



CLEMSON UNIVERSITY INTERNATIONAL CENTER FOR AUTOMOTIVE RESEARCH

2014 ANNUAL REPORT



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INTRODUCTION

The vision and mission of CU-ICAR have always included a targeted focus on building a globally renowned center for automotive engineering. Today we see indicators that the international reach of CU-ICAR is stronger than ever.

In each and every element and facet of CU-ICAR today, the international characteristics shine through (see the globe icon in each of the four sections of the report.) In looking at the international makeup of the student population in the Automotive Engineering Department, with representatives from more than 17 countries, or in the continued attraction of the CU-ICAR campus to internationally-based companies the reach of the center around the world is evident. This year's Annual Report highlights more international companies who have co-located their operations in Technology Neighborhood One.

During the past few months, CU-ICAR has also represented Clemson University at uniquely prominent international automotive locations and events taking place around the world in Taiwan, China, Frankfurt and Munich, Germany just to name a few. Close to home on the CU-ICAR campus, we also provide a glimpse at the overwhelmingly popular inaugural Millennium Drive, which was the Clemson flagship event in support of Upstate International Month.

Just as the automotive industry reaches into every corner of the world, so has CU-ICAR's brand and reputation begun to do so in very tangible ways.

We sincerely hope you will enjoy reading about how the international character of CU-ICAR's vision and mission are thriving.

CONTENTS

03 Foreword by
Fred Cartwright

05 Foreword by
Dr. Imtiaz Haque



EDUCATION

08 Dept. of Automotive
Engineering Overview

09 Awards
and Honors

11 Deep Orange 3

13 Fellowships

15 Alumni
Spotlight



RESEARCH

18 Research
Portfolio

19 Strengthening
International Ties

20 SEMA
Research Grant

21 Research Spotlight:
Advanced Materials

23 Research Spotlight:
Advanced Powertrain Testing

25 Testing
Services



ECONOMIC DEVELOPMENT

28 Overview

29 New Campus
Partners

30 Campus
Progress

31 Center for
Manufacturing Innovation



MAGNET VENUE

33 Overview

35 Millennium
Drive

36 Artisphere

37 Distinguished
Guests

39 Contact
Information

MESSAGE FROM FRED CARTWRIGHT

This past year has been a significant one for CU-ICAR. It began with the roll-out of Deep Orange 3, which garnered greater international publicity than anything CU-ICAR had accomplished to date, and concluded with the announcement of a \$2M award from the Economic Development Administration (EDA) for construction of our last building in Technology Neighborhood I, “One Research Drive”. In between, we have experienced a growing international interest in all that CU-ICAR has to offer. This has manifested itself in increased research funding and a growing student population, as well as visits to and from organizations all around the world. We are pleased to share with you our experiences from this past year and provide some glimpses of what’s yet to come. I hope you will see that CU-ICAR’s future looks very bright indeed!

Even after over 30 years in the automotive industry, it’s still an exciting area to work, maybe more so now than ever before. I believe the car is on the cusp of such change that it has never before seen in its 100+ year history. The need for greatly improved fuel economy, as well as reduced global greenhouse emissions, is contributing toward this “rapid change trajectory” over the next ten (10) years. This need, along with extraordinary

digitization, sensor development, and the “internet of things”, is creating a world of increasingly intelligent and connected cars, that will change our lives, much like the smart phone did a few years ago. Fortunately, CU-ICAR is in a good position to ride this wave of innovation, in areas of lightweight materials, increased electrification, and connected vehicle technology. But, it’s also the technology associated with the manufacturing of automobiles that is rapidly changing. Methods for joining dissimilar materials, advanced robotics and the digitization of manufacturing make us excited to have formed a partnership with Greenville Technical College to build the Center for Manufacturing Innovation.

With all the changes facing the automotive industry today, I am grateful for the vision for emphasizing “systems integration” in the automotive engineering program. All of the foregoing changes to the automobile mean greater and greater complexity. There are 30,000 parts in today’s vehicle, an average of 75 computers (ECU’s), and one hundred million lines of code. Imagine what the future will hold. A total vehicle systems experience and education is increasingly important to industry, and we’re prepared to meet these challenges head-on.

Of equal importance over the past year has been a review of the vision and mission of CU-ICAR. This is especially important in times of change. The discussion process resulted in the realization of who we are and who we want to become.

Our Vision: To be the premier automotive research, innovation and educational enterprise in the world.

We are truly an “innovation enterprise”, the primary source of interest from around the world, with a vision that will keep us fresh and relevant to the world around us. It’s also the multi-dimensional aspect of the CU-ICAR model, working together as one, that forms the enterprise concept. Our research is fundamental, translational and industry-relevant. Our component test work is value-creating for the automotive sector. Our land and capital assets offer significant opportunities for economic development in this region:

Our Mission: To be a high seminary of learning, in the field of automotive engineering; Lead translational research, with emphasis on industry relevance, and support with excellence in basic research; Contribute to high value job creation in South Carolina; Lead global thinking on the sustainable development of the automotive sector.

LOOKING AHEAD

2015 will be a year of growth for CU-ICAR. One Research Drive will offer significantly more space for laboratories, offices and a growing automotive community. The construction of the Center for Manufacturing Innovation will be underway, ultimately providing a showcase for education and research in a state-of-the-art advanced manufacturing environment. Look for us to roll-out new initiatives in the incubation and acceleration of new technology and companies in the automotive space. And, finally, we will take a fresh look at this beautiful 250 acre campus, given the continued development of the Greenville community, as well as the many changes that have occurred since our original Master Plan was developed in 2007.

My first full year at CU-ICAR has been extremely rewarding. It’s not easy to transition from industry to a more academic setting. However, this is not just any setting. CU-ICAR’s focus is on the needs of industry—in the areas of workforce and innovation. It is an environment of collaboration that others desire to emulate. I think you will get the sense of this as you read this report. There is something very special happening in this part of the U.S. Please come and see!

FRED CARTWRIGHT,
EXECUTIVE DIRECTOR, CU-ICAR



MESSAGE FROM DR. IMTIAZ HAQUE

There is perhaps no time more exciting to be engaged in the automotive sector than today. The industry is undergoing a revolution powered by digital technologies and new materials. On the horizon are advances in fuel efficiency, navigation capability, and safety advances that are the stuff of science fiction and will forever change the way we view the automobile. CU-ICAR and the Department of Automotive Engineering are right in the middle of all of this and continue to put South Carolina on the global map as a key player in this transformation.

The vision that drives the research at the Department of Automotive Engineering is sustainable transportation. This vision is closely aligned to the goals of governments and industries globally. Faculty are engaged in translational research in areas that are critical to reduce the impact of fossil fuels and improve safety. The relevance of this research is validated by the fact that a majority of the funding for this research (see page 17) comes from industry and that some of the world's most recognized automotive brands such as BMW, GM, Honda, Mazda, Toyota and Chrysler, are currently engaged with us.

But research is not enough. The confluence of mechanical technology with digital technology and advanced materials poses new challenges that require a special set of skills to solve and we are proud to say that we are continuing to produce a workforce that has those skills. As a result, the educational program continues to garner international and national attention being featured both at the 3rd International Commercial Vehicle Technology Symposium, Kaiserslautern, Germany and at the 20th anniversary of the Automotive Research Center at the University of Michigan. The Deep Orange project continues to be immensely successful with new sponsorships obtained from Toyota and BMW.

In 2013-2014 the department started a number of multi-disciplinary initiatives focused around connected vehicles and multi-materials joining. These initiatives involve multiple departments and address the hot button challenges of the industry. In addition, the department played a key role in initiatives around advanced manufacturing. This includes the development of a unique collaboration with Greenville

Technical College to create a Center for Manufacturing Innovation (see page 32 to learn more). The latter if successful will have significant economic impact in South Carolina.

In summary the past year has been very productive with more faculty, more students, more research and more industry partners engaged. The Department of Automotive Engineering is proud of these accomplishments but there is a lot more to do. In this fast paced environment, where change is the only constant we, just like the auto industry itself, never stop moving forward towards progress.

DR. IMTIAZ HAQUE,
EXECUTIVE DIRECTOR
CARROLL A. CAMPBELL GRADUATE
ENGINEERING CENTER

FOUNDING CHAIR,
DEPARTMENT OF
AUTOMOTIVE ENGINEERING



DR. IMTIAZ HAQUE, CGEC EXECUTIVE DIRECTOR

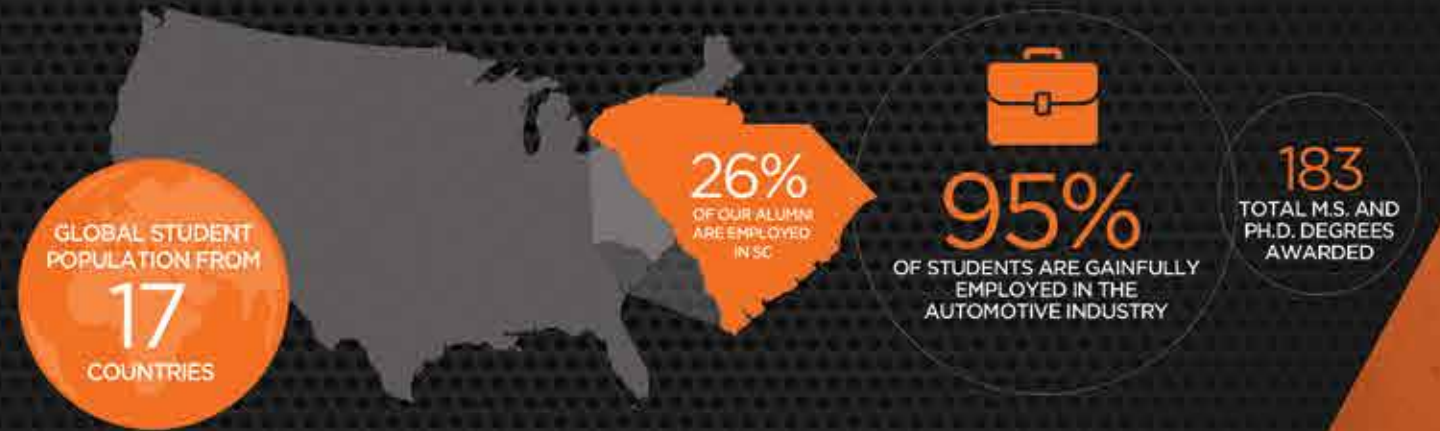


Dr. Laine Mears with Stäubli Fellowship recipients Abhishek Bondre and Aditya Ramanujam.



EDUCATION

The Department of Automotive Engineering's cutting edge M.S. and Ph.D. programs have continued to receive national and international recognition resulting in a record number of applicants for a limited number of seats. The growth in the graduate program has been immense with 219 students from 17 different countries registered for the Fall 2013 semester. Through May of 2014, the Department of Automotive Engineering graduated a total of 23 Ph.D. and 160 M.S. students. Students from the program continued to draw attention from top industry players with a number of OEMs making special visits to the campus just for the purpose of recruitment.





AWARDS AND HONORS

VALERIE PEZZULLA, a mechanical engineering graduate student at Clemson University received \$100,000 for manufacturing software she developed at the Clemson University International Center for Automotive Research. She won first place in the 2014 MTConnect Challenge with the application she developed that detects vibrations in metal-cutting machines. The detection allows corrections to be made before parts are damaged. The data can also be analyzed and communicated to help prevent vibrations in future operations. Pezzullo said, "As a student, it was exciting to go through the design and see it through to the final product." The app was part of Pezzullo's thesis and an offshoot of research by her adviser, Laine Mears, an associate professor of automotive engineering.

"It will have a big impact on manufacturing, especially in the Upstate, because manufacturing is such a large part of the economy," Mears said. "This is a great example of automatically generating information and using it to improve manufacturing quality and productivity."

Upon graduation from Clemson University, Valerie accepted a position with CU-ICAR Campus Partner, Koyo Bearings NA.

OTHER STUDENT AWARDS:

JUN HU
Won the NSF/ASME Essay Competition in "Challenges in Design of Complex Systems", through the 2013 ASME Design Technical Conference (IDETC), Portland, Oregon, 4-7th August 2013.

MELISSA BOWLER
Best Paper Award, 2013 International Conference on Sustainable Automotive Technologies

VALERIE PULAZZO,
2014 MTCONNECT CHALLENGE WINNER

2013 GLOBAL CONNECTED CAR CONTEST SPONSORED BY CHEVROLET AND SAP

Clemson's global reputation as a source of innovation for the automotive market was once again recognized this year as Ph.D. Candidates won two of the six categories in the 2013 Global Connected Car Contest. Pablo Sauras-Perez and Andrea Gil submitted their concepts and now have the opportunity to travel to Palo Alto in Silicon Valley to meet with industry experts and start work on prototypes. Pablo Sauras-Perez hopes "ParkinGain" will help drivers find the best parking spots based on their own preferences and allow them to feed the meter without going back to their cars. Andrea Gil is working on a shopping application, "Ready2Pick," that would allow drivers to keep traveling down the road as they order fast food and groceries from businesses with drive-through service.

“IT WAS AN **INTERNATIONAL** CONTEST,
SO THERE WERE SUBMISSIONS FROM ALL OVER THE WORLD.
IT MEANS WE'RE **DOING SOMETHING RIGHT.**”

- ANDREA GIL -

“YOU HAVE TO SEE THE **BIG PICTURE.** TECHNOLOGY IS
AWESOME, BUT YOU HAVE TO HAVE BUSINESS MODELS TO MAKE ITS
DEVELOPMENT **SUSTAINABLE.**”

- PABLO SAURAS-PEREZ -

FACULTY HONORS

BESHAH AYALEW
SAE 2014 Ralph Teetor Young
Educator Award

DR. IMTIAZ HAQUE
Keynote address at
3rd International Commercial
Vehicle Technology Symposium,
Kaiserslautern, Germany

DR. LAINE MEARS
2013 Institution of Mechanical
Engineers George Stevenson Gold Medal
SAGE Best Paper Prize of 2012,
Journal of Engineering Manufacture

DR. TODD HUBING
Plenary session address
at the 30th International
Review of Progress in Applied
Computational Electromagnetics,
Jacksonville, Florida

DR. ZORAN FILIPI
February 2014, "New Technologies
Highlighted at the Washington Auto
Show", Interview for the Voice of America
Global Television and Web News
July 2013, invited speaker, "Natural
Gas and Electrified Powertrains for
Heavy-Duty Vehicles," South Carolina
Clean Energy Summit



"IT STANDS AS A
SHOWCASE
OF WHAT THE SCHOOL
AND ITS YOUNG
CAR ENTHUSIASTS
ARE CAPABLE OF."

- FOX NEWS



**DEEP
ORANGE**
CLEMSON UNIVERSITY

COLLABORATIVE INDUSTRY-BASED LEARNING

As part of the two year Deep Orange program, students in Clemson's graduate automotive engineering program are required to create and manufacture a new vehicle prototype. The vehicle's concept and design are developed in partnership with students from the transportation design department at the Art Center College of Design, focusing holistically on the vehicle and the end-user. The program provides students with experience in vehicle design, development, prototyping and production planning. Each year, a prototype vehicle is developed with a new market focus and technical objectives.

The project showcases advanced vehicle technologies and provides students an opportunity to work directly with automotive industry partners to innovate and develop ideas.

"THE BEST PART OF THE DEEP ORANGE 3 PROTOTYPE IS THE FACT THAT IT WAS **BUILT & DEVELOPED** EXCLUSIVELY BY **YOUNG STUDENTS** WHO NO DOUBT ALL HAVE PROMISING FUTURES IN THE AUTO INDUSTRY!"

- TOPSPEED -

DEEP ORANGE 3: THE NEXT BIG THING

It has innovative engineering inside and out, and it's all the work of students. Deep Orange 3, a next-generation Mazda concept vehicle, conceived and engineered by Clemson University automotive engineering students was unveiled at the Center for Automotive Research Management Briefing Seminars in Traverse City, Michigan. During this four day premier automotive conference, leaders from industry, government, economic development and academia convene to discuss the critical issues of the day. This year, Deep Orange was named a top 10 hot topic of the week and was featured in publications around the world. Media coverage included national exposure in FOX, Yahoo, AOL, and Time as well as international attention in over 15 countries!

ENGINEERED BY

CLEMSON

POWERED BY



DESIGNED BY

● Art Center College of Design



CU-ICAR FELLOWSHIPS: INVESTING IN TOMORROW'S WORKFORCE

Graduate fellowships help Clemson recruit and develop exceptional engineers who are passionate about shaping the future of the automotive industry. CU-ICAR's fellowship partners have direct communication with our top automotive engineers and are helping diversify and grow the talent pool.

FELLOWSHIP PARTNERS

We thank the following partners for their commitment to supporting the next generation of automotive engineers.



Dr. Kilian Funk with
BMW Fellowship
Recipients Kevin
Aiken, Thomas
Harris, and Trevor
Rodriguez-Sotelo.



A \$500,000 grant from the Bosch Community Fund will establish an endowment in perpetuity for automotive-engineering fellowships.



Bridgestone Annual Fellowship represents a \$25,000 commitment for the next 5 years.

SAWF FELLOWSHIPS

Two automotive engineering doctoral candidates, Jackeline Rios and Sarah Mohon, were awarded with fellowships at the 2013 Southern Automotive Women's Forum (SAWF) conference. By leveraging the talents of women from the industry as role models, SAWF collaborates with companies and organizations to attract and retain women to the automotive industry.



ALUMNI SPOTLIGHT

The following featured alumni are examples of our exemplary student body. Each came to Clemson with a passion for the car and a thirst for knowledge. Clemson's Department of Automotive Engineering develops each student into an automotive engineer prepared to enter the workforce. Our graduates learn by conducting research and collaborating with leading automotive companies.

KAVIT ANTANI

Kavit Antani graduated with a Ph.D. in Automotive Engineering from CU-ICAR in May 2014 and is currently working at the BMW Manufacturing Plant in Spartanburg, SC as a Quality Engineer responsible for Powertrain Assembly for the X5 and X6 Sports Activity Vehicles.

Kavit joined the CU-ICAR team in July 2011 as a graduate student to pursue a Ph.D. in Automotive Engineering. He was selected as a Research Assistant and BMW Scholar in Manufacturing to work on the Robust Work Optimization project led by Dr. Laine Mears and to develop a learning system for manufacturing task relationships for the BMW assembly plant in Spartanburg, SC. His doctoral research was focused on understanding Manufacturing Complexity and its effects on Product Quality in Mixed-Model Automotive Assembly.

"The primary reason I chose CU-ICAR to pursue my career goal was because of its collaboration with the automotive industry and the industry focused research projects driven by the automotive engineering faculty members."

During the program, I also participated in the Deep Orange program (DO4) and got a unique opportunity to develop a comprehensive manufacturing strategy for a new low-volume BMW variant that would be produced in a high-volume existing manufacturing environment. My entire research project was based at the BMW manufacturing plant and the research was directly applicable to the manufacturing processes upon completion. The facilities at CU-ICAR were also industry standard and the transition to an industry role became seamless for that very reason. After working for 11 years after the Master's degree program, I could not have chosen a better program to pursue an industry relevant Ph.D. in Automotive Engineering."

JOHN ADCOX

Adcox came to CU-ICAR directly after receiving his bachelor's degree in Mechanical Engineering from Tennessee Technological University in 2008. He received both his Master's and Ph.D. degrees in Automotive Engineering with a focus on vehicle dynamics & controls from CU-ICAR between 2008 to 2014. John also won the Superior Student Paper Award at the Tire Society Conference in 2011. Currently John is working with Michelin at the research facility located in Greenville, SC as a Performance Research Engineer where he is able to investigate the fundamental mechanisms related to a tire's traction capabilities under wet, dry, and winter conditions.

"As a Ph.D. candidate I had the opportunity to work on several industry projects with BMW and Michelin and was involved with CU-ICAR's 1st Deep Orange project. Through several collaborative projects with Michelin, I was able to work on TWEEL™ related projects and also study the interactions between Anti-lock braking systems (ABS) and tires. During my time at CU-ICAR I was able to grow intellectually and as a person. I was able to pursue topics that were of interest to me and was given many opportunities to improve my knowledge through projects both big and small. The opportunities available to me at CU-ICAR allowed me to develop my personal networks to a level that would have been unachievable without their support. It was these networks that undoubtedly led me to the career with Michelin I have today."

ASHISH DUBEY

Dubey is a Product Design Engineer at FIAT Chrysler Automobiles since October 2013. In his current role, he is responsible for the design, development, testing and manufacturing of base engine components and systems for upcoming engines. He received his M.S. in Automotive Engineering from Clemson University (CU-ICAR) in August 2013 with a specialization in IC Engines and Alternate Powertrain Architecture. Ashish led the Deep Orange 4 vehicle prototype program, which was primarily sponsored by BMW and their Tier-I suppliers.

"As the project manager of Deep Orange 4, I had the opportunity to understand different aspects of vehicle development processes such as: understanding the market, analysis of customer requirements, brand identity, benchmarking, concept development, team organization, project timeline, project cost estimation, manufacturing and assembly processes, etc. I was able to apply my core engineering skills and creativity while involved in the concept development and design phase of the project. The role of a team leader and responsibilities associated with it helped me to sharpen my leadership skills and at the same time learn new tools and skill sets to manage a team in an efficient way. During the course of the project, I led various management reviews for the project status, participated in key industry visits, and represented CU-ICAR at MBS 2013 and 2014. I also served as a graduate assistant for the Deep Orange 5 group to help them finalize the high level requirements of the project. CU-ICAR has been instrumental in helping me pursue my professional goals and preparing me for a challenging career in the field of automobiles. Specifically, the systems approach that I developed while working on the Deep Orange project played a key role in my hiring at a major global OEM, FIAT Chrysler Automobiles. The diverse group of students from around the world and a great faculty and staff provided an atmosphere conducive for learning and developing new ideas and concepts."

RESEARCH AND DEVELOPMENT

CU-ICAR's research portfolio is driven, as is our philosophy, by industry needs. We continuously analyze the market and survey industry partners, industry leaders and automotive companies to determine their technology and R&D focus. Based on that knowledge, today the research clusters and "technology identity" of CU-ICAR are centered in the following seven areas: Advanced Powertrain, Vehicular Electronics, Manufacturing & Materials, Vehicle-to-Vehicle Infrastructure, Human Factors/HMI, System Integration.

2013 / 2014 RESEARCH PORTFOLIO



PERCENTAGE OF RESEARCH SPONSORED BY AUTOMOTIVE COMPANIES



TOTAL RESEARCH AND SPONSORED PROGRAMS AWARDS RECEIVED BY THE DEPARTMENT OF AUTOMOTIVE ENGINEERING



TOTAL PROJECTS

CLEMSON UNIVERSITY STRENGTHENS TIES WITH BMW GROUP

In April 2014, Clemson University displayed a range of research capabilities at BMW R&D and Engineering Center (FIZ) in Munich as part of an effort to expand the university's partnership with the German automaker. A team of 17 faculty, staff and students travelled to Germany to share the broad scope of Clemson's capabilities with the world-class automaker.

On display were examples of research that demonstrate Clemson University's capabilities and competencies in five key focus areas: Business IT • Product Development • Product Quality Simultaneous Engineering • Productivity

“THE TEAM'S GOAL WAS TO SHOW THE UNIVERSITY'S CAPABILITIES TO THE BMW NETWORK, NOT JUST IN MANUFACTURING RESEARCH BUT ALSO IN THE AREA OF BUSINESS IT AND ENERGY MANAGEMENT,” SAID DR. IMTIAZ HAQUE.

Haque, who is Executive Director of the Carroll A. Campbell Graduate Engineering Center and Founding Chair of the Department of Automotive Engineering, opened the two-day event with Manfred Erlacher, president of BMW Manufacturing Co.

The visit consisted of two components. A large exhibit area featured research topics and hardware display. There was also a full program of presentations over the course of two full days. Josef Kerscher, past president of BMW Manufacturing, attended the exhibition. Top executives from BMW's Production Technologies group and the Vehicle Development group also attended the exhibition.

“The visit was clearly a success,” said Haque. “We were able to open new doors and strengthen already existing relationships. I am very proud of the work that our faculty and students have done over the last few years and the quality and its impact was evident in this exhibition.”

SEMA GRANT FUNDS RESEARCH AT CU-ICAR

The Specialty Equipment Market Association (SEMA) expanded its five-year relationship with CU-ICAR by awarding the Department of Automotive Engineering with a \$1 million research grant. These funds ensure vehicle dynamics and emissions compliance while developing high-quality aftermarket performance products. As part of the two-year grant, CU-ICAR will develop a Transient Emissions and Fuel Economy Laboratory and a Vehicle Dynamics Laboratory to provide physical testing, engineering resources and research support for performance product development, testing, analysis and integration. The grant will help speed to market performance aftermarket components for SEMA members that design, engineer and produce emissions-regulated and vehicle dynamics products. The research also will provide SEMA members with detailed insight and guidance related to the latest powertrain and suspension technologies.

The research grant project has four specific objectives: Collaborate with SEMA members in research and development for compliance of aftermarket products with a focus on transient emissions/fuel economy and vehicle dynamics; develop guidelines and best practices through case studies with SEMA members to more efficiently achieve product and vehicle compliance; support SEMA members during product development by jointly resolving critical compliance issues by applying these best practices and guidelines; and develop an engineering workforce that understands the unique challenges of the aftermarket performance industry and can use that knowledge in the original equipment workplace and specialty equipment industry.

Two automotive engineering doctoral students will lead the research in the focus areas. The dissertation for each Ph.D. student will address the fundamentals associated with vehicle performance modifications. Base funding required for these students will be provided through the SEMA grant. Further, each focus area will be designated two second-year automotive engineering master's degree students to support the hands-on integration and development of the research projects. The students will work under the supervision of CU-ICAR faculty member Paul Venhovens, BMW Chair in Automotive Systems Integration, and Robert Prucka, a faculty member on the powertrain team at CU-ICAR. Prucka said current and future federal and state regulations for emissions, fuel economy and vehicle dynamics pose significant challenges to SEMA members. The interaction of aftermarket performance products on overall vehicle performance often require large capital and engineering investments to develop and ensure vehicle compliance. “Many SEMA members do not have access to full-scale laboratories where they can receive comprehensive engineering support for product development,” Prucka said. “This project will help fill that gap, and provide another unique level of education for our students.”

“The goal of the innovative SEMA-CU-ICAR collaboration is to ensure reliable and high-quality operation of aftermarket performance products, as well as establish and grow new business opportunities in the areas of customization and accessorization while educating automotive graduate students and SEMA members on engineering, product development and vehicle technology integration critical to the automotive performance aftermarket industry.”



Serving the Motor Vehicle Aftermarket



RESEARCH SPOTLIGHT: ADVANCED MATERIALS

The constant pressure to meet demands and regulations for fuel economy is transforming the materials and production methods used in today's vehicles. Lightweighting is crucial to the cost-sensitive automotive sector and extends beyond to performance-based aerospace and military sectors. CU-ICAR is playing an important role in this critical area through its focus on Advanced Materials Research.

There is no lack of materials with strong lightweighting potentials; aluminium, magnesium and titanium alloys, as well as several classes of fiber reinforced composites. However, these materials share two major drawbacks that prevent their use on a large scale: high material cost and technical manufacturing difficulties that stem from the fundamental material behavior. At CU-ICAR, our approach is to address the latter in a way that alters the former.

The advanced materials research activities tackles the technical problems in an integrated approach that starts with (i) fundamental characterization and understanding of material behavior, then (ii) altering material behavior through advanced processing to produce favorable properties, and ultimately (iii) developing energy-efficient cost-effective manufacturing techniques that would tip the balance towards greater utilization of these lightweight materials.

ADVANCED MATERIALS FOCUS AREAS

THERMOPLASTICS CU-ICAR researchers have shown that the microcellular process aids in reducing the energy by 30%, cycle time by 26% with a weight savings of 18-20%, compared to a conventionally fabricated part.

THERMOSETS CU-ICAR's researchers focus on the development of hybrid matrices with tailored functionality i.e. desired stiffness, strength, toughness while able to resist the high-temperature applications.

MAGNESIUM For magnesium, the lightest structural metal and one of the hardest metals to deform, CU-ICAR has developed a new hybrid-process, called friction stir back extrusion (FSBE), in which inefficient indirect heating in a conventional process is replaced with direct heat generated during friction stirring.

SHEET METAL CU-ICAR is taking a pioneering position by fostering a new forming approach referred to as "Hot Blank-Cold Die" (HB-CD) sheet stamping. This approach is more economic than conventional warm and hot forming, and promises high production rates without any significant changes to the current stamping infrastructure.

SUSTAINABILITY CU-ICAR's researchers are developing innovative biobased polymeric blends and composites that have near ZERO carbon footprint, and processes that will enrich the properties of recycled plastics and metals, which possess lower life-cycle impact.

Dr. Fadi Abu-Farha and Dr. Srikanth Pilla lead the Advanced Materials Research team at CU-ICAR.

RESEARCH SPOTLIGHT: ADVANCED POWERTRAIN TESTING

The future of transportation will be shaped by our ability to address major challenges related to energy security, impact on the environment, global market forces and consumer adoption patterns. Solutions for sustainable transportation will require considering a diverse set of energy sources, carriers and powertrain architectures. Therefore, the Department of Automotive Engineering has identified advanced powertrains as a strategic direction and set very ambitious goals for research in this area.

In 2014, CU-ICAR has expanded our research capabilities to include a broader scope of propulsion systems testing. The Advanced Powertrain Laboratory is located on the first floor of the Carroll A. Campbell Graduate Engineering Center and is led by Timken Endowed Chair in Vehicle System Design, Dr. Zoran Filipi. This new infrastructure provides unique flexibility for combining in-depth research and powertrain system integration. In addition to experiments with fully instrumented IC engines, batteries, supercapacitors and electric motors, APT will ultimately enable integration of the real hardware and virtual components to create an emulated vehicle environment.

APPLICATION OF ADVANCED DIAGNOSTICS WILL ALLOW UNIQUE INSIGHTS UNDER REALISTIC OPERATING CONDITIONS AND ULTIMATELY CREATE A NEW PARADIGM FOR POWERTRAIN SYSTEM DESIGN AND OPTIMIZATION.

The new facility features two state-of-the-art powertrain test-cells, a smaller reconfigurable space in the middle, the power transformer, HVAC system, intake air and exhaust systems, and a new fuel farm. A natural gas system will enable combustion research in the test-cell, as well as an outside dispenser for refueling of prototype vehicles.



Peter Barthel, Test Operations Manager and Steffen Martin, Director of Engineering at Pure Power Technologies LLC, deliver a donated AC Dynamometer to Dr. Zoran Filipi, Timken Endowed Chair in Vehicle System Design.

TESTING SERVICES

Opened in 2012, the CU-ICAR Component Testing Laboratory (CTL) offers commercial component testing to the automotive industry. In its short history, the laboratory has proved to be a valuable resource for Tier 1 BMW Suppliers. The CTL is one example of CU-ICAR's commitment to serving the regional automotive ecosystem.

The Component Testing Lab has served as a model for other incubation projects to promote business locally and globally. First envisioned to address missing testing services local to the BMW Plant Spartanburg, since opening the lab has performed over sixty new product validation tests for BMW tier 1 suppliers located in the Upstate. The initial testing portfolio should certainly grow to meet the testing needs of these same customers and new customers as well. Additional capacity and capabilities are planned to capitalize on this foundation that has proven valuable to various companies.

To highlight another goal envisioned from starting the Component Testing Lab (CTL), four Clemson University graduate students have completed six-month internships in the lab as Test Engineer Trainees. These students gain experience in daily lab operations, test procedures, data collection, as well as application of mechanical engineering principles to product development. Our interns capitalize on CU-ICAR's global enterprise, as many of them call El Salvador, Nepal, and India their home countries. They also learn about many of the nuances of automotive engineering careers through interaction with customers who visit the lab for test evaluations and results. All four of these graduate student interns are now employed in the automotive industry.

Accreditation of testing labs is important to customers, and the Component Testing Lab is progressing quickly toward ISO 17025 certification by the American Association for Laboratory Accreditation. All CTL tests are backed by operational procedures, methods, and calibrated testing equipment to ensure the testing specifications are accurately met.

TESTING PORTFOLIO 2012 / 2013

77 VALIDATION TESTS

180 COMPONENTS

6 INDUSTRY PARTNERS

17K TEST CHAMBER HOURS

COMPONENT TEST LABORATORY OFFERINGS:



Chamber 1 comprises a vibration chamber, which features temperature and humidity control, and a shaker system, which can accommodate vertical and lateral vibration testing. Chamber 2 features a walk-in solar chamber for OEM climate solar simulation tests, and a solar array with solar simulation that can simulate in-vehicle conditions of components commonly exposed to solar irradiation inside the cockpit. CU-ICAR's Component Testing Laboratory also offers Optical Measurement, Gap Measurement, Adhesion Testing, Color Measurement, Materials Testing, Fracture Analysis and Microstructural Examination and duplication of OEM Final Assembly Processes.



“ We have had a very positive experience using the new start-up Component Testing Lab at CU-ICAR. The collaboration with the ICAR-Lab-staff is outstanding. The colleagues there are very professional and competent. This helped us to establish solid testing capabilities in the NAFTA-region for BMW today but also for other OEMs in the future. ”



“ CU-ICAR's Component Testing Lab has given us a great advantage in time and cost savings. Being able to test our interior components close to our manufacturing facilities is very valuable to Faurecia. The team at the CU-ICAR CTL Lab have been very good to work with— professional and flexible. ”



“ Performing the shaker test locally in South Carolina at CU-ICAR allowed our engineering teams to speed-up the analysis process and reduce the lead-time to implement the required optimizations. Your team is very professional and its flexibility was well appreciated. ”





A SPECIAL VISIT

Clemson President James P. Clements and CU-ICAR Executive Director Fred Cartwright lead U.S. Commerce Secretary Penny Pritzker on a tour of campus.

ECONOMIC DEVELOPMENT

The CU-ICAR campus is an automotive ecosystem that helps companies make connections and build relationships. We have created a community where industry meets academia. With the addition of the Center for Emerging Technologies in 2012, CU-ICAR currently has 20 Campus Partners from around the world. These on-site residents work in close quarters with our students and faculty and share the many amenities of the Millennium Campus.

Clemson University is among 12 universities nationwide that have been cited for helping drive economic growth at a time when more states are looking to their higher-education institutions to create jobs and investment. State Commerce Secretary Bobby Hitt said investment distinguishes South Carolina and helps attract new industry and jobs. In the new book, "Innovation U 2.0: Reinventing University Roles in a Knowledge Economy," Clemson is recognized for expanding research and development, enhancing instructional programs and adopted a "daring and novel" mission in a "relatively short" 15 years. The authors called Clemson an "enlightening example" that continued its progress even as the last recession hit South Carolina particularly hard.

"BY **INVESTING** IN PROGRAMS THAT **APPLY ACADEMIC RESEARCH** TO INDUSTRY NEEDS, WE'RE POSITIONING SOUTH CAROLINA TO **BETTER COMPETE** IN THE GLOBAL ECONOMY."

— STATE COMMERCE SECRETARY BOBBY HITT —



CU-ICAR CAMPUS PARTNERS

CREATING A COMMUNITY OF COLLABORATION AND INNOVATION

CU-ICAR's unique automotive community is comprised of 20 campus partners that represent a wide range of public and private organizations from around the world. We are focused on the broad spectrum of companies that make up the automotive sector, including research, development, personnel recruiting, and total vehicle recycling, to name a few. This year, we welcomed six new companies to the Center for Emerging Technologies. This incubation environment helps foster ideas and innovation that can more broadly impact the automotive sector, in South Carolina and beyond.



"We are very excited to join the CU-ICAR partnership. CU-ICAR has created a very powerful and innovative way for OEM's, suppliers, research and education to collaborate in mutually beneficial ways. Along with the strong State/County support, training programs and technical workforce, it became clear that there is a very strategic advantage for us to expand into the Greenville area. This expansion will allow Esys to enhance support to our existing customers and provide a solid foundation to grow our business in the southeast region."

DAVE VALENTINE, PRESIDENT,
ESYS AUTOMATION

"We are pleased to establish our North America headquarters in South Carolina's Upstate, and are particularly excited to be locating here in Greenville County at CU-ICAR. This strategic expansion will help us meet accelerating demand for our innovative carbon fiber technologies and manufacturing capabilities sought by automotive, aerospace and marine industry customers. Greenville County provides us with an excellent business environment, a top notch workforce and exceptional market access. We are proud to become a growing part of the Palmetto State business community."

RICHARD SMITH, CEO NORTH AMERICA,
RODING TECHNOLOGY

"We have visited the CU-ICAR facility and witnessed the innovative and dedicated people from all over the world who are working on testing and designing the cars of the future. We are assisting them in seeing the environmental effects of these designs... With our partnership with Clemson we can plan for all the changes coming in the composition of the automobiles of the future."

JOHN SUCHON,
COMMERCIAL MANAGER, OMNISOURCE

CAMPUS PROGRESS

RESEARCH ONE BUILDING

Research One, the final building completing Technology Neighborhood I, will be made possible by a \$2 million grant awarded by the U.S. Department of Commerce's Economic Development Administration. The building will provide space for private-public partnerships focused on developing new technologies in the automotive, mobility and IT fields, supporting the intersection of productivity, innovation and entrepreneurship.

"CU-ICAR is an excellent example of what higher education, government and industry can accomplish when they work together. This grant will strengthen those bonds. Research One will be a world-class facility. It will be a place for students to get a highly relevant education on the latest in automotive research and for industry to get fresh ideas from our students."
- James P. Clements, president of Clemson University



CENTER FOR MANUFACTURING INNOVATION

Greenville Technical College and Clemson University announced an agreement to educate the advanced manufacturing workforce to serve the automotive, transportation and other high-tech sectors.

According to a memorandum of understanding signed by Greenville Tech President Keith Miller and Clemson University President James F. Barker, the vision is for collaboration between a leading research university, an innovative technical college and advanced manufacturers to create a center that enhances the development and implementation of advanced manufacturing technologies. The Center for Manufacturing Innovation (CMI), to be located at the Millennium Campus adjacent to the Clemson University International Center for Automotive Research (CU-ICAR) Technology Neighborhood 1, will offer education designed to meet industry needs. It will include dual-credit programs in partnership with Greenville County Schools, bridge programs that allow a student to move from associate's degree to bachelor's degree and workforce training and certificate programs that increase the qualifications of manufacturing employees.

Research for innovation in advanced manufacturing and future technologies related to advanced manufacturing will be incorporated into instruction. This will allow students to gain practical experience working alongside experienced engineers, faculty and staff. The center will engage K-12 students and show them the possibilities that exist in advanced manufacturing careers through dual enrollment programs, tours, camps and open houses. From an economic development perspective, Upstate leaders have said that the economic development race will be won by communities that offer the services manufacturers need. To help companies compete globally, employers need a flexible, highly-skilled workforce equipped to maximize new technologies, adapt to evolving production processes and work organization models and solve problems rapidly.

The Center for Manufacturing Innovation also will offer landing pad space that helps companies start up or relocate and will provide flexible space where manufacturers can create prototypes and teach their current employees new skills to keep them on the cutting edge of improvements in technology. The idea for the campus began with the needs of employers. As the concept has been developed, leaders with area manufacturers, including BMW, Michelin, GE, Bosch Rexroth, ADEX Machining Technologies, League Manufacturing, JTEKT Koyo, Fabri-Kal, SpecFab Services, Master PT, Standard Motor Products and more, have voiced strong support for the project and have provided input that has allowed plans for a Center for Manufacturing Innovation to take shape.

In September, the Greenville County Council gave unanimous approval to a \$25 million bond issue for Greenville Technical College to build an enterprise campus. "Our intent as we have worked toward the creation of this Center for Manufacturing Innovation has been to better meet the needs of manufacturers in our area, so that those companies can continue to move our economy forward," said Miller. "By collaborating with Clemson University as we also work closely with Greenville County Schools, we have education in the Upstate serving as a powerful and united force for workforce development."

Barker said Clemson is proud and happy to be Greenville's public research university partner. "Today we celebrate another important partnership with Greenville Technical College to provide the advanced manufacturing workforce education our community needs."

"TODAY WE **CELEBRATE** [AN] IMPORTANT **PARTNERSHIP** WITH GREENVILLE TECHNICAL COLLEGE TO PROVIDE THE **ADVANCED MANUFACTURING WORKFORCE** EDUCATION OUR COMMUNITY NEEDS."

— JAMES F. BARKER, PRESIDENT EMERITUS OF CLEMSON UNIVERSITY —



JAMES F. BARKER
OF CLEMSON UNIVERSITY
SPEAKS AT THE EVENT.





CU-ICAR: MAGNET VENUE

THE HOT SPOT FOR REGIONAL, NATIONAL & GLOBAL AUTOMOTIVE AND MANUFACTURING EVENTS

CU-ICAR continues to be the magnet venue for industry gatherings in the Southeast.

Beyond housing 20 campus partners, multiple research laboratories and Clemson University's automotive engineering program, the CU-ICAR campus also lends itself to accommodating regional and global conferences and events.

Community Stakeholder Meetings, held semi-annually, keep key partners informed on the latest CU-ICAR news.



MILLENNIUM DRIVE

On Saturday March 22, 2014 CU-ICAR hosted an inaugural community event, The Millennium Drive International Car Cruise. Nearly 3,000 people flooded the campus to experience the first annual auto festival, which featured a diverse display of over 200 exotic and domestic cars—each one an automotive engineering marvel.

The Millennium Drive brought the Upstate community together to share in a day of celebration. Car clubs, car collectors, auto dealers, racers and car enthusiasts of all ages gathered at CU-ICAR to share their passion for the automobile.

The procession of cars was truly a complete spectrum of vehicles from around the world. Futuristic concept models sat beside quirky, souped up, decked out, vintage collectibles, which displayed carrying luggage, surf boards, and even a bright yellow trailer. The sheer variety was a car lover's dream. True car buffs enjoyed them, small children explored them, and some event-goers seemed fascinated, if not transfixed, as they learned more about these masterfully engineered, truly novel wonders of their time.

The Millennium Drive International Car Cruise also included a beer garden, food trucks, a kids play area and lots of great entertainment including Soul Stew, The Soul Feathers, The Erica Berg Collective and Mac Arnold and Plate Full O'Blues.

Constancio Nakuma, Clemson assistant dean and co-chair of Upstate International remarked, "The Millennium Drive was so excitingly fresh in spirit, like a children's first experience at some carnival...My kids had a great time with the music and the food...I'm looking forward to next year's event already!"

From an organizer's perspective, Amy Bulger commented, "What made 'Millennium Drive' such an amazing event is that it introduced so many people, particularly young people, to a whole new world of technology, imagination and innovation—a world they may have never had the chance to experience before. To me personally, what made it exciting is how it was completely volunteer-driven and supported. That made this a genuine and full community celebration of the Upstate's global reach."

ARTISPHERE

One of Artisphere 2014's largest exhibits showed how Clemson University brought together technology and art to create cars, movie special effects and 3D computer programs, while inspiring the next generation of engineers, scientists and artists. The College of Engineering and Science had a major exhibit at Artisphere for the first time in the festival's 10-year history, at the corner of Broad and Main streets in downtown Greenville. It included the student-built Deep Orange concept car, animated productions, and hands-on activities.

Anand Gramopadhye, the college's dean, said Clemson's exhibit allowed visitors to explore how technology and art can lead to playful innovation.

The display was called the "Clemson University STEAM Exhibit: Exploring Technology and Art." STEAM stands for Science, Technology, Engineering, Art and Math.

"At Clemson, we believe that creative collaboration between different areas of the university is crucial to our success," said Richard Goodstein, dean of the College of Architecture, Arts and Humanities and member of Artisphere's board of directors. "We are thrilled to see art and science working together so beautifully and with such imagination."

SOUTH AMERICAN DELEGATION

MORE THAN 20 CHIEF EXECUTIVES FROM 19 COUNTRIES VISITED THE UPSTATE TO LEARN ABOUT INNOVATION AND ENTREPRENEURSHIP IN THE REGION AND TO SEE FIRSTHAND HOW THE PUBLIC AND PRIVATE SECTORS HELPED MOLD CU-ICAR INTO A MODEL CAMPUS.

CU-ICAR hosted the U.S. Department of Commerce Economic Development Administration; the International Trade Administration; and ministers, vice ministers, university officials, mayors and other government officials from Central America, South America and the Caribbean.

Fred Cartwright and Dr. Imtiaz Haque welcomed the group to the campus and led a tour of the facilities, including the Carroll A. Campbell Graduate Engineering Center (CGEC) and the Center for Emerging Technologies.

Other speakers to address the group at CU-ICAR included Lynn Mann, director of programs for A.J. Whittenberg Elementary School of Engineering, and Nick Rigas, Executive Director of the Clemson University Restoration Institute, who presented an overview of the public-private partnership model of the North Charleston campus and its synergies with CU-ICAR.

The group's day also included a tour of BMW Manufacturing Co. in Greer. The two-day visit, which also included a reception and tour of downtown Greenville, was coordinated by the Greenville Chamber of Commerce.

U.S. SECRETARY OF COMMERCE

"CU-ICAR IS A TREMENDOUS EXAMPLE OF AN EDUCATIONAL INSTITUTION CONDUCTING THE TYPE OF LEADING-EDGE RESEARCH THAT WILL KEEP AMERICA COMPETITIVE IN THE 21ST CENTURY AND ALSO WORKING DIRECTLY WITH INDUSTRY TO TRAIN WORKERS FOR IN-DEMAND, HIGH-SKILLED JOBS."

PENNY PRITZKER , U.S. SECRETARY OF COMMERCE

In Spring 2014, U.S. Secretary of Commerce Penny Pritzker visited the CU-ICAR Campus. Her visit included a private roundtable discussion about developing a qualified workforce and came as expanding automotive and tire companies heighten the state's importance in manufacturing. The visit was an opportunity to show Pritzker how Economic Development Administration (EDA) grants have supported CU-ICAR and the state's economy. The EDA, which is part of the Commerce Department, helped fund the Center for Emerging Technologies building.



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