CAVS
ANNUAL REPORT

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WELCOME
TO THE 2017 CAVS ANNUAL REPORT.

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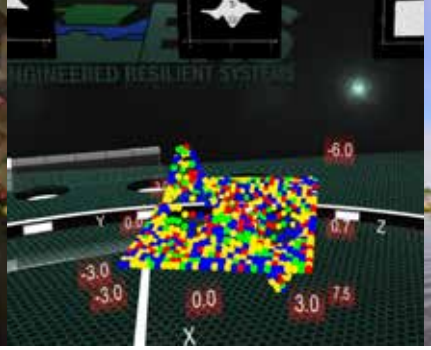


TABLE OF CONTENTS

"We're at a great time in terms of advancing technologies," CAVS Executive Director Clay Walden said. "There's a tremendous amount of interest in the work we're doing at CAVS. Our researchers have very diverse backgrounds, which enables us to forge relationships with other universities to help meet companies' needs," Walden said. "It allows us to work as a team, which is the real power of entire CAVS consortium of partners."

DIRECTOR'S MESSAGE

Welcome to the Center for Advanced Vehicular Systems, one of the premier university automotive research centers in the world. I am proud to lead a group of over 300 staff and researchers in addressing some of the world's most pressing challenges. Together with our government and industry partners, we are developing solutions to enhance transportation safety, improve vehicle efficiency, increase the productivity of our workforce, and enable a brighter future.

CAVS is a strong partner at the state, national and international level; with academic partnerships in place across multiple continents, we form collaborations which help us work smarter, faster and more efficiently. Through the Institute for Systems Engineering Research (ISER), co-located with the U.S. Army's Engineering Research and Development Center in Vicksburg, Mississippi, CAVS serves our national interests with expertise in systems engineering and big data management. CAVS Extension arm has a 15-year history of enhancing our state's manufacturing operations and aiding economic development, and the Institute for Imaging and Analytical Technologies (I2AT) provides cutting-edge services to industry across the region.

I encourage you to read further, hearing our story and learning more about the exciting things that we are doing at CAVS and at Mississippi State University.

Go Dawgs!
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.

2016: $16,830,669

2015: $12,739,594

2017

TOTAL AWARDS 40%

$19,613,004

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.

‘CAR OF THE FUTURE™’ PROVES THAT MSU GRADUATES ARE CAREER READY

For more information on CAVS, please visit https://www.cavs.msstate.edu/

Amid vast and exciting innovations within the automotive industry, the Center for Advanced Vehicular Systems at Mississippi State University has created a hybrid ‘Car of the Future™’ built with industry-leading artificial intelligence capabilities while also giving the workforce an influx of graduates equipped with new and fresh ideas.

Dubbed the ‘Car-of-the-Future,’ it boasts model predictive control, an AI-based recognition program capable of monitoring and predicting driving patterns in order to optimize use of the battery and engine. This technology is industry-leading as automotive producers expand AI-based systems to improve user comfort and safety.

The CAVS vehicle arrives ahead of the AI-application curve. According to IHS Markit, a London-based information and analysis company, only 8 percent of new cars in 2015 had AI systems installed, and these mainly focused on speech recognition. However by 2023, sixty-nine percent of passenger vehicles will have AI handling much broader responsibilities. CAVS has not only produced the Car-of-the-Future in name but overall capability and concept.

Fuel and energy efficient, the car can run 100 miles on the equivalent of a single gallon of gas and showcases a custom-designed cast magnesium sub-frame that is 40 percent lighter than stock subframes. Cars based on CAVS research can save users money on fuel and lessen the negative impact on the environment.

Despite the vehicle’s impressive capabilities, Matthew Doude, CAVS associate director, focuses the program on preparing students

to enter the workforce ready to contribute. "CAVS is a very diverse and capable engineering center on par with anyone in the world. Our goals are to prepare and develop students for careers in the automotive industry, create intellectual property and secure patents for the university, and increase the profile of what Mississippi State engineers can accomplish."

The program has graduated 30 students who worked on the project. In addition, it has cultivated various relationships throughout the automotive industry that could help these and future students begin their careers.

CAVS utilizes high-performance computational resources and state-of-the-art analytical tools for modeling, simulation and experimentation within 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.

"CAVS is a very diverse and capable engineering center on par with anyone in the world. Our goals are to prepare and develop students for careers in the automotive industry, create intellectual property and secure patents for the university, and increase the profile of what Mississippi State engineers can accomplish."

RESEARCHERS ANALYZE DATA THAT REALLY COUNTS

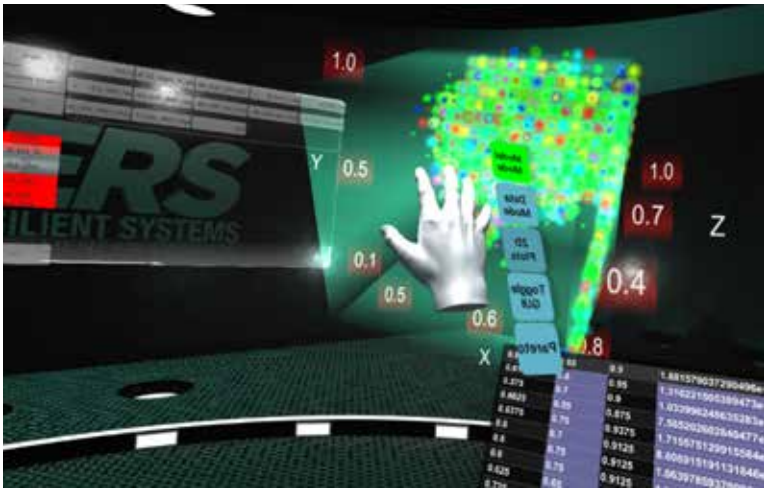
Michael Hamilton, associate director of ISER

As tensions rise from shifting international politics, how proactive America is in keeping troops and civilians safe is of acute importance. The solution lies within the vast amount of digital information the military collects. For instance, the armed forces are generating colossal amounts of data ranging from videos taken by drones, to text files, to satellite imagery, not to mention the tremendous quantities of unstructured data from media reports, blog posts, and social media that needs to be analyzed to try to anticipate events and plan interventions.

"Big Data' analytics are a powerful tool for the armed forces to counter external threats, but it is growing to overwhelming levels. The U.S. Department of Defense question becomes how to clean, organize and assess the data to find the best and most reliable information to determine what works and what doesn't work. This is where the job of T.C. Falls, associate director of the Institute for Systems Engineering Research, becomes of utmost importance. Falls' task is to render the most useful and reliable data.

"This information is disparate data, meaning the files are not saved in a uniform format. In fact, a lot of the data files are not

"Big data visualization allows us to see patterns in data that we could never see before," Hamilton explained. *"It helps us find the dots of information that was previously unknown and then connects those dots by finding associations among different people, activities or materials, and then it shows us what we don't know by revealing the unknown patterns and facts."*



readable across all systems, and some may be corrupt. The challenge is how to design software that can analyze the files and make them uniform and compatible across all systems," Falls explained. "We are working to write software that processes, assimilates and distributes huge amounts of data most efficiently and effectively."

Big data have millions of variables that require high-performance computers that can run calculations at that volume, but many who need to use the data do not have access to supercomputers. Also, transfer speeds are slow compared with the information in transit. At times, transferring data requires days or even weeks. Storage needs also require a petaflop of hard drive space which eliminates the use of personal computers.

While Falls' team is designing sophisticated software systems that will analyze, clean, reformat, manage and distribute data, the next step is how to interpret data so it is easily understood and can provide important and accurate insights to DoD decision makers. That is the specialization of Michael Hamilton, an associate director of ISER. Hamilton writes software that makes graphic visualizations of data that enables DoD decision makers to grasp difficult concepts quickly.

"Big data visualization allows us to see patterns in data that we could never see before," Hamilton explained. "It helps us find the dots of information that was previously unknown and then connects those dots by finding associations among different people, activities or materials, and then it shows us what we don't know by revealing the unknown patterns and facts."

Hamilton and Falls said developing models for the DoD means designing software that continually keeps data up-to-date and also creating sophisticated security code to prevent loss of information.

The expertise to accomplish this work requires a diverse scientific knowledge base. The members of the research team come from Mississippi State's Center for Advanced Vehicular Systems, the industrial and system engineering, computer science and engineering, mathematics and statistics, and electrical engineering departments.Their collaboration will help the DoD process information about America's troops, equipment, training, installations, and force readiness with the hopes of improving the efficiency, effectiveness and accuracy of information. In the big picture of big data analytics and big data visualization, this enables the military to protect freedom and save lives.

3D LASER SCANNING TECHNOLOGY INCREASES PRODUCTIVITY AND OFFERS FASTER SOLUTIONS FOR MANUFACTURERS

The Center for Advanced Vehicular Systems Extension is offering Mississippi manufacturers a competitive edge by using 3D laser scanning technology. This powerful tool provides images that can be analyzed virtually to help companies make faster and more well-informed decisions to optimize work processes and improve building and equipment utilization of existing facilities, as well as to evaluate potential site locations.

For a year-and-a-half, CAVS-E has utilized a FARO Focus 3D Room Scanner for over a dozen companies' facilities, ranging in size from 4,000 to over 200,000 square feet. Once companies see the benefits of utilizing this technology, they often expand initial requests for scanning from one building to all of their facilities.

Physical information concerning industrial facilities, infrastructure, and utilities is captured in digital format within minutes. Millions of data points are collected and converted into point clouds, providing a 3D digital recording of complex geometries and structures, easily accessed for use by manufacturers, suppliers and CAVS-E.

"The benefit to our clients is that it enhances our ability to provide a master plan that supports growth and minimizes potential issues," Glenn Dennis, director of the Center for Advanced Vehicular Systems Extension, located in Canton, Mississippi, explained.

"The benefit to our clients is that it enhances our ability to provide a master plan that supports growth and minimizes potential issues," Glenn Dennis, director of the Center for Advanced Vehicular Systems Extension, located in Canton, Mississippi, explained.

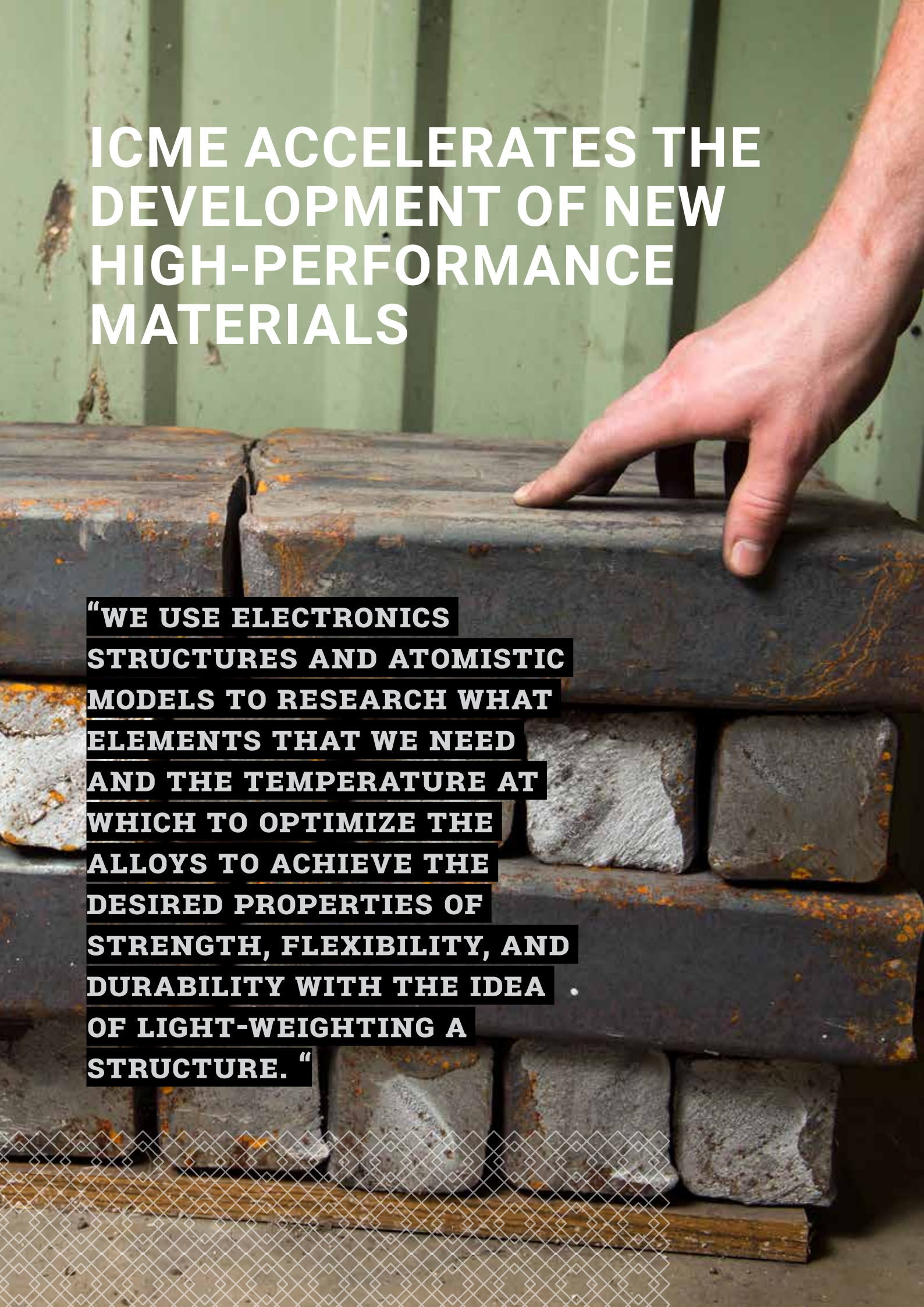
Jonathan Curtis, a project engineer with CAVS-E and a 3D laser scanning specialist, said, "We can now collect the majority of the information needed for an existing facility in one visit, which would have previously taken several visits over a much longer period of time."

From the 3D data set an AutoCAD layout is created much faster than could be accomplished with a tape measure. From the digital images, other elements such as processing equipment, material handling systems and utilities can be inserted. Floor plans, profiles, elevations, and 3D models can be efficiently generated.

In two recent projects, scanning multiple buildings in manufacturing complexes, including seven buildings in one company and 10 in another, provided layouts for existing buildings, so that CAVS-E could analyze the as-is condition and recommend product flow improvements. Both projects resulted in the design of new consolidated workspace buildings with room for future growth.

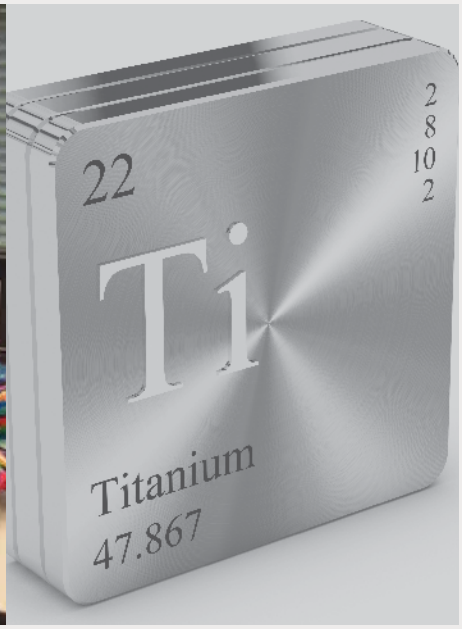
Collaborating online with an Alabama builder and a manufacturer in North Mississippi, CAVS-E engineers, located in Canton, Mississippi, scan facility results were used to locate new equipment and design a bridge crane system. This capability facilitated the determination of dimensional details for crane supports, allowing for much quicker design and installation, thereby avoiding unnecessary delays in the manufacturing processes.

In a short period of time, companies have documented savings of over $4 million and more than 100 jobs created or retained due to projects using this technology, which is sure to play a significant role in the services that CAVS Extension provides for many years to come.



ICME ACCELERATES THE DEVELOPMENT OF NEW HIGH-PERFORMANCE MATERIALS

“WE USE ELECTRONICS STRUCTURES AND ATOMISTIC MODELS TO RESEARCH WHAT ELEMENTS THAT WE NEED AND THE TEMPERATURE AT WHICH TO OPTIMIZE THE ALLOYS TO ACHIEVE THE DESIRED PROPERTIES OF STRENGTH, FLEXIBILITY, AND DURABILITY WITH THE IDEA OF LIGHT-WEIGHTING A STRUCTURE. “



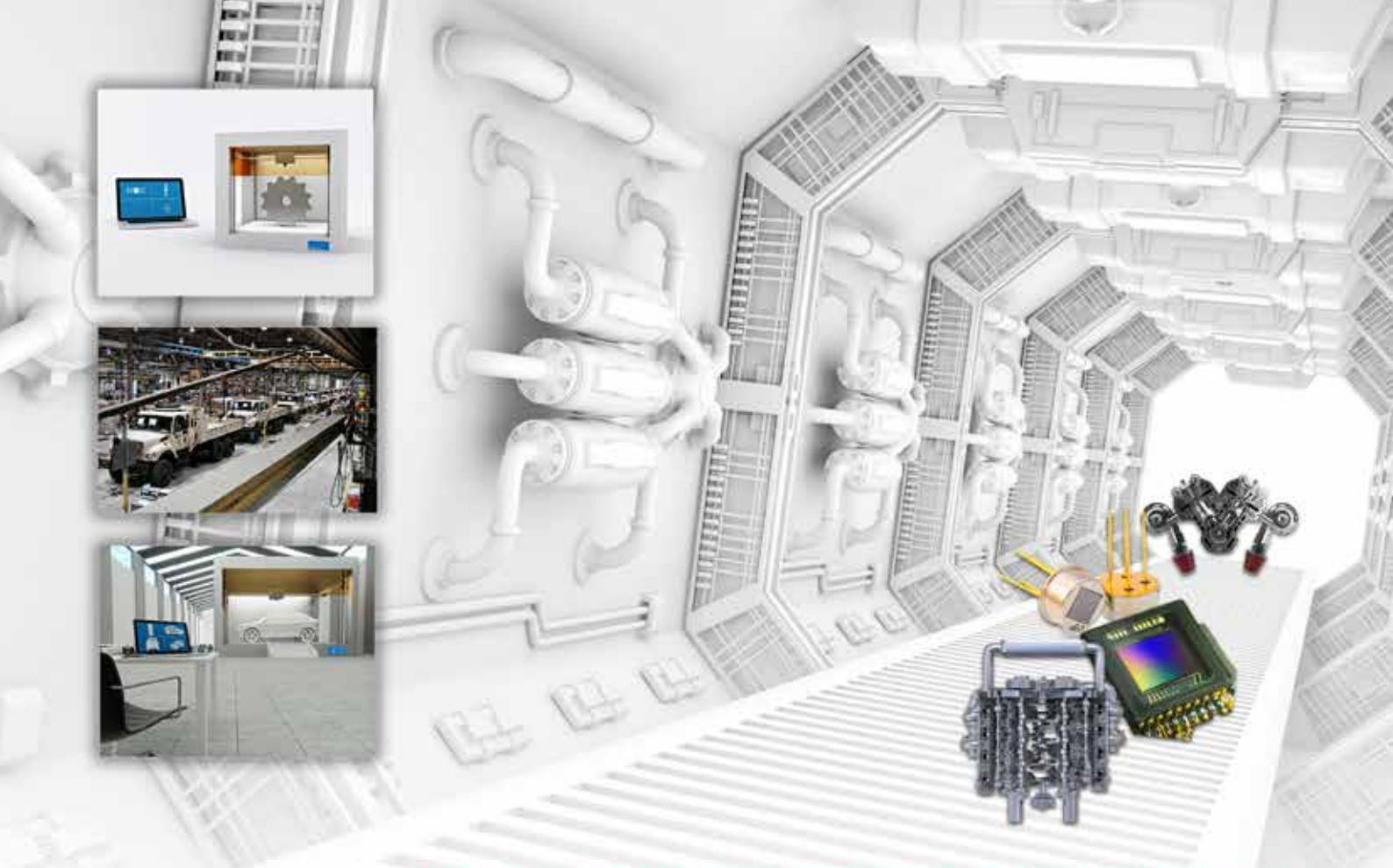
The CAVS Integrated Computational Materials Engineering capability complements the DoD's national research laboratories in the US and is the only one of its kind in the Southeast. As such, Mississippi State's ICME ingenuity has created long-term research collaborations with industry and government entities.

For instance, the Army Research Laboratory (ARL) and Mississippi's Engineering Research and Development Center (ERDC) are partnering with the CAVS' ICME team to research the nature of steel and cement to develop new high-strength and lightweight alloys for a range of applications. Mark Horstemeyer, a Giles Distinguished MSU professor and CAVS endowed chair of mechanical engineering, is leading a team of computational researchers to precisely model and simulate stress-strain behaviors, fatigue strengths, as well as testing a variety of chemical mixtures for steel and titanium alloys to prevent creep, corrosion and cracks.

"I call the process 'from atoms to autos,' because we're adding and testing different chemical properties to our alloy recipe to engineer a material that is 25 percent lighter in weight and stronger than the current metal products on the market," Horstemeyer said. "Computer models that can better predict how a design will perform will let engineers do less "making and breaking" of multiple test parts before they know the design is right for a specific critical component."

ICME modeling and simulation allows Horstemeyer's group to tailor new alloys at the atomic level to achieve the level of desired properties that can help improve carbon emission rates, increase fuel economy and boost safety features. Developing high-efficient and durable vehicles is of particular interest to the auto industry and armed forces. The materials can be used to create super-strong armor for military vehicles, and the materials can help vehicles meet stricter fuel consumption standards by shedding hundreds of pounds. By 2025, the auto industry hopes researchers can speed past the technological roadblocks because automobiles are required to meet a per gallon standard of 54.5 miles per gallon.

"There is an enormous number of perturbations we can try to make alloys that are associated with the different elements of the Periodic Table," Horstemeyer said. "We use electronics' structures and atomistic models to research what elements that we need and the temperature at which to optimize the alloys to achieve the desired properties of strength, flexibility, and durability with the idea of light-weighting a structure. If we can discover those secrets, along with optimizing the manufacturing performance, then the next generation alloys can be created and used for a wide range of applications."



IMAGINE THE FUTURE OF MANUFACTURING. WE ARE.

The Center for Advanced Vehicular Systems-Research at Mississippi State is a global leader for the development of engineering solutions that expand and enhance the design, technology, production, and infrastructure necessary for sustainable mobility.

CAVS Extension is focused on delivering solutions to industry, and it possesses a strong track record of results working with teams across a wide variety of industries.

The Institute for Systems Engineering Research is a collaborative effort between the U.S. Army Engineer Research and Development Center and Mississippi State. The goal is to mitigate risk, reduce cost and improve efficiency in Department of Defense acquisition programs, and serve as an additional asset for the state's industrial base.

The Institute for Imaging and Analytical Technologies, (I²AT) is a University-wide institute that provides multi-disciplinary research, education and outreach in the life and materials sciences. I²AT houses state-of-the-art research tecnology instrumentation that is available to faculty, staff, students and exteranl users.

Mississippi State works for Mississippi, and we are ready to work with you. To learn more, please contact Dr. Clay Walden at walden@cavs.msstate.edu (662) 325-5431 or visit www.icres.msstate.edu or www.cavs.msstate.edu.

WE RING TRUE

#WERINGTRUE

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IMAGINE PRODUCING LIGHT-WEIGHT HIGH STRENGTH STEELS. WE ARE.

At the Center for Advanced Vehicular Systems' Steel Research Center researchers are exploring new ways to make steel stronger without sacrificing formability. The next generation advanced high strength steels being developed at Mississippi State provide that unique combination.

At the MSU small-scale manufacturing facility, researchers are designing, fabricating, and characterizing steel alloys to simulate industrial production lines. In addition, researchers are modeling and optimizing the alloy design and manufacturing processes as their discoveries grow from ideas in the lab to products in the marketplace. They expect the research to lead to new design methodologies that industry can use to manufacture better steels.

To learn more, please contact Dr. Clay Walden at walden@cavs.msstate.edu, 662.325.5431 or visit www.-cavs.msstate.edu.

WE RING TRUE

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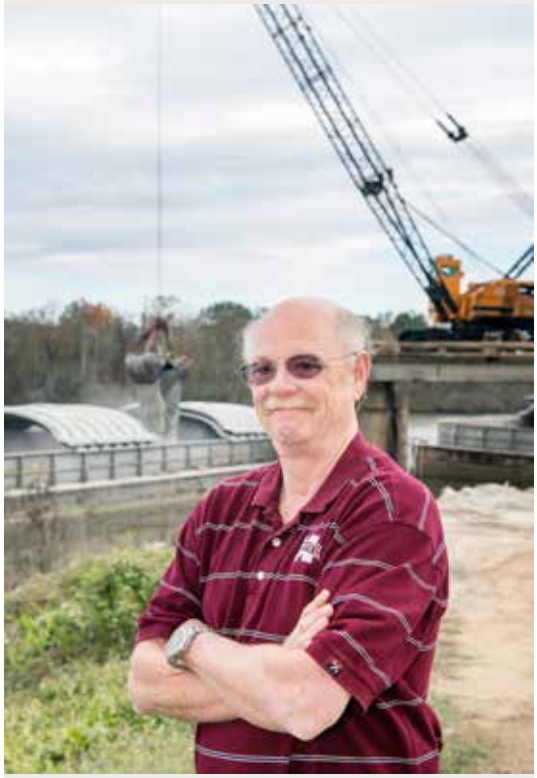
STREAMLINING AND STRENGTHENING THE INFRASTRUCTURE OF MISSISSIPPI'S PORTS

"I want MDOT and the different ports around the state to work as a team."



For more information about CAVS-E, please visit https://www.cavse.msstate.edu/

The ports that service Mississippi's inland waterways provide significant commercial resources to the state. Ports alone provide over 125,000 jobs while waterway traffic generates nearly $5.4 billion of income and approximately $17 billion in gross state product annually. This means the port system supports 16 percent of the state's economy and one out of every 10 jobs. With such significant economic contributions, a well-maintained and robust infrastructure surrounding the state's 16 ports is vital.

Currently, each port operates according to individual strategic plans made internally. This is inefficient for statewide growth and infrastructure because it allows port officials to report different metrics and meet uneven standards, thus eliminating comparisons on efficiency. Mississippi State University researchers in conjunction with the Mississippi Department of Transportation (MDOT) are working on a project that will provide a systematic approach and statewide baseline for Mississippi's inland waterways.

The overall goal of the project is to enhance the efficiency of Mississippi's ports and the infrastructure of their cities. These improvements make the state more competitive and attractive to businesses and industries that are looking for viable markets. Mississippi State researchers will generate simulation studies and graphs based on the historical data of freight movements and how long it takes each port to handle the cargo. Port layout and the tools used to load and unload barges also are factors. With this data, researchers will be able to set performance benchmarks, determine the most efficient practices for different situations, and create guidelines for what kind of tools are needed. Port directors and MDOT can then judge efficiency using the same metrics allowing for more well-informed decisions on funding and resource management. More efficient ports mean more profit opportunities for the state.

Before the researchers, employees, and students from the Center of Advanced Vehicular Systems-Extension, the Institute for Systems Engineering Research, and the Department of Civil and Industrial Systems Engineering

can do their jobs; they need empirical data from the ports. Steve Puryear, the principal investigator, and manager of the project as well as a senior research associate with CAVS-E in Canton, Mississippi, gathers the data by traveling throughout the state and interviewing port officials about historical freight movements, port capabilities and storage facilities.

This project is not without its challenges. According to Puryear, the critical problem preventing the project from progressing is the companies' interest in protecting information. The state of Mississippi does not own all 16 ports. Instead, some are operated by private businesses and cities/counties. Privately operated ports are not required to report the amount of freight coming in or out of their facilities because that information is considered proprietary to the parties involved. MDOT cannot force them to share since that violates privacy laws. Although some information is available, such as what type of storage these ports have available, the amount and category of freight moved at any given time is unknown.

Without access to this data, researchers cannot make simulations or graphs that factor in all necessary information, making a statewide baseline near impossible to achieve. To overcome the challenge, Puryear establishes good relations with port directors so he can show them the benefits of having a statewide system. If that fails, he observes waterway traffic moving into and out of ports to determine the type of hauled freight.

When describing his ultimate goal with this project, Puryear said he wants everyone in the state to work toward a common goal: "I want MDOT and the different ports around the state to work as a team. People running ports complain about lack of funding, but from MDOT's side, lack of data prevents them from justifying petitioning the federal government for funding and grants. What we are trying to do is bridge the gaps in conversation so that everyone can benefit."

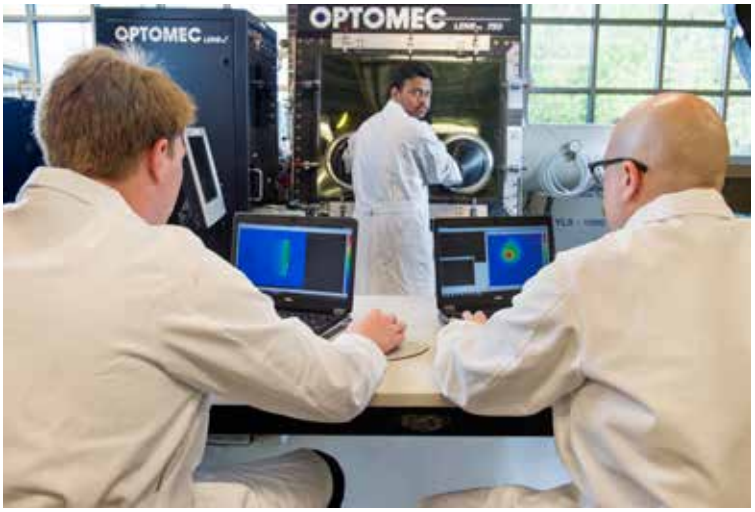
CAVS-R OFFERS FULL RANGE OF RESEARCH EXPERTISE AND EQUIPMENT FOR ADDITIVE MANUFACTURING

From the laboratory to fabricating complicated, high risk parts describes the work CAVS researchers are conducting to help an emerging technology move from the laboratory to a production environment. Additive manufacturing (AM), more commonly known as 3-D printing, is mainly used to create three-dimensional prototypes from a digital blue print for engineers and designers.

AM has the potential to propel the United States to a position of worldwide leadership in the production and repair of complex/precious parts, which will impact automotive, aerospace, biomedical and other major industries. With over 3,500 patents related to AM, it has received considerable attention in the past few decades from both the commercial and academic sectors. AM has made the headlines of mainstream and online media, and its relative simplicity in generating three-dimensional, polymeric prototypes on the desktop, has allowed for a large cross section of society to become enthused with '3D printing.

"The biggest question with additive manufacturing technology now is how to apply the process to produce components that can be certified for use in high risk

"The biggest question with additive manufacturing technology now is how to apply the process to produce components that can be certified for use in high risk applications like the aerospace and biomedical industries."

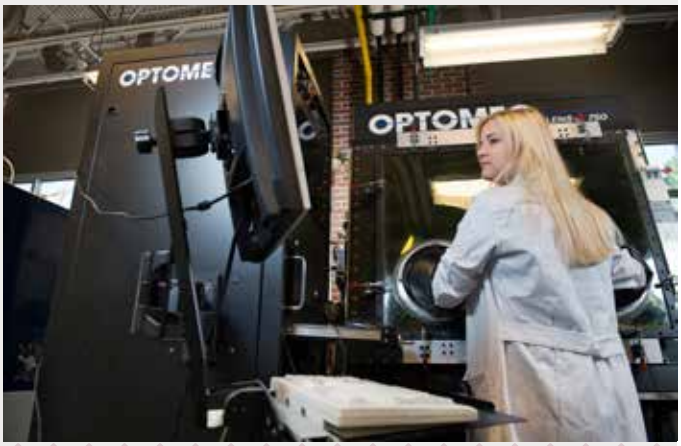


applications like the aerospace and biomedical industries," Linkan Bian, assistant professor of industrial engineering explained. "Our researchers are developing methods to optimize the AM process and identify areas of concern during a build so the component properties are well understood before putting the part to use."

At CAVS, researchers are using our unique resources to ensure research success at an accelerated pace, including uniquely-equipped AM machines and mechanical characterization equipment. Researchers also have access to analytical equipment in the Institute for Imaging and Analytical Technologies' full-service machine shop, and the high-performance computing network/cluster at the High Performance Computing Collaboratory.

The Additive Manufacturing Laboratory consists of a Laser Engineered Net Shaping (LENS®) machine, as well as a Selective Laser Melting (SLM) machine. CAVS is one of only a few universities in the nation with a LENS equipped with a Stratonics thermal imaging and control system. This system allows for the real-time collection of infrared images during additive manufacturing and can be utilized for in-situ monitoring and control of part quality.

According to Haley Doude, research engineer at CAVS, "Our multidisciplinary teams provide us with expertise in material science, process control/optimization, solidification, and aerospace and biomedical applications. With that diversity, we are able to approach additive manufacturing from multiple viewpoints to provide a better understanding of the process. Our end goal is to develop an AM procedure that is ultimately a 'hands-off' process that successfully produces high quality, certifiable materials."



I2AT REVEALS THE TRUE RESEARCH STORY OF WHAT HIDES BENEATH

Exploring beyond what the human eye can see is a critical area of work for CAVS, and the Institute for Imaging and Analytical Technologies (I²AT) provides the capability that enables Mississippi State University researchers to produce world-class research results. I2AT is a multidisciplinary research, education and outreach institute focused on supporting the life and materials sciences by providing primary research instrumentation that is available to faculty, staff, students and external users.

For scientists and engineers at CAVS-R and CAVS-E, equipment such as electron microscopes, X-ray diffraction and X-ray computed tomography is crucial to understanding material behavior in various intellectual research projects. In addition, a range of diverse industries uses I2AT technology to support commercial enterprise projects. For instance, a local steel mill uses X-ray diffraction to investigate the structure of mill scale. Not to mention that auto manufacturers located within the region also use the scanning electron to understand the microstructure of a material of interest. It's also important to point out that researchers and industries use X-ray CT to determine the porosity of additively manufactured components.

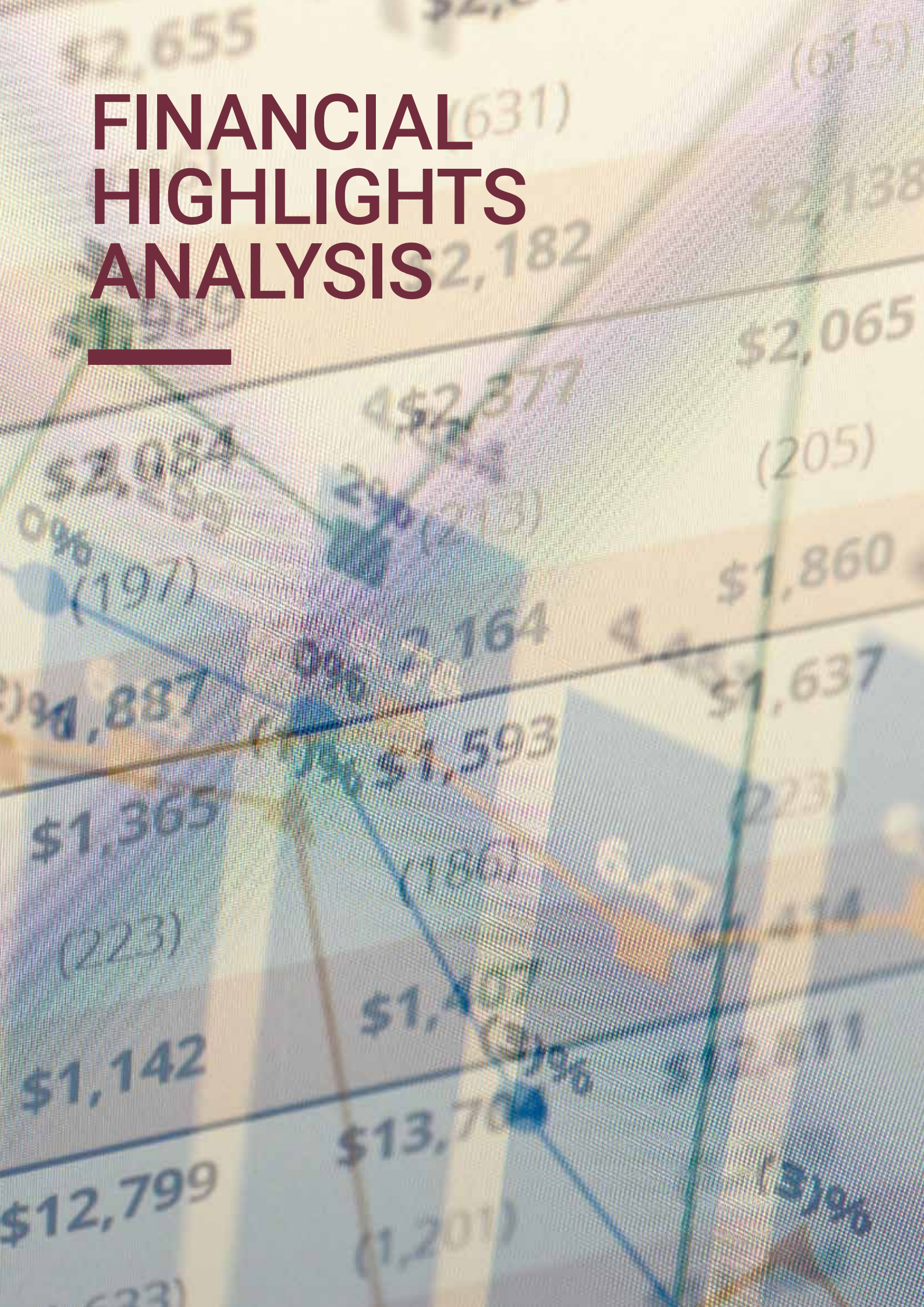
"Few institutions have the extensive analyt-

"Few institutions have the extensive analytical resources that Mississippi State maintains and operates. This high-tech, high-resolution equipment is essential for both life science and materials' researchers to explore and understand the intrinsic composition or the nature of the samples."

ical resources that Mississippi State maintains and operates. This high-tech, high-resolution equipment is essential for both life science and materials' researchers to explore and understand the intrinsic composition or the nature of the samples," Zach Rowland, director of I2AT, explained. "Mississippi State's faculty, researchers, students and industrial partners have access to advanced tools and expertise that can provide opportunities for insight and understanding to further successful outcomes from their investigations."

Instrumentation includes technologies for high-resolution microscopy (light, confocal, atomic force and electron) along with precision microanalysis (e.g., X-ray diffraction) applications. For the medical and health care areas, the MRI, 64 slice CT and 4D ultrasound are used in clinical services, areas of veterinary medicine, cognitive science and medical research. These technologies provide state-of-the-art analytical capabilities for both education and industrial applications.

FINANCIAL HIGHLIGHTS ANALYSIS



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TOTAL CAVS PROPOSALS 2015 - 2017

2015	65,645,069
2016	44,886,544
2017	131,247,663

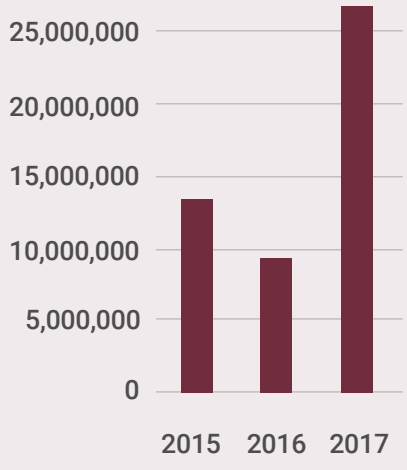
TOTAL CAVS AWARDS 2015 - 2017

2015	12,878,849
2016	16,847,478
2017	19,613,003

TOTAL CAVS RESEARCH EXPENDITURES 2015 - 2017

2015	14,009,076
2016	16,594,741
2017	20,561,084

TOTAL CAVS PROPOSALS 2015 - 2017



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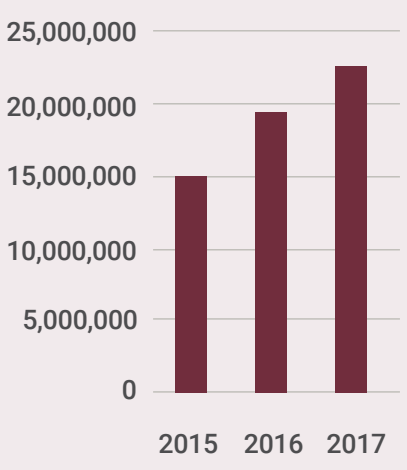

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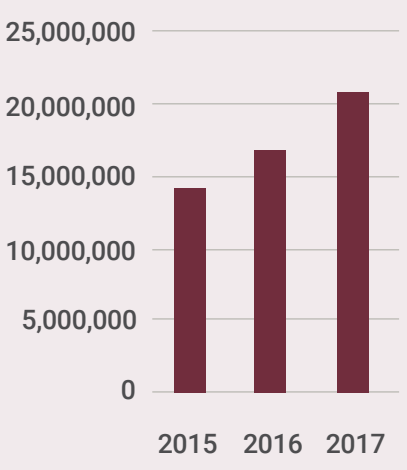

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