluids, including gases, liquids and even some plasmas through computer simulations, because you have to account for all the intertwined, swirling, apparently random dynamics,” Walters said. “That is why Richard Feynman, the Nobel Prize winning physicist, called it, ‘The most important unsolved problem of classical physics.’” And it is why the Clay Mathematics Institute refers to it as one of seven Millennium Problems and offers \$1 million dollars to anyone who can provide a purely mathematical solution.

Shanti Bhusan, assistant professor of mechanical engineering and a CAVS faculty member states, “It’s unlikely that anyone will win that \$1 million because some of the most brilliant physicists and mathematicians have attacked and are attacking this problem of fluid turbulence. It’s recognized as being really one of the last great unsolved problems. Some of these models are very good, and some are better than others, but our work really boils down to making the current models better but still relatively easy to use.”

Walters and Bhusan’s turbulence research team is working on a project with the Engineering and Research



Development Center in Vicksburg, Mississippi, to significantly improve a turbulence model that applies to ground, air and marine vehicles. “Turbulence generation for each one of these vehicle types is very different, but we want to create one reliable model that will apply and make accurate turbulence predictions for all of them,” Bhushan explained. Over the years researchers have created hundreds of turbulence models and one of the challenges is choosing the model that is best for each type of vehicle.

“We talk about generalization because if you’re designing a car you don’t want the burden of having to pick from hundreds of models to determine which one is best for a truck and which is best for a limousine.” Walters further clarified, “We want to be able to say this is a general purpose turbulence model that we can take to the Navy, Air Force, Army, NASA or whomever and say this works really well for all vehicle turbulence scenarios.”

Working with Edward Luke, a computer science professor and researcher, the CAVS team is developing a new approach to model turbulence. Originally funded by NASA, they have implemented this innovative approach into a number of computational fluid dynamics (CFD) codes including the Loci-CHEM code that was developed at MSU by Dr. Luke. The CFD code and turbulence model are being tested by NASA and Department of Defense users as a new method to model their air and space vehicle simulations. “After we developed the model for NASA, Argonne National Laboratory and the Office of Naval Research expressed an interest as well, and that additional funding has helped us further refine and test it for different types of flows, such as marine vehicles or nuclear reactor cooling,” Walters said.

The research team was also recently awarded additional funding through the DoD High Performance Computing Modernization program, in partnership with ATA Engineering, Inc. and the Air Force Research Laboratory. The new project is based largely on attacking issues with high-speed aircraft that are of interest to the Air Force. “Roger King, director of ICRES, has been extremely supportive of our work, both in terms of finding opportunities and providing material support,” Walters added. “CAVS provides us with the environment to collaborate with researchers with a variety of backgrounds, such as David Thompson an endowed professor in aerospace engineering; Greg Burgreen, a CAVS associate research professor; Edward Luke, professor in computer science; and Adrian Sescu, assistant professor in aerospace engineering.”

Fluid turbulence is prevalent in an incredibly wide array of engineering and natural systems—that is the breadth of impact. Turbulence is critical to understanding how fuel is burned in an engine, how air flows around cars and planes, or how weather patterns form and change. Consequently, millions if not billions of dollars could be saved if researchers can improve the ability to accurately model turbulence.

Bhushan explained the ‘big picture’ impact of the research, “In the long term if you refine one model, so that designers can design aircraft that save gasoline—then tickets are less expensive; or if you use it to improve nuclear reactor cooling systems—then power becomes cheaper; or to improve moving machines that optimize food processing systems—then ultimately the impact is actually helping consumers save money on goods and services.”

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Increasing Road Crew Safety: What are the Signs?

“Road Work, Detour Ahead, Construction Next 5 Miles, Lane Closed 500 Feet—Lower Speed,” as highway infrastructure ages, signs like these are becoming more prevalent. Despite the growing numbers of these bright orange signs placed on roadways to alert drivers of the presence of construction crews, the abundance of these cautionary signs may desensitize drivers, and that puts road workers at risk. So much so that transportation incidents accounted for 66 percent of roadway work zone fatal injuries in 2013. In 69 percent of these transportation incidents, a pedestrian worker was struck by a vehicle, reports the National Institute for Occupational Safety and Health. NIOSH is trying to prevent highway worker injuries and deaths by providing support to CAVS researchers investigating whether changing road construction signage standards increases the safety of the road crews.

Lesley Strawderman, associate professor of Industrial and Systems Engineering, and Teena Garrison, CAVS faculty member, compared static signage to dynamic message signs. The two CAVS Researchers analyzed the design and the interpretation of construction signs. They also researched the impact of mentioning if workers were present, along with the sign's distance from the work zone. The majority of the data was collected through a driving stimulator located at CAVS. The simulator environment included a four lane divided highway with a speed limit of 55 miles per hour.

“We really hope to find ways to help protect workers in construction zones without adding to the inconvenience of drivers,” Garrison said.



"In the driving simulator, we cannot only collect the speed of the vehicle, but we can also determine what the driver was looking at because the simulator contains an eye tracker—a camera that we calibrate to track where the driver's eyes are moving," Strawderman explained. "What we noticed was that if the sign mentioned the workers were present there were significantly more glances toward the construction workers. Drivers spent a longer time looking at the road construction workers compared to when the sign would not mention the workers being present."

Strawderman said the research results are significant for increasing the road crews' safety because capturing motorists' attention and for a longer period of time could be interpreted that they would be more cautious driving in road construction zones.

"We really hope to find ways to help protect workers in construction zones without adding to the inconvenience of drivers," Garrison said. "The best ways to do that are understanding the drivers' perspective, and finding ways to communicate the needs of the workers that lead to safer work zones with fewer distractions related to ongoing vehicle traffic."

Garrison and Strawderman hope state departments of transportation will use the research results to change sign standards of informing motorists of when workers are present. In the meantime the two scientists are looking to build upon this study by evaluating conflicts between drivers and vulnerable road users such as pedestrians, motorcyclists and others.



Research Providing Real-world Solutions for Industry

On the national level it is called, “Accelerating technology transfer to the market place,” and it is one of the key elements on the current White House Administration’s Management Agenda to get federal laboratories to build closer collaborations with industry in an effort to build more economic prosperity. Mississippi State is taking the lead at the state level to help stimulate economic growth by establishing the Institute for Systems Engineering Research, located at the Engineering Research and Development Center in Vicksburg, Mississippi. Randy Jones, ISER’s director, has spent the past year developing a team and building upon existing relationships to help facilitate industry adoption of ERDC research innovations into solutions for manufacturing processes. Before becoming the director of ISER, Jones spent 31 years working as an ERDC research civil engineer. He is capitalizing on his connections to facilitate the extraction of technology solutions from federally funded research labs to meet industrial business needs in the commercial world.

“The university and the ERDC are in a unique position to work together and share research expertise with industry by creating a ‘lab to market’ process that could enhance technology and attract new industry to the state, which creates new job opportunities,” Jones explained. “ISER’s job is to serve as the catalyst to marry the government’s research investments with industry problems. The outcome is to provide solutions that more efficiently produce a product that will be impactful to the citizens of the state.”

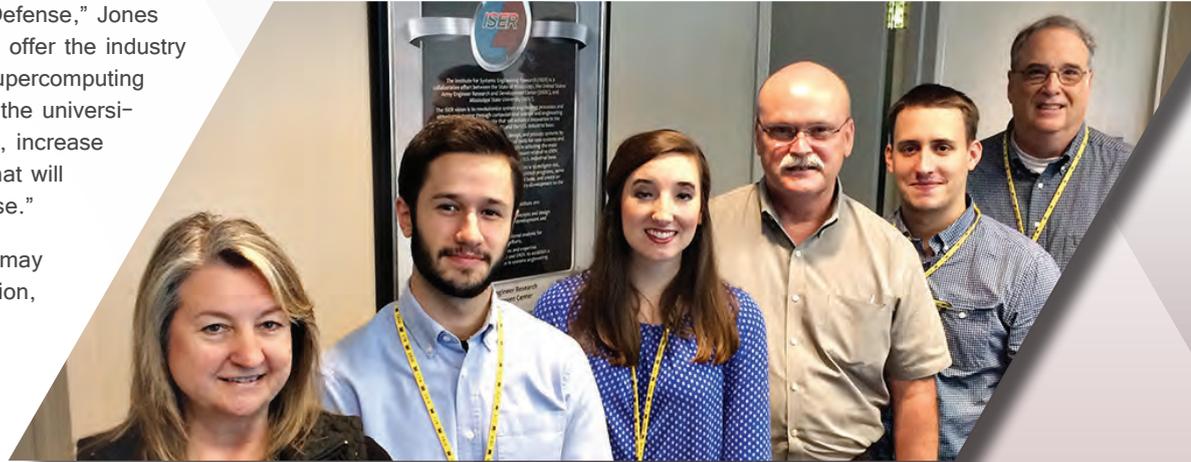
ISER is part of the Institute for Computational Research in Engineering and Science, which offers fundamental research expertise through the Center for Advanced Vehicular Systems, located at Mississippi State University, and applied research through the Center for Advanced Vehicular Systems Extension, located in Canton, Mississippi. CAVS-E, ISER’s sister organization, addresses manufacturability concerns and develops recom-

Creating an environment that enhances innovation and draws industry to the state.

mentations for simplifying the manufacturing and assembly process. Approximately 50 companies have already been able to take advantage of CAVS-E services that help these manufacturers and innovators reduce cost, reduce complexity, and create standardization of components.

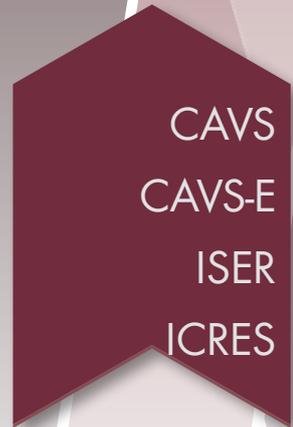
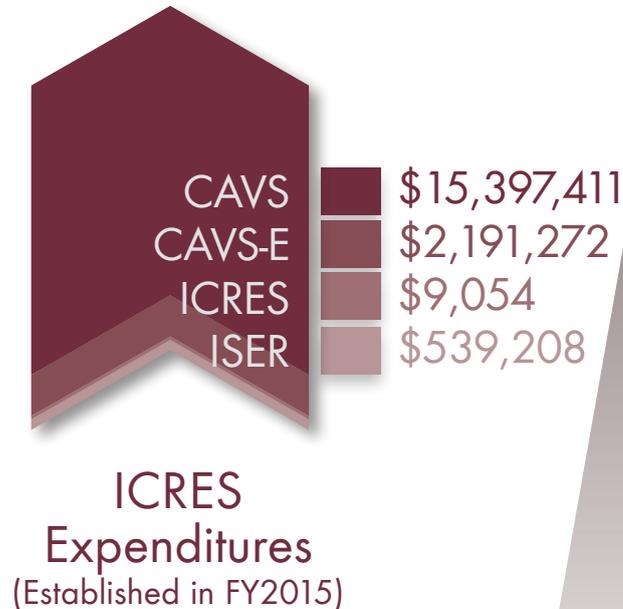
“Using the speed and power of high performance computers, the ERDC develops highly efficient and inventive systems engineering processes for the Department of Defense,” Jones said. “Now ISER, CAVS and CAVS-E can offer the industry in the state the connection to use those supercomputing applications through the DoD and through the university. We hope it will help them reduce costs, increase competitiveness and create new products that will potentially expand the state’s industrial base.”

These cutting edge research technologies may create new ventures that either the education, federal or industry entities alone may not have ever expected.

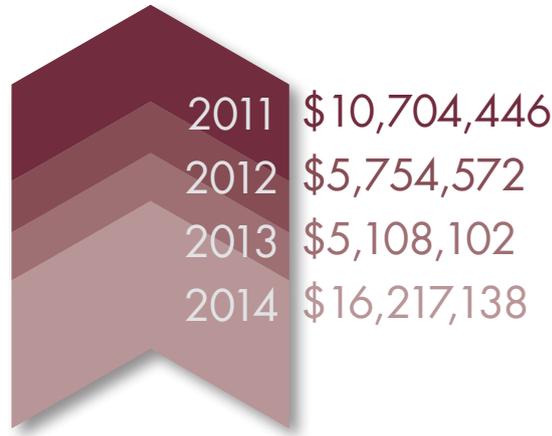


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ICRES By the Numbers



\$42,251,797
 \$96,819
 \$0
 = \$42,251,797*



CAVS Awards



CAVS Expenditures

* One proposal worth \$23 million making up 54 percent of the total value of the 82 submitted was granted in FY15 and will be awarded in FY16.



MORE INFO

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

**Dr. Roger King at rking@icres.msstate.edu
or visit www.icres.msstate.edu.**



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