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CAVS

ANNUAL REPORT 2018

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"It has been such an exciting year," said Clay Walden, CAVS executive director. "I encourage you to engage with us and explore the impact that CAVS is making, along with our clients and partners, around the nation and within the state."

DIRECTOR'S MESSAGE

As the Executive Director at the Center for Advanced Vehicular Systems, I'm excited to publish this year's annual report. I am extremely proud of the accomplishments made this year by our team of over 300 researchers, engineers, staff and students.

Together with our government and industry partners, we have had an exciting year at CAVS. Our research teams have had the privilege to work on some of our nation's most strategic problems, while our industrial outreach teams have had the opportunity to pursue projects with strong impacts on economic development around the state of Mississippi.

Inside these pages, we have chosen to highlight our diverse range of initiatives, impacts and people from the past year, and represent all of our affiliated centers – CAVS-Research, CAVS-Extension, the Institute for Systems Engineering Research, and the Institute for Imaging and Analytical Technologies. From our investment in off-road and next-generation steel research to working with hospitals to improve health care delivery, this collection of articles showcases the impact of our organizations.

I invite you to read further and explore the impact that CAVS is making around the state and nation. Also, I would like to invite you to provide feedback on our efforts and follow us throughout the year on Facebook, Twitter and LinkedIn.

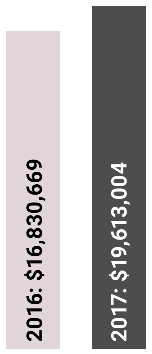
Hail State!

Clay Walden

Clay Walden
Executive Director
Center for Advanced Vehicular Systems

OUR VISION

The Center for Advanced Vehicular Systems (CAVS) will be a global leader in interdisciplinary education and research for the development of engineering solutions that expand and enhance the design, technology, production, and infrastructure necessary for sustainable mobility.



2018
TOTAL AWARDS
$25,448,355

OUR MISSION

CAVS strives to be a world-class center of excellence for research, technology and education equipped to address engineering challenges facing US mobility industries. Utilizing high performance computational resources and state-of-the-art analytical tools for modeling, simulation, and experimentation, CAVS will provide a distinctive, interdisciplinary environment wherein next-generation engineers and scientists train alongside field experts to investigate, design, and verify novel solutions in materials, propulsion, and design for efficient human and vehicle mobility. Harnessing our broad impact research along with our state, national, and international industrial alliances, CAVS will support economic development and outreach activities throughout the State of Mississippi.

MSU DEBUTS ‘HALO PROJECT’ SUPERCAR IN LAS VEGAS

BY JAMES CARSKADON | PHOTOGRAPHY BETHY NEWMAN WYNN

Mississippi State researchers and students traveled 1,757 miles to Las Vegas, Nevada, to unveil the university’s “Halo Project” supercar at the world’s premier automotive specialty products trade event.

The SUV, an all-electric sport utility vehicle that is pushing the boundaries of autonomous vehicle capabilities, made its debut at the 2018 SEMA (Specialty Equipment Market Association) show.

Designed to function autonomously in off-road environments by an MSU team at the university’s Center for Advanced Vehicular Systems, the vehicle is built with the latest automotive technology and is paving the way for advancements in a key area with personal, military, agriculture, and search and rescue implications.

“The Halo Project itself serves as a platform for our researchers to demonstrate their expertise, on a real-world, high-performance vehicle,” said Matthew Doude, CAVS associate director and Halo Project lead. “Less than one percent of the Earth is paved, so we needed a vehicle that could be a capable development and test platform both on- and off-road. The Halo Project vehicle is all-wheel drive with tons of wheel torque from its four independent electric motors. This allows us to do research on topics like self-driving cars, even in rugged environments.”

The supercar, a modified Subaru Forrester, utilizes an on-board NVIDIA supercomputer that allows the vehicle to navigate on and off-road terrain without human intervention. MSU recently acquired property that CAVS will use to house an autonomous vehicle test track. CAVS also is developing the MSU Autonomous Vehicle Simulation platform.

“The students and researchers have been working so hard to make this project possible,” said CAVS Executive Director Clay Walden. “I think this car makes an impactful statement about our contribution to the future of autonomy and off-road mobility.”

“Less than one percent of the Earth is paved, so we needed a vehicle that could be a capable development and test platform both on- and off-road. The Halo Project vehicle is all-wheel drive with tons of wheel torque from its four independent electric motors. This allows us to do research on topics like self-driving cars, even in rugged environments.”

The project builds on a series of MSU automotive research projects, including the “Car of the Future,” an all-electric hybrid that combines superior efficiency, sporty handling and advanced technological features. MSU student, faculty and staff research teams have long been recognized for excellence in projects like “Car of the Future,” national competitions such as EcoCAR, and other initiatives that have pushed innovation.

The completion of the Halo Project supercar shows the strength and depth of MSU’s research partnerships, Doude said. In addition to students and research faculty, the Halo project team comprises domestic and foreign companies that have successfully partnered with MSU on previous projects and serve a global customer base.

FEATURES OF THE CAR INCLUDE:

- Navigation of a wide variety of terrain autonomously by using a sensor packing that includes LiDAR, radar and cameras. Four LiDAR sensors will create detailed 3D maps of the vehicle’s surroundings, while stereo cameras will serve as the car’s eyes and help it recognize and classify objects. Radar will allow the vehicle to see better through rain and snow, as well as identify types of terrain in front of the vehicle. All of the sensor data will be fed into an onboard supercomputer, provided by NVIDIA.
- Next-generation lithium ion battery produced by Michigan-based A123, an international leader in battery technology, enabling the vehicle to travel an estimated 230 miles on a single charge. The battery has more than 50 percent more energy capacity than the previous generation.
- Four electric motors powering each wheel individually and providing over 10,000 newton meters of torque. Built by YASA, the motors are coupled with high-power inverters made by Rinehart Motion Systems.
- Torque to the wheels through custom-designed transmissions provided by Hewland Engineering of Berkshire, United Kingdom.
- Custom body work and paint by Clinton Body Shop to ensure that the vehicle looks the part of a supercar. The shop also provided the paint for MSU’s internationally-recognized “Car of the Future” vehicle.
- A suspension that was partially built using steel that was melted, cast and rolled at the CAVS steel research center.

Work on the Halo Project has been ongoing for more than a year. The car will be displayed at various conferences and automotive events. In addition to highlighting MSU’s advanced engineering capabilities, the car will immerse undergraduate and graduate students in advanced automotive technology and research.

MSU SET TO COMPETE IN ECOCAR MOBILITY CHALLENGE

BY JAMES CARSKADON | PHOTOGRAPHY BY GENERAL MOTORS AND HAILEY HANNIS

Mississippi State University has been invited for the fifth consecutive time to participate in the nation's premier automotive engineering competition.

Competition sponsors U.S. Department of Energy, General Motors and Mathworks announced that MSU is among 12 North American universities participating in the EcoCAR Mobility Challenge. Over the next four years, MSU students will re-engineer a 2019 Chevrolet Blazer to incorporate advanced propulsion systems, automation and vehicle connectivity, all while maintaining improved energy efficiency, safety and consumer acceptability.

The competition is managed by Argonne National Laboratory and provides students with real-world experience solving complex engineering challenges, while also building teamwork and leadership skills that they will take with them into their future careers. MSU's team is led by faculty advisor Randy Follett, an associate professor in the university's Department of Electrical and Computer Engineering. The team will work on the car at MSU's Center for Advanced Vehicular Systems.

"This competition is a great opportunity for students in a wide range of majors to get real work experience in the automotive industry," Follett said. "Students who have participated on our teams previously have gone on to take jobs at the Department of Energy, General Motors, and other related businesses. Not only that, but it is a great opportunity to get to work on a multidisciplinary team, which provides benefits to the students, no matter where they end up working."

MSU has been competing in the Department of Energy's Advanced Vehicle Technology Competitions since 2004. Among many honors the student teams have received in the competitions, MSU's EcoCAR teams earned overall first place finishes in 2007, 2008, 2010 and 2012.

> "Students who have participated on our teams previously have gone on to take jobs at the Department of Energy, General Motors and other related businesses. Not only that, but it is a great opportunity to get to work on a multidisciplinary team, which provides benefits to the students, no matter where they end up working."

The EcoCAR Mobility Challenge will incorporate SAE Level 2 automation, which provides for some automated functions like acceleration and steering, but the driver must remain engaged with the driving task and monitor the environment. The teams will use onboard sensors and wireless communication from the vehicle's surrounding environment to improve the car's overall operation.

In addition to providing hands-on experience with the latest automotive technologies for MSU Bagley College of Engineering students, the competition will provide opportunities for communication and business students to participate in projects that give students a multi-disciplinary approach like what they would experience while working in the automotive industry.

In addition to MSU, participating universities in the EcoCAR Mobility Challenge include: Colorado State University, Embry-Riddle Aeronautical University, Georgia Tech, McMaster University (Canada), Ohio State University, University of Alabama, University of Tennessee, University of Washington, University of Waterloo (Canada), Virginia Tech and West Virginia University.

General Motors provides each of the 12 competing teams with a 2019 Chevrolet Blazer, as well as vehicle components, seed money, technical mentoring and operational support. MathWorks provides teams with a full suite of software tools, simulation models, training, technical mentoring and operational support. The U.S. Department of Energy and its research and development facility, Argonne National Laboratory, provide competition management, team evaluation and logistical support. Other sponsors provide hardware, software and training.

Additional sponsors include: NXP Semiconductors, Inc.; National Science Foundation; Intel Corporation; American Axle Manufacturing; Robert Bosch, LLC; PACCAR, Inc.; dSPACE, Inc.; Siemens PLM Software; Denso International America; Horiba; Delphi Technologies; California Air Resources Board; Proterra, Inc.; tesa Tape; Vector North America, Inc.; and The Electric Power Research Institute, Inc.

MANUFACTURERS TURN TO REGIONAL RESEARCH CENTER TO DEVELOP AHSS

BY DIANE GODWIN | PHOTOGRAPHY HAILEY HANNIS

Mississippi State's Steel Research Center has what many would call "a license to innovate." Researchers at the Center for Advanced Vehicular Systems are working with several steel manufacturing companies in the region, as well as the Department of Defense (DoD), to explore ways to make steel stronger while sustaining its flexibility as lightweight components.

The CAVS Steel Research Center is the result of its visionary participants and collaborators including CAVS associate director and ME associate professor, Hongjoo Rhee. Rhee began constructing the Center in 2014, and by continuously increasing its capability, the Center can duplicate a wide range of materials steel manufacturing plants can produce on a small scale, including melting, casting, rolling and heat treating custom alloys. Many researchers have come up with solutions to make next generation, advanced high strength steels (AHSS) at the lab-scale, but the issue is the means of converting the complex processes to the commercially viable mass production lines.

Rhee 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, Rhee transfers his outcomes 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 production lines and we continuously install tailored equipment to fabricate and test the designed materials to figure out how to efficiently transition existing technology and next generation steels from laboratory to fabrication."

Getting the intricate details of making custom alloys right on the small scale is incredibly important for a company's bottom line. The global, lightweight materials market is dominated by a few players, which is why companies are looking to hire the next generation of engineers who have the background to help them invent lightweight, high strength materials.

Will Williams is earning his Ph.D. in mechanical engineering. Williams helped install and runs various tests on the thermal-mechanical simulator, Gleeble machine, that can heat and cool custom alloys at 10,000 degrees Celsius per second.

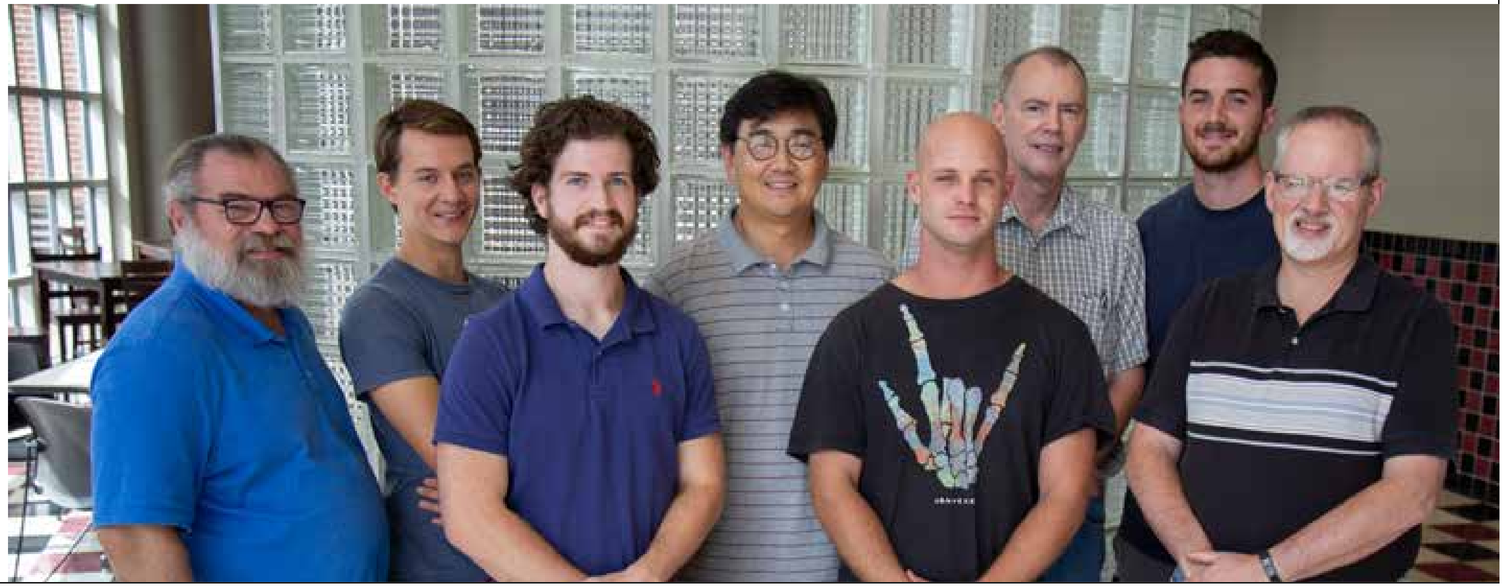
"What I learn in theory I get to apply it at the Steel Research Center, which makes understanding the process of making these advanced high strength steels that much easier," Williams explained.

Josiah Phillips, a CAVS research associate, who is in charge of manufacturing facility of the Steel Research Center in the Edwards building on campus added, "It's really helpful to see and get the experience of running the process from beginning to end."

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 the CAVS researchers' 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. One of the DoD's main goals is to protect their troops from harm and has granted the CAVS Steel Research Center two large research projects.

"The projects involve perfecting high strength steel for military vehicles. If the metal is too heavy these vehicles flip and if they are too light they can't withstand a blast," Rhee said. "So, you could say, the impact of our research is about saving lives."

"We continuously install tailored equipment to fabricate and test the designed materials to figure out how to efficiently transition existing technology and next generation steels from laboratory to fabrication."



REVOLUTIONIZING HEALTH CARE

STORY AND PHOTOGRAPHY BY DIANE GODWIN

The CAVS-E Healthcare Lean Certificate Program is transforming the way hospitals in the region care for their patients. John and Susan Moore, of CAVS-E, developed the Healthcare Lean Certificate program, that is helping these hospitals create health care management systems where employees, from housekeeping, to the medical staff, to the C-suite understand the patients' treatment processes so well that they are more in touch with their patients' health and overall welfare than the patients themselves.

At Anderson Regional Health Systems in Meridian, the improvement process began four years ago, when the hospital's leadership was willing to dismantle the traditional health care management model and embrace a forward thinking, patient driven management style called Lean. As a result Anderson is seeing reductions in patient wait times, improvement in employee morale, higher quality ratings in the delivery of medical care, and they are doing this without adding resources and cost. It is possible because Anderson is focusing on improving quality and speed of service through the elimination of errors and wasteful work practices.

"Health care professionals are dedicated people. Individually they will do whatever it takes to provide the best care. Unfortunately, this can lead to a highly variable set of work practices," explained Susan Moore, the CAVS-E healthcare coordinator. "Our class teaches them to carefully examine the work that they do, and create the best standard methods that everyone can be trained to do every day."

John Moore, the CAVS-E project manager added, "In the past, health care problem-solving often involved a great deal of blaming and shaming. We help them understand that it is not the people, but the process that is broken."

Connie Lee, director of quality, and an RN for over 22 years at ARHS knows that when working in health care the smallest of things can save a person's life. Years ago, she was working in telemetry as an RN, where at risk, critical

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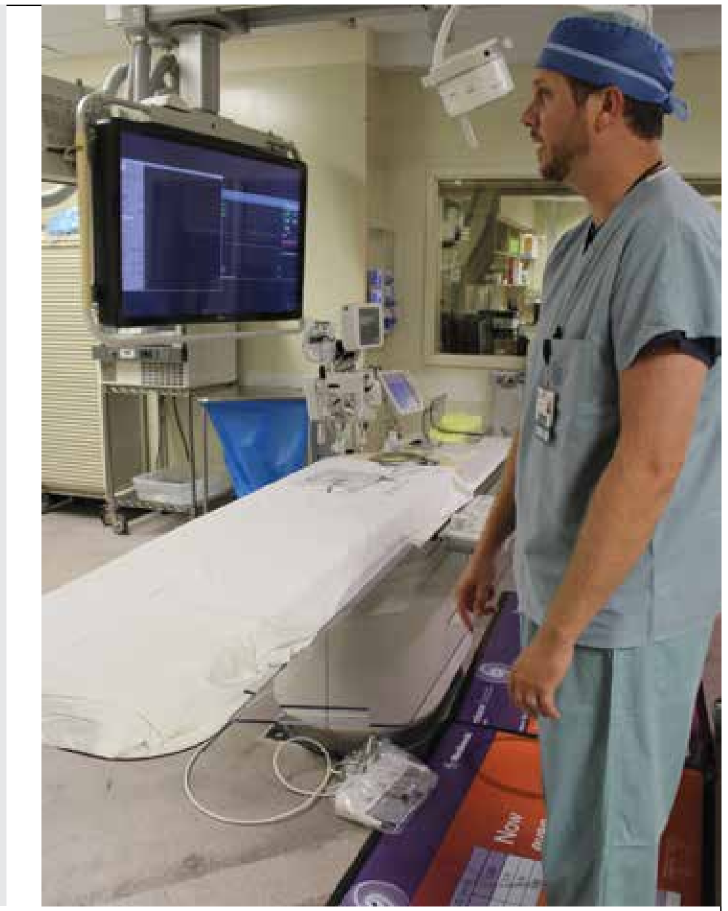

patients are monitored, when a patient suddenly coded.

"The patient was a cardiac surgery patient whose chest needed re-entry immediately. This was before the deployment of Lean training. As a result, nurses made many trips back and forth to ICU in order to get all of the needed supplies to save the patient, " Lee explained. "We saved her, but with leaner processes, our efforts would have been much more efficient and beneficial for the patient and the staff involved. Since that time, a student in John and Susan's class has developed an open-chest cart that contains all of the equipment that is needed in such a case as this."

This is just one of many examples where process improvement was needed before Lean training being implemented throughout the health system. There is now a waiting list to get into the Lean classes, because the program empowers staff and provides resources to remove roadblocks that prevent their teams from delivering the best care possible.

John Moore said, "It works because we don't go into a hospital and try to tell people how to do their jobs. Our goal is to teach people to see wasteful work practices and improve them. If we change the way that they think, they will still be making improvements long after we are gone."

SURROGATE MODELING ACCELERATES ENGINEERING DESIGN RESPONSES

BY DANIELLE HAMILTON | PHOTOGRAPHY GARY R. HAYGOOD | TECHNICAL GRAPHS JONATHAN STOREY

The Institute for Systems Engineering Research (ISER) is working with the Engineer Research Development Center (ERDC) to provide surrogate models to customers as an alternative to the high-fidelity simulations conducted on HPCs (High Performance Computers). The surrogate models, also known as metamodels, serve as lower fidelity substitutes that allow customers to conduct trade-off analyses on their local machines. Additionally, surrogate modeling offers rapid approximations that yield more prompt responses to science and engineering design evaluations.

"ERDC has excellent HPC capabilities that can be used to collect data with high-fidelity simulations, but they have identified a need for surrogates of these high-fidelity models," Jonathan Storey, an ISER research engineer explained. "Specifically, this can be seen in two aspects: First, surrogate models are needed to explore large trade spaces which will help decision-makers in selecting better designs through set-based design. Second, surrogate models are needed so that ERDC can provide usable models back to customers instead of requiring that the models reside on an HPC because of their computational expense."

Equipped with the capacious processors, nodes and disk storage to perform complex simulations on large data sets, HPCs are exceedingly more expensive than their desktop and laptop counterparts. In addition to the costs to procure and maintain HPCs, the duration of its simulations must also be considered. Many simulations can take days, weeks or even months to complete, which is not ideal for meeting customer demands. As researchers continuously strive to improve the fidelity of surrogate models, there are many advantages of sacrificing some of the response-prediction accuracies for reduced computational time.

Storey also detailed that large data sets add greater complexity to constructing the surrogate models. However, he advises that there are ways to take on that issue.

"All of the surrogate modeling techniques that we are working with are well established for smaller datasets, but it can be a challenge to apply these techniques to data that contains billions of observations. That's where the resources at MSU are so critical. MSU's supercomputing resources will allow us to construct not only larger individual models, but also hundreds of smaller models that can be combined using ensemble learning."

A team of engineers, mathematicians and computational scientists collaborate to build the algorithms and methodology required for this project. When describing his overarching goal with his surrogate modeling research, Storey said he endeavors to, "…help decision makers make better design decisions by providing them with a more complete picture of the trade space. To be more specific, to develop a toolset that enables analysts to construct surrogate models using a variety of techniques easily, analyze the models for accuracy, and easily make predictions using the models."

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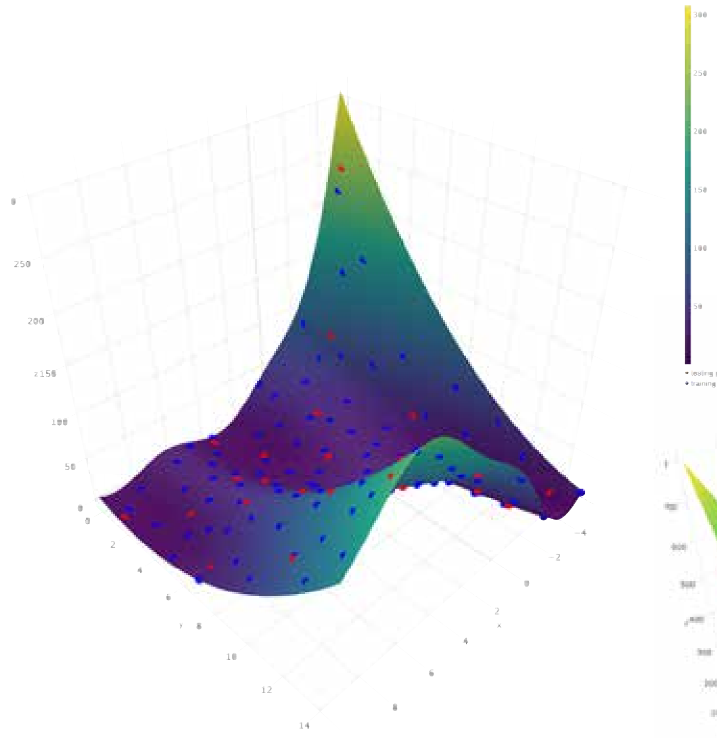

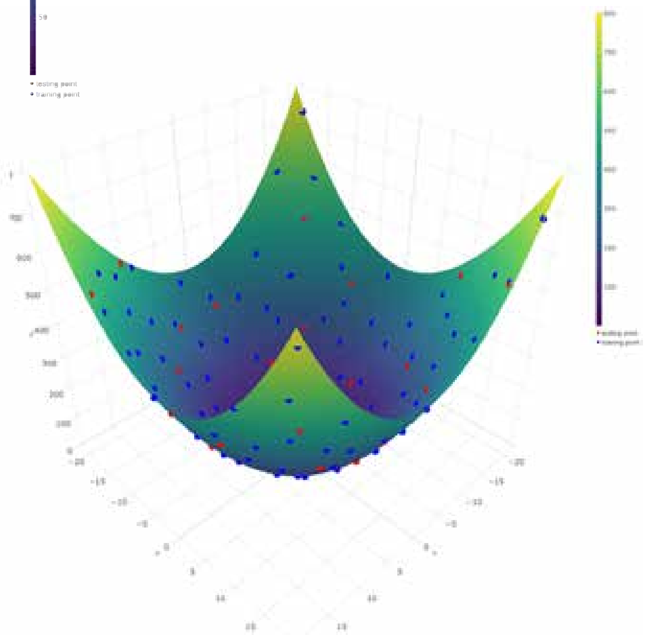

RESEARCHERS UTILIZE VR TO MEET CUSTOMER DEMANDS

BY DANIELLE HAMILTON | PHOTOGRAPHY GARY R. HAYGOOD | VR IMAGES MICHAEL HAMILTON

Virtual reality has taken the world by storm presenting new and innovative methods to mimic real-world scenarios. Along with the mounting usage of smartphones, the progression of computer technology and internet connectivity have been significant contributors to the growing market. In the workplace, VR has become a beneficial training tool due to its ability to create complex, interactive learning environments.

Daniel Carruth, associate director for Human Factors and Advanced Vehicle Systems at CAVS, is working with a manufacturing facility to train employees on conducting hazard assessments. The training was previously rendered through PowerPoint presentations. Carruth explained that while slideshows provided images and demonstrated how to fill out forms, the actual experience of having the employees identify and report hazards was a vital, yet fleeting element of the training. Carruth's team created an immersive VR environment to fill that gap.

Based on the manufacturer's decision to use VR for training, Carruth clarified that "When conducting real-world training, companies want to keep employees and facilities as safe as possible. VR provides the opportunity for workers to go into the environment where we create hazards that normally would be unsafe, which lets them experience identifying the unsafe elements and reporting them."

The CAVS Mixed Reality Lab, located in the Mitchell Memorial Library's Digital Media Center, is another VR project lead by Carruth. Among other equipment, the lab hosts five VR devices: two HTC Vives and three Oculus Rifts. In response to the escalating interest in VR applications, the lab offers cutting-edge learning opportunities for MSU students and faculty.

Similar devices are employed for VR research by Michael Hamilton, an associate director of the Institute for Systems Engineering Research for Data Analytics and Visualization.

"Oculus Rift headsets will grant patrons access to a virtual library where they can investigate book material, metadata and related photos and videos," Hamilton said. "Patrons will also be able to port into the library simultaneously. Likewise, we're looking to implement a means for patrons to request material through the virtual library and have it mailed to them, which would result in cost-savings."

Hamilton is working with the Engineer Research Development Center (ERDC) to build a virtual library that would allow ERDC's employees to peruse the contents of the library without traveling to the facility.

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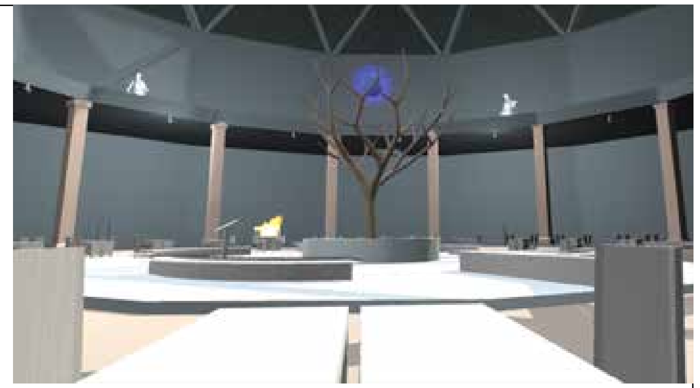
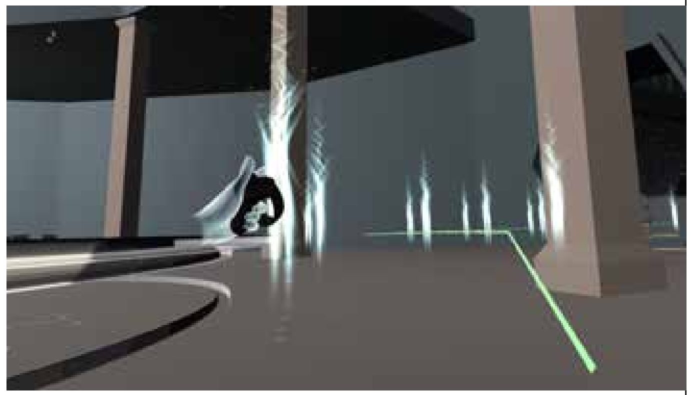
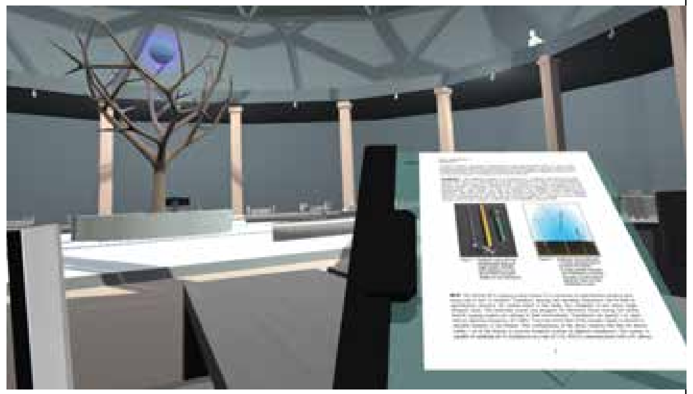
Hamilton also is designing VR environments for ERDC's data analytic projects. His team has created a data visualization module that allows stakeholders to visualize trade space options in a 3D environment by using Oculus Rift and HTC Vive headsets and a Leap Motion Controller.

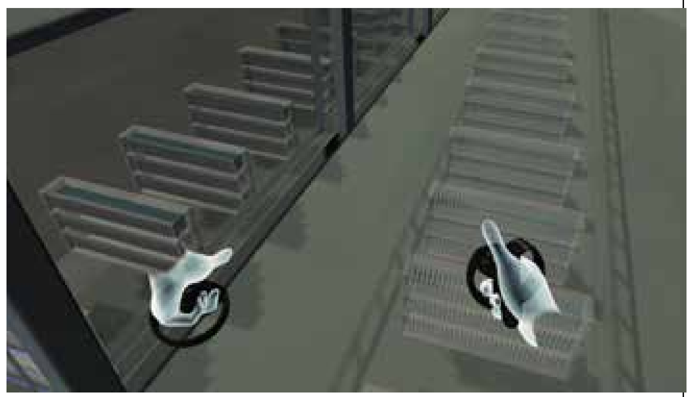
"Ultimately, the objective is to be able to conduct decision-based, trade space analytics completely within the virtual space," Hamilton stated.

Hamilton and Carruth explained that a team of engineers, computer scientists, mathematicians, and digital content artists collaborate to program and design each virtual environment that will be used to train, educate, entertain, and reduce costs across many industries. As technology advances, VR is patently poised to revolutionize the way the world learns and communicates.









EDA GRANT TO HELP MSU'S I2AT CONSTRUCT ADVANCED TECHNOLOGY INSTITUTE

BY HARRIETT LAIRD | RENDERING BARLOW • EDDY • JENKINS ARCHITECTURE

A $1.8 million federal grant announced by Commerce Secretary Wilbur Ross and former U.S. Sen. Thad Cochran (R-Miss.) will help fund a new research facility at Mississippi State University.

The Economic Development Administration award will provide a new building for MSU's Institute for Imaging and Analytical Technologies, also known as I2AT. EDA operates within the U.S. Department of Commerce to promote innovation and competitiveness, preparing American regions for growth and success in the worldwide economy.

To be located in the Thad Cochran Research, Technology and Economic Development Park, I2AT will expand on its already successful mission to provide researchers on campus and in industry access to a wide range of microscopy and microanalysis capabilities. These resources include light, confocal, atomic force and electron, as well as magnetic resonance imaging used in such fields as advanced manufacturing, veterinary medicine, agriculture, cognitive science and medical systems.

David Shaw, MSU vice president for research and economic development, said, "Industries in our state and beyond will benefit greatly from the help this new facility will provide in solving many technically challenging problems they face. The university thanks the EDA, former Sen. Cochran and Commerce Secretary Ross for helping us meet this critical need."

Along with materials testing, I2AT aids quality control departments in mitigating the high cost of equipment ownership and supports research and development of infrastructure.

"Looking ahead, we know that I2AT's research capabilities in this innovative building will enhance our partnerships with industry across the region and, at the same time, enrich the research experiences of the university's faculty and students," Shaw said.

I2AT is part of the organizational structure of MSU's Institute for Computational Research in Engineering and Science or ICRES. ICRES serves as a center of excellence for research, technology and education, which addresses challenges facing the nation's industrial base and utilizes high performance computational resources and innovative analytical tools for modeling, simulation and experimentation.

"This is an exciting investment in scientific research through education and workforce development in Mississippi. I thank Secretary Ross and the Economic Development Administration for recognizing the value in Mississippi State University's efforts to promote innovation and economic growth," Cochran said.

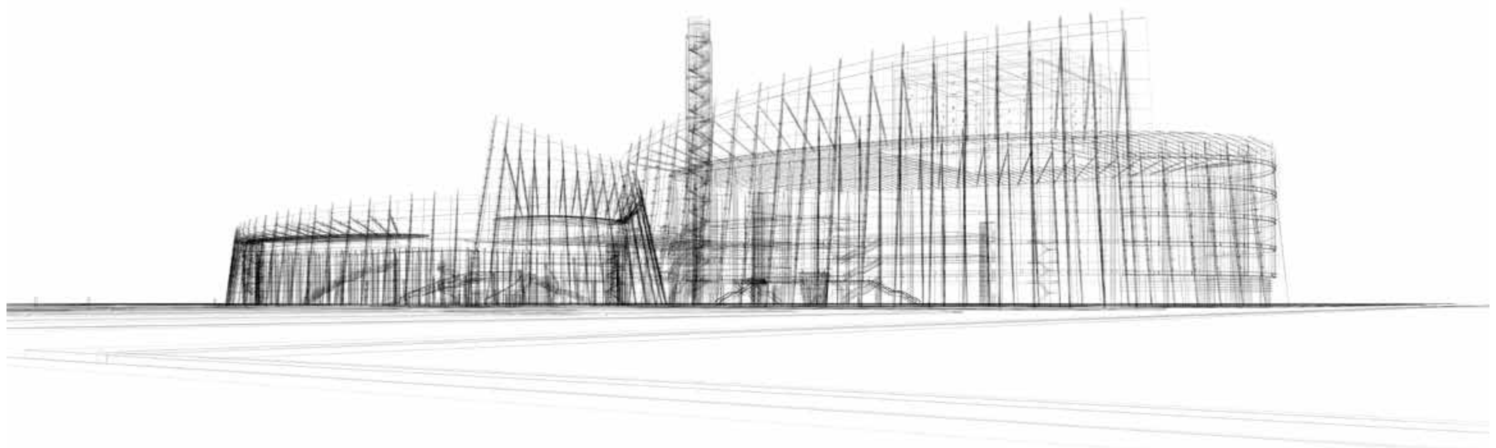
"This project is the product of local leaders' efforts to generate greater economic opportunities in Mississippi," said Commerce Secretary Ross. "The new Analytical Center for Advanced Microscopy and Microanalysis will boost the state's competitiveness by providing regional businesses with the support they need to grow while simultaneously delivering the critical workforce training necessary to help them thrive."

Governor Phil Bryant said, "This will strengthen Mississippi's status as a leader in economic development, and will advance the great work being done at the Thad Cochran, Research, Technology and Economic Development Park, whose namesake has devoted his life to making our state stronger.

"I have shared numerous times with Secretary Ross that Mississippi is well-positioned to compete and win in the global marketplace, and I am grateful to him and the U.S. Economic Development Administration for recognizing that," Bryant said.

The Thad Cochran Research, Technology and Economic Development Park is operated by a university affiliate, the Research and Technology Corporation, a nonprofit company that facilitates relationships between the university, researchers, and public and private partners.

"This is an exciting investment in scientific research through education and workforce development in Mississippi. I thank Secretary Ross and the Economic Development Administration for recognizing the value in Mississippi State University's efforts to promote innovation and economic growth," former Sen. Cochran said.



CREATING ORIGINAL ALGORITHMS FOR CALCULATING APPROXIMATE SOLUTIONS TO COMPLEX PROBLEMS

BY DIANE GODWIN | PHOTOGRAPHY BETH NEWMANN WYNN

CAVS assistant faculty researchers, Doyl Dickel and Sungkwang Mun are working to develop an algorithm that creates a computational model that simulates the interaction between organic and inorganic materials at the atomistic scale level. It is a feat that has not been accomplished by any other computational scientist throughout the world.

A key feature of today's computational models is that they are able to help scientists study biological and non-biological material systems at multiple levels, but the models run separately, they are not programmed to interact due to the distinctively different characteristics in each system. Thus scientists can't predict how inorganic composites and organic molecules interact. For instance, there is the case of how a biological implant made of various polymer and metallic materials would connect with the organic cells in the body.

"Our goal is to develop a universal formalism to create a computer simulation that will one day improve the treatment of dangerous reactions to medical implants. Giving the researchers the ability to combine and witness a variety of composite systems with all the atoms connecting in one simulation," Dickel said. "They will see the titanium plate, the polyethylene that is sort of holding it in place, the organic cells and fibers that are growing onto it and they will see how it all works together and exists as one coherent computational simulation."

The computational capabilities at Mississippi State's High Performance Computing Collaboratory have vastly expanded, which enables Dickel and Mun to develop new and sophisticated mathematical formulas that can reveal the nature of foreign body responses.

"We are using the Modified Embedded Atom Method that is used to simulate metallic systems as a base model equation to create and merge with our organic materials method," Mun explained. "We are trying to provide the calculation software as well as the development kit for their own research problem."

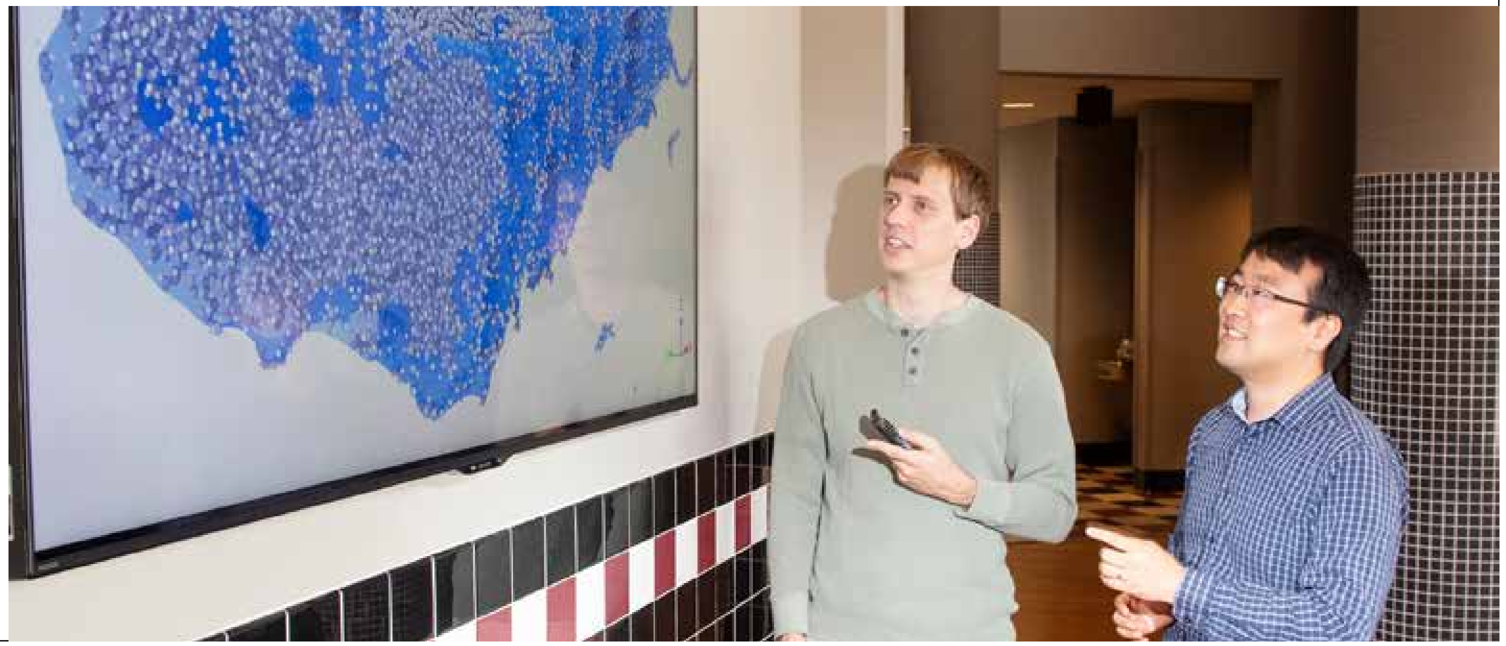
> "Our goal is to develop a universal formalism to create a computer simulation that will one day improve the treatment of dangerous reactions to medical implants. Giving the researchers the ability to combine and witness a variety of composite systems with all the atoms connecting in one simulaton," Dickel said.

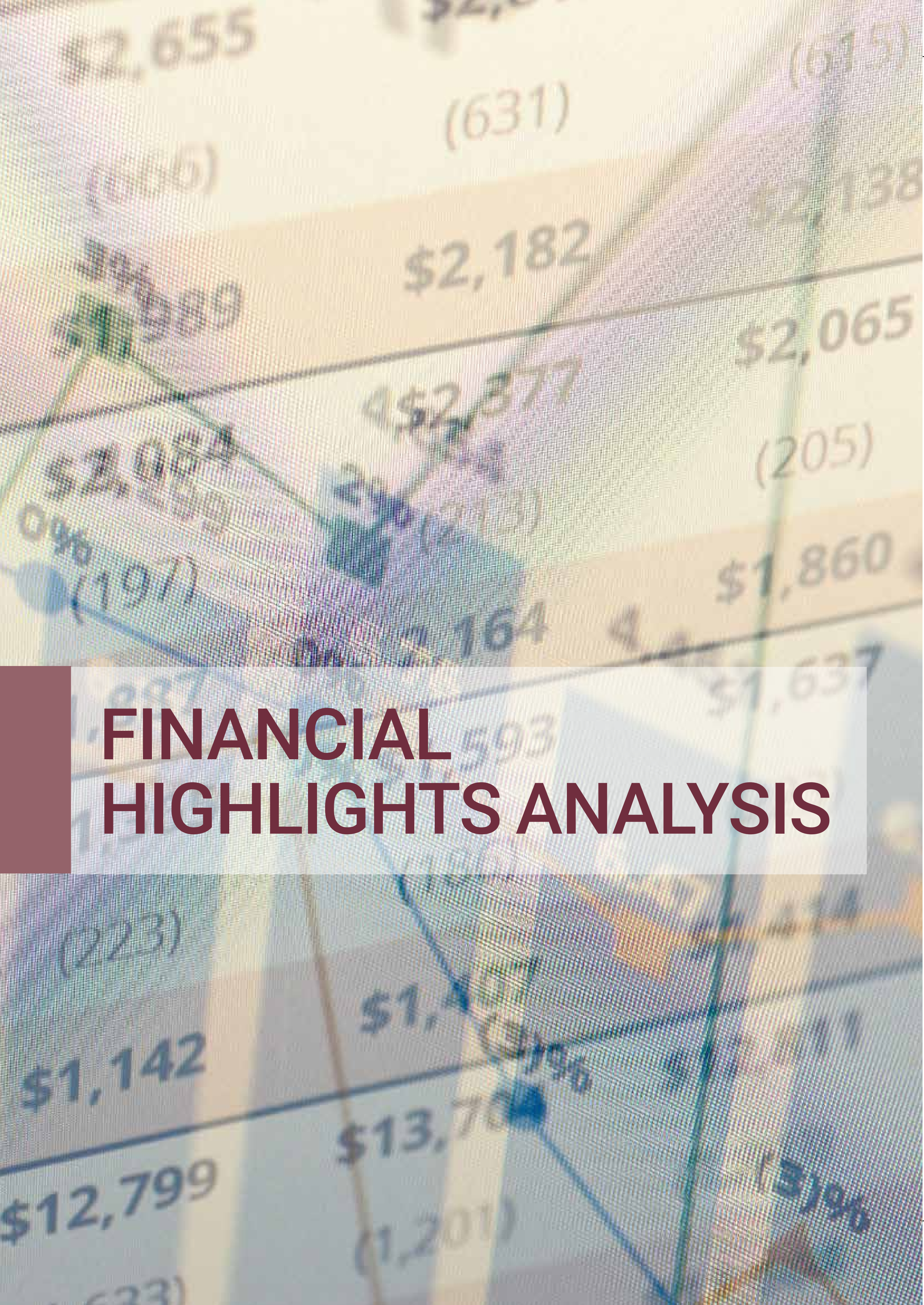
The MEAM formalism, developed by Michael Baskes, a Mississippi State research professor, has become very popular for the metallic system since its initial launch years ago. Mun and Dickel are working to extend this method to include polymer and organic material as well, which requires modifications to the original equation to distinguish between the different compositions of the metal polymer and organic systems.

"Our goal is that researchers will be able to create their own recipes and run their own simulated experimentations to create and test new products as a result of using our universal formalism," Mun said.

The idea with simulation is computational models can sample the same 10,000 things in the 10th of the time for a thousandth of the cost and has the ability to reveal the final five simulations that should produce the results expected when actually building the experimental tests.

Dickel explained, "When it is at its most optimal, computational simulation is not cutting just half the cost and time, it is 10 to hundreds of thousands of times cheaper if you can trust the model. That is what we are doing is making sure that the things we predict reflect the true underlying physics."





FINANCIAL HIGHLIGHTS ANALYSIS

CAVS-R • CAVS-E • ISER • I2AT

TOTAL CAVS PROPOSALS 2016-2018

2016	$42,929,941
2017	$129,658,763
2018	$29,803,120

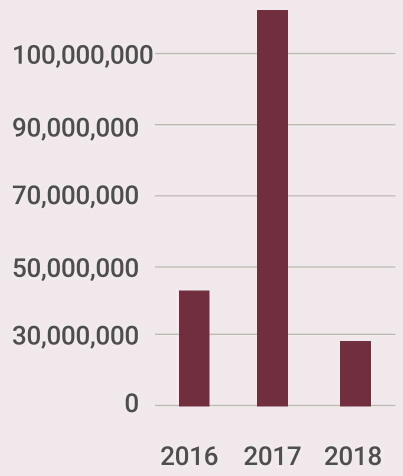
TOTAL CAVS AWARDS 2016-2018

2016	$16,830,669
2017	$19,613,004
2018	$25,448,355

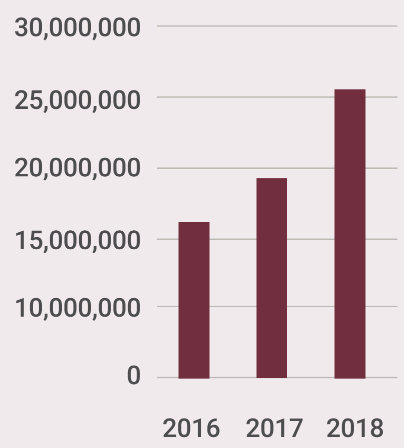
TOTAL CAVS RESEARCH EXPENDITURES 2016-2018

2016	$20,410,848
2017	$24,891,284
2018	$25,802,557

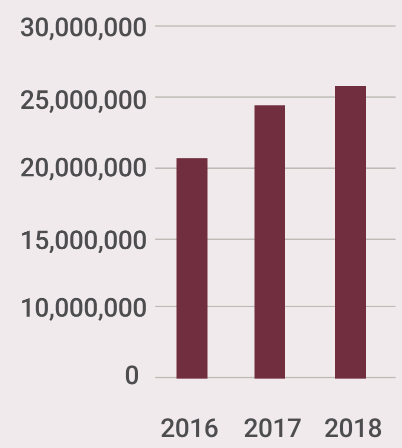
TOTAL CAVS PROPOSALS 2016 - 2018



TOTAL CAVS AWARDS 2016- 2018



TOTAL CAVS RESEARCH EXPENDITURES 2016 - 2018



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