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CENTER FOR ADVANCED VEHICULAR SYSTEMS

ANNUAL REPORT 2009

MISSISSIPPI STATE UNIVERSITY™

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The Center for Advanced Vehicular Systems (CAVS) at Mississippi State University is an interdisciplinary center supporting economic development in the state of Mississippi through its research and extension activities while its academic activities are advancing the university's national recognition in higher education. CAVS provides solutions for complex problems encountered in manufacturing technologies. The development efforts provide short-term solutions relevant to regional manufacturers, while the core research builds longer-term knowledge needed for sustained economic development. Through direct involvement in various activities at CAVS, students gain valuable experience that compliments their formal classroom learning.

CAVS serves as the focus for the Bagley College of Engineering's high performance computing activities that has been a longtime strength of the college. This strength was first recognized in 1990 when the National Science Foundation (NSF) awarded an Engineering Research Center (ERC) to the college that focused on Computational Field Simulations. CAVS now represents the strengths of that previous work in computational fluid dynamics and has married it with computational structural mechanics and manufacturing to support the diverse needs of the state of Mississippi. CAVS also is the home of the college's Computational Engineering graduate degree program. This interdisciplinary graduate program began with the NSF ERC and continues to this day with 20 graduate students presently enrolled and a total of 17 doctoral graduates.

CAVS also provides support to the automotive industry and other manufacturers around the state through engineering applications which enhance the competitiveness of the state's industry. This support occurs in a variety of ways including direct engagement with manufacturers and other key stakeholders (e.g., state agencies and industrial associations). Engagements with manufacturers focus on introducing and applying best practices and technologies through both on-site projects and workshops. Other engagements are more strategic in nature and address the broader needs of economic development throughout the state. CAVS, through its CAVS Extension office,


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works with the U.S. Department of Commerce's Manufacturing Extension Partnership to support the manufacturing industry of the state of Mississippi. The MEP program is designed to provide companies with services and access to public and private resources that enhance growth, improve productivity, and expand capacity. MEP also offers a third party survey to independently assess the impact on the manufacturer. Since 2006, the total impact CAVS has had (total dollar economic impacts and jobs either created or retained) through working with 56 different manufacturing clients across the state are:

Total Economic Impact: $4.28 Billion
Jobs Created: 1,280
Jobs Retained: 346

CAVS is representative of the state of Mississippi's commitment to serve Mississippi State University, government, and industry through research and development of advanced computational modeling, simulation, and design of physical systems to solve real world problems. As a result of CAVS' application-driven, team-oriented approach to basic and applied research on complex industrially-relevant engineering problems, we have contributed to:

- improved vehicle performance and reduced design cycle time and cost;
- timely generation of knowledge on the behavior and capabilities of missile, flight, naval vessels and other physical systems;
- analysis of behavior and performance of engineering systems (including humans) under adverse or catastrophic conditions;
- development of high-fidelity simulation tools and training;
- simulation and design systems to both enable and support designers and manufacturers of land, sea, air and space vehicular systems.

With a staff of about 250 faculty, research staff, postdocs, and students, the research and extension enterprise of the Center for Advanced Vehicular Systems is well situated to support the long-term needs of industry. The Center for Advanced Vehicular Systems goal is to be the primary Southeastern academic resource for solutions and innovations in complex interdisciplinary fields, such as those characteristic to the automotive, aerospace, and transportation industries.

An indicator of the interdisciplinary nature of CAVS research in 2009 was our graduate students from the following 15 degree programs: Aerospace, Agriculture and Biological Engineering, Architecture, Biological Sciences, Business, Chemical Engineering, Civil Engineering, Computer Science and Engineering, Electrical and Computer Engineering, Forest Products, Industrial Engineering, Mathematics, Mechanical Engineering, Physics, and Psychology.

This report will provide some details of just a few examples of the many research projects taking place at our center. The point to keep in mind is that our exceptional faculty, researchers and students are the reasons why the Center for Advanced Vehicular Systems aspires to greater excellence.

LIGHTENING THE LOAD

It is an obesity epidemic, however humans are not the focus; it is the vehicles we drive. They are too heavy. In fact, all mechanical modes of transportation work, but the metal used to make the parts and frames have never been optimized, meaning they are not running at the most efficient level. For instance, if researchers can figure out how to take 25 percent weight off every vehicle part, that equates to a Cadillac achieving 75 miles per gallon of fuel for every mile driven, versus 20.

This is the kind of research taking place at the Center for Advanced Vehicle Systems (CAVS). Mark Horstemeyer, chair professor of solid mechanics, worked 15 years at Sandia National Laboratories before being recruited to Mississippi State to oversee, build and conduct computational multi-scale modeling.

"We've built an experimental facility where we conduct exploratory experiments of the metals to figure out the mathematical models and theories for multi-scale modeling. Next, we transform the math into computational codes to make-up the simulation," explained Horstemeyer. "The metals are run through different simulation, constraint tests to gather history of performance. That gives us a veracity model that is believable. Then we validate and improve the final design."

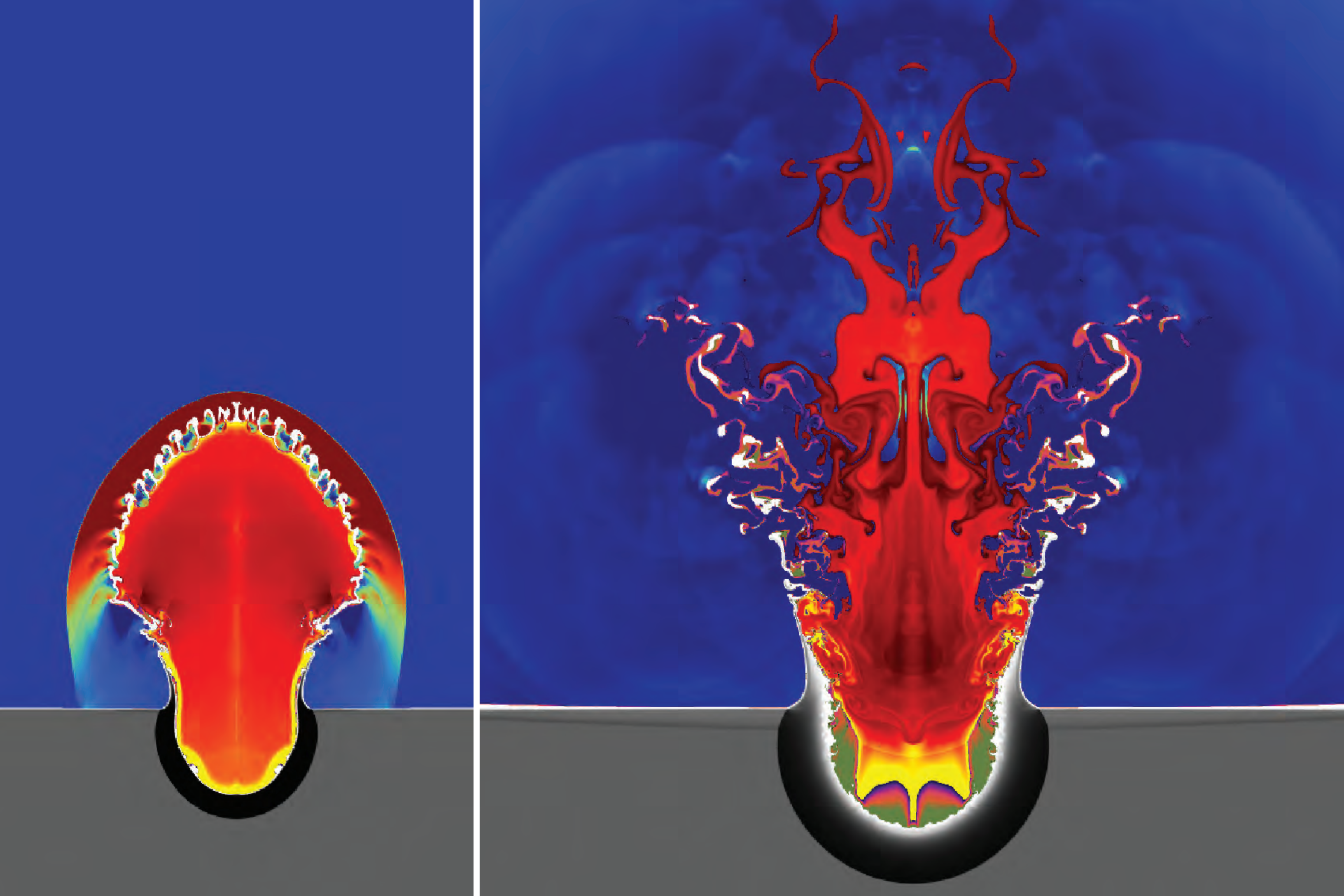
Through writing and earning Department of Energy (DOE) grants, Horstemeyer has built a laboratory infrastructure, including state-of-the art equipment that rivals the nation's best-equipped national laboratories. America's return on investment, Horstemeyer's team built a Cadillac control-arm that is 25 percent lighter and 50 percent stronger, while doubling the fatigue life.

"Our simulations save money. For every vehicle built, they run 10 to 12 crash tests, which costs about $1 million to $2 million each, so they're spending around $20 million just to test the design," said Horstemeyer. "Through the simulations we've created we can eliminate at least two designs, which is a savings of around $4 million."

Horsetmeyer's team created the lightweight magnesium cradle for the Corvette C6, creating a 70 percent weight savings for this component. Currently, all Corvette engine cradles use the magnesium cradle designed at Mississippi State. In the future, cars may be built out of polymer-based composites that come from fibers made from Mother Nature.

The future definition of the "green" vehicle might also mean being made biodegradable, achieving higher fuel economy, are safer for the environment, and less dependent on foreign oil, thanks to MSU research, a leader in material metals modeling.

Story written by Diane L. Godwin.
For more information about this research, contact Dr. Mark Horstemeyer at (662) 325-5449 or mfhorst@cavs.msstate.edu



ADVANCED COMPUTING INCREASES SOLDIER SAFETY

History has proven that the tactics of war constantly evolve, but from trench warfare to the dogfights of World War I, the need to quickly develop effective defenses for each situation has remained constant.

Today, one of the biggest threats to American soldiers comes from improvised explosive devices (IEDs). While developing protective gear for these hazards would appear to be a simple process, the situation is complicated because the only unifying element to these roadside bombs is their ability to cause harm. By utilizing the advanced computing capabilities of MSU's Center for Advanced Vehicular Systems (CAVS), the Department of Defense hopes to overcome these devices' unpredictability to better protect military personnel.

"Part of the problem when dealing with an IED is that it does not have well-defined specifications. It's improvised and that's a challenge in determining its effects," said Dr. David Thompson, an associate professor of aerospace engineering. "We are trying to predict the effects of these IED blasts on vehicles in order to mitigate their effect on the occupants."

Thompson is part of an interdisciplinary team that's combining computational fluid dynamics and computational structural dynamics to develop detailed simulations of IED blast effects. He explained that by utilizing advanced computational codes developed at MSU, the team can determine how a blast wave will travel through various media and react to the shape of a vehicle.

"You have to have an accurate representation of a vehicle's geometry. For instance a shockwave will intensify as it interacts with the underbody of a vehicle," Thompson explained. "Accurate numerical simulations have advantages relative to experiments. You can only blow-up a physical vehicle one time, but these simulations can be run many times with different parameters." He added, "We are providing the technology to perform more accurate analyses to increase survivability in IED attacks. These tools will provide capabilities to simulate different scenarios and develop the best possible equipment for our soldiers."

This project is part of the Simulation-Based Reliability and Safety program through which CAVS and the Army are working to increase the battlefield effectiveness of ground vehicles. Team members include Dr. Eric Blades, Dr. Pasquale Cinnella, Dr. Mark Janus, Dr. Edward Luke, Dr. James Newman III, Dr. Xiao-Ling Tong, and Chris Moore.

Story written by Susan Lassetter.
For more information about the project, contact Dr. David Thompson at (662) 325-2068 or dst@cavs.msstate.edu.

THE ANSWER INCLUDES OPTIMIZATION

Alternative energy captures most of the media and political limelight, however as fuel prices increase one intrinsic component is left out of the story. It's called magnesium, and America's government and auto industry turned to the Center for Advanced Vehicular Systems (CAVS) to find innovative answers for using it to reduce America's dependence on foreign oil and produce emissions that are safer for the environment.

Drs. Haitham El Kadiri and Brian Jordon, assistant professors of research at CAVS, are studying the material at the microstructure level to understand how to manipulate magnesium to form shapes that can make critical automobile parts that are up to 50 percent lighter and stronger than ones made from steel. "No one has really looked at it from a very thorough process of using magnesium in a mass produced vehicle. So, the bottom line is can we do it?" said El Kadiri.

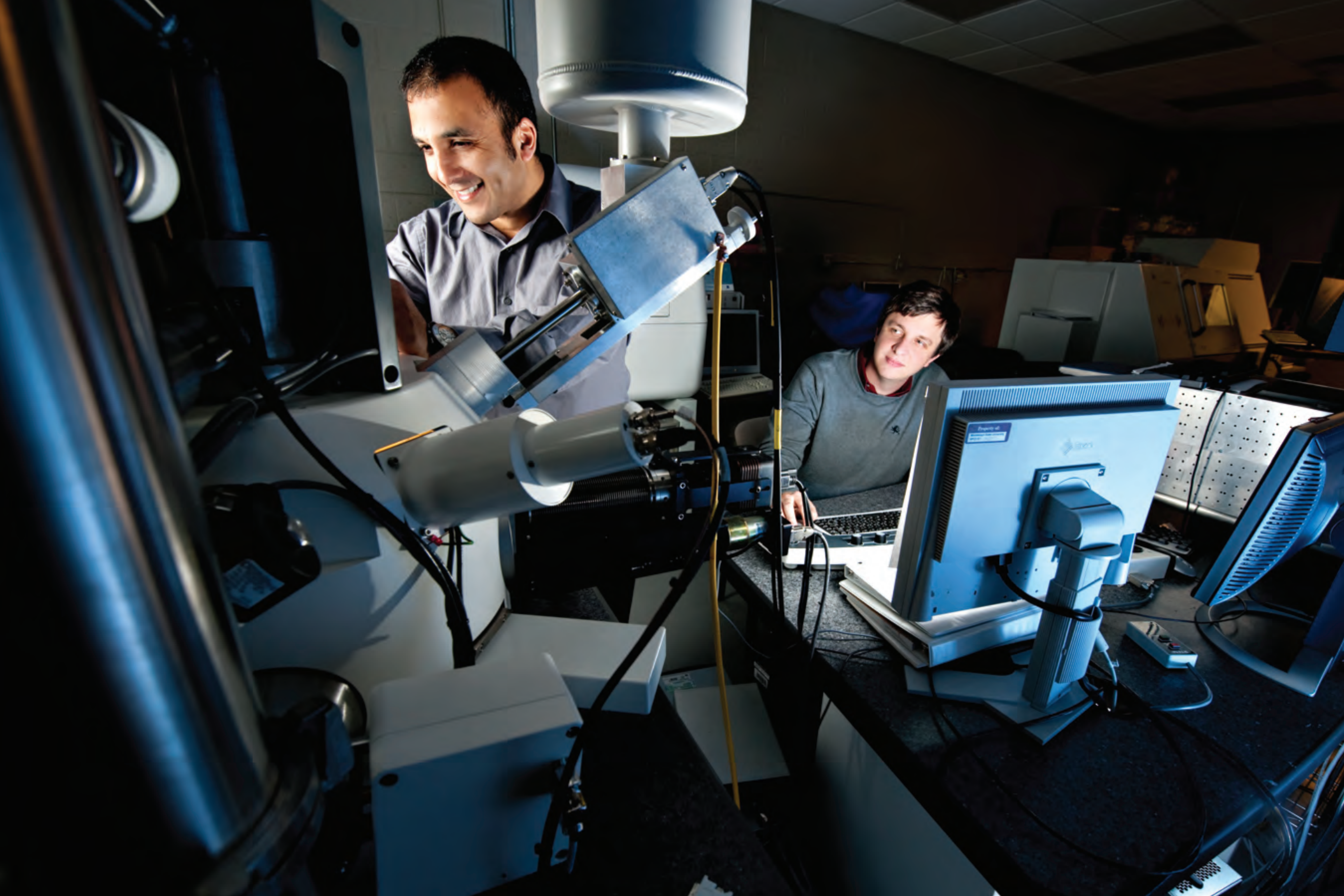
In the past, magnesium has been used as an alloying element for the desulphurization of steel to make lightweight, non-critical auto parts, such as doorframes, instrument panel holders and seat rests. Experts discovered that this lightweight bodywork technology reduces a vehicle's weight by 10 percent and produces a 6 percent decrease in fuel. Working with the Department of Energy's Integrated Computational Materials research team, along with Ford, GM and Chrysler, El Kadiri and Jordan's challenge is to discover how to make an automobile made solely from magnesium.

"We can produce magnesium parts at very low extrusion [forming] rates, which equates to about four feet per minute. Producing parts at that rate isn't cost-effective," explained El Kadiri. "We need magnesium extrusion rates of about nine feet per minute. At those high rates the problem is magnesium distorts and produces unique curves. We're trying to rationalize and find solutions for those behaviors."

As El Kadiri researches to find answers for forming magnesium, Jordon continues the process by testing the fatigue issues associated with this lightweight material. Both are important facets, when considering the new hybrid vehicles have a curb weight heavier than standard vehicles.

"We often hear the need to make vehicles lighter to reduce fossil fuel consumption," stated Jordon. "We're looking at tackling the problem from a material science point-of-view. Optimizing the hybrid technology could mean increasing fuel efficiency by at least another 20 miles per gallon."

Story written by Diane L. Godwin.
For more information about this research, contact Dr. Brian Jordan at (662) 325-8977 or bjordon@cavs.msstate.edu.




EcoCAR
The NeXt Challenge
ENERGY

ECOCAR TEAM ACCELERATES INTO THE NEXT PHASE OF COMPETITION

With first-round success in the rearview mirror, Mississippi State University's vehicle design team is accelerating into the second year of EcoCAR: The NeXt Challenge competition.

Sponsored by the Department of Energy and General Motors (GM), the three year competition asks 17 competitively selected collegiate teams to reengineer a sport utility vehicle to improve its fuel economy and reduce emissions while maintaining performance and consumer appeal. The Bulldog team selected a plug-in range extending vehicle architecture. Tests indicate that once implemented, this design will earn over 100 mpg and have a 40 mile all-electric range.

"Seventy-seven percent of Americans drive 40 miles or less to work each day so that number was our all-electric range goal," explained Ryan Williams, the team's mechanical group leader. "With our design, people in that category will basically never have to turn their engine on."

The team tested its architecture during the first round of the challenge, earning special attention at the year-ending competition for going beyond the minimum requirements. Participants were obligated to have hardware-in-the-loop simulations of their designs, but the Bulldogs went a step further by constructing a driving simulator which includes a full-sized automotive seat, steering column and instrument panel. Stacked monitors and a computerized environment let the judges have the experience of actually driving the vehicle.

The team brought home third place overall honors, as well as, first place in mechanical systems presentation, second in outstanding outreach, and special recognition for creative promotion.

After receiving its GM donated vehicle in October, the team began focusing on design execution. This second year of the challenge will culminate in a two-part competition which will include both technical presentation and road performance evaluations.The team has reason to hope for continued success in this year's round of competitions. At the January winter workshop, it earned first place honors for Web site design and third in modeling and simulation. MSU was the only team to place in both categories.

This provided the team renewed energy to push forward with its ambitious schedule. Team members worked to have the vehicle running on front and rear axles by December and will spend the remainder of the spring focusing on controls refinement.

"We don't want consumers to know that they are driving a hybrid vehicle. The goal is to make it feel and perform just like a regular automobile," Williams said.

This year's culminating events begin May 17, 2010 and include competitions in both Yuma, Ariz., and San Diego, Caifl.

Story written by Susan Lassetter.
For more information about the team e-mail the team's outreach coordinator Elizabeth Butler at ebb42@msstate.edu. or mfhorst@cavs.msstate.edu.

NEW DRIVING SIMULATOR PUTS RESEARCH IN THE EXPRESS LANE

Already a leader in automotive research, the Center for Advanced Vehicular Systems (CAVS) recently pulled further away from the pack with the addition of a state-of-the-art driving simulator to its facility.

Boasting front and rear display screens, integrated side view and rearview mirrors, and eye-tracking technology, the simulator allows researchers to capture real-time data. In addition to the five visual channels, any performance measures that could be gathered from a standard vehicle can be collected in the safety of a lab environment with just the click of a mouse.

"The simulator lets us understand how humans interact with equipment and different scenarios in an environment that is much safer than the real world," said Teena Garrison, a doctoral candidate. "If someone wrecks the simulator we might laugh, but we just reset and move on. You can't do that in the real world. There is a lot more than embarrassment at that point."

The U.S. Army Tank Automotive Research, Development and Engineering Center (TARDEC) funded the installation in order to establish CAVS as a test bed for refining man-in-the-loop driving simulations in which a test subject interacts with a computerized scenario. While they may resemble video games, Garrison explained that these research simulations must not run from a story-like script.

"If you don't want someone to do something in a video game you simply put it in the storyline, but if you do that in a research simulation you might take away an action that people might take," Garrison explained. "It can't be so scripted that if the driver breaks from script the simulation will break down. That's the problem we are helping the military overcome."

While TARDEC funded the driving simulator its use is not limited to military research. Though the physical car body in the simulator is a Nissan donated Maxima, the simulator can be programmed to act as any ground vehicle and has been incorporated into CAVS to open the door for research ranging from mechanical engineering to human factors.

"This is an engineering center so our overall goal is to use this equipment to gather information and apply it to designing and building better products and systems," Garrison said.

Story written by Susan Lassetter.
For more information about this research, contact Dr. Daniel Carruth at (662) 325-5446 or dwc2@cavs.msstate.edu, or Dr. John McGinley at (662) 325-7195 or jam@cavs.msstate.edu.


CAUTION
HOT

It's a simple truth that creates a political hotbed for the transportation and energy industry. Traditional American engine technologies are not compatible with renewable fuels. Consequently, recyclable fuels, such as E85, a gasoline and ethanol blend, are not giving vehicles the same fuel economy and range as gasoline and diesel. However they meet EPA regulations by emitting lower emissions that are safer for our environment.

Drs. Sundar Krishnan and Kalyan Srinivasan, assistant mechanical engineering professors and researchers at the Center for Advanced Vehicular Systems (CAVS), are in the business of adapting renewable fuels for advanced combustion concepts. They're tailoring combustion strategies for fuels made from biomass to enable highly efficient engines that meet performance requirements while reducing harmful exhaust emissions.

"Our research is not just fuel-centric or solely focused on engine design or even trying to adapt current engines to run efficiently with renewable fuels; that is the traditional approach," said Krishnan. "We're working on futuristic solutions of how to co-design new engine combustion strategies and biomass-derived fuels so they complement rather than work against each other."

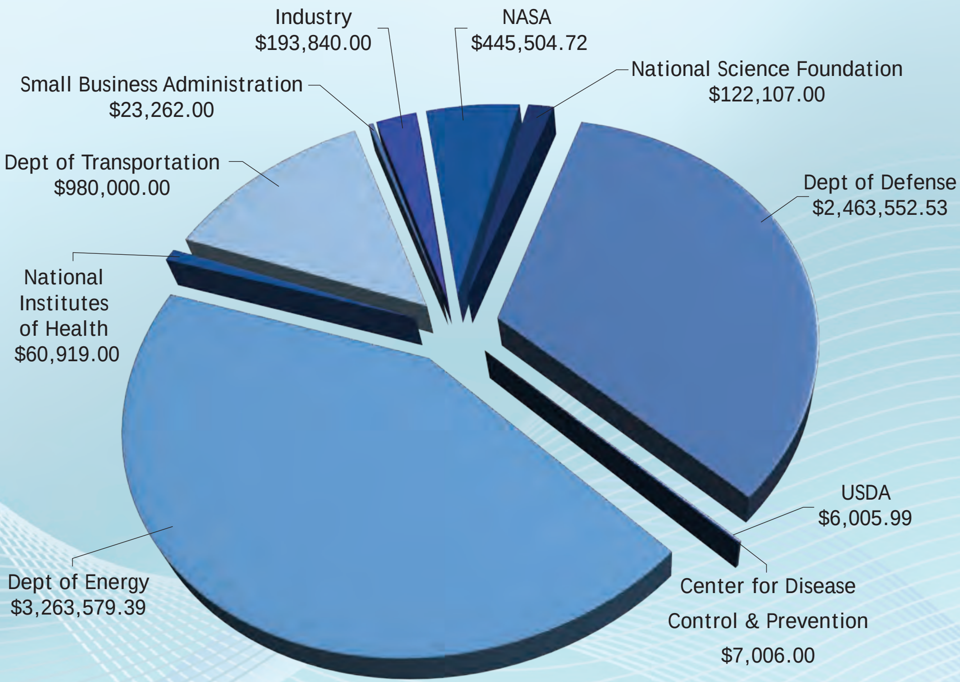
Mississippi State is one of only a handful of universities in the nation that are pursuing this innovative research. This "bottom-up" approach has a high probability of positively reinvigorating the auto industry, economy and at the same time protecting our environment. The work is possible through a unique alliance of experts from different academic areas, who work together at the Sustainable Energy Research Center to create renewable alternative fuels from Mississippi's natural resources, and the researchers at the Advanced Combustion Engines laboratory at CAVS, who optimize novel combustion strategies for future vehicles.

"They'll give us biomass-derived fuels to perform our low temperature engine combustion experiments. We'll characterize the fuel in its ability to produce power and to ensure high efficiency and very low emissions," CAVS researcher Srinivasan explained. "Based on our feedback, they'll tweak the fuel to meet engine requirements and we'll meet them in the middle by tailoring the engine combustion strategy."

The two researchers are working on an umbrella of new engine combustion concepts called low temperature combustion (LTC). The concept is capable of handling different fuels, meaning they can design engines that efficiently work with many fuels. Their work holds enough promise that a heavy-duty truck engine manufacturer has donated one of their heavy-duty engines to support Srinivasan and Krishnan's LTC research to further refine the concept that they hope will break into the commercial market in the future.

2009 FISCAL YEAR AWARDS

TOTAL AWARDS: **$7,565,776.63**



RECOGNITIONS

Mark Horstemeyer
2009 Thomas French Alumni Achievement Award, Ohio State University

Tonya Stone
2009 Research Award for the division of Bagley College of Engineering — Research Support Staff

Matthew Doude
2009 Research Award for the division of Bagley College of Engineering — Graduate Research Assistant

James Baird
2009 Research Award for the division of Bagley College of Engineering — Undergraduate Student

Masoud Rais-Rohani
2009 Bagley College of Engineering Outstanding Educational Paper Award in May 2009

Thomas Lacy
2009 Society of Automotive Engineers Ralph R. Teetor Educational Award, Aerospace Division

Thomas Lacy
Named Scientific Advisor, Golf Digest Magazine

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