IDEaS

INQUIRY, DISCOVERY IN ENGINEERING AND SCIENCE SPRING 2015 COLLEGE OF ENGINEERING AND SCIENCE

Virtual Reality Comes into Focus

Clemson's simulation technology widens the talent pipeline.

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CLEMSON
College of ENGINEERING AND SCIENCE

FROM THE DEAN

I have frequently emphasized the importance of providing a world-class infrastructure to support cutting-edge educational and research experiences. As this issue of *IDEaS* goes to press, several building initiatives are underway in response to this need. These projects will influence the future of South Carolina's engineering and science landscape for years to come as we work to provide the technical talent needed by the state and nation.

Construction on one such project, the Zucker Family Graduate Education Center, has begun on the former naval shipyard at the Clemson University Restoration Institute in North Charleston. When its doors open next year, this center will offer master's and Ph.D. degrees in engineering and science, programs that will eventually grow to approximately 250-plus students, 20 faculty, and 40 researchers and staff.

We are also planning a new building on campus for our Advanced Technological Education Center, which will house four academic support initiatives that take students from kindergarten to career:

1. *Emagine!*, a program that encourages middle and high school students to pursue careers in STEM fields as part of our K-12 outreach
2. Programs for Educational Enrichment and Retention (PEER) and Women in Science and Engineering (WISE), both of which provide support for underrepresented students in math, science and engineering. One of our strategic aims is to create a diverse and vibrant talent pipeline to support the knowledge economy of the 21st century
3. Clemson University Center for Workforce Development: (CUCWD) and the Center for Aviation and Automotive Technical Education Using Virtual E-Schools (CA^2VES), two programs supporting career pathways yielding improved educational outcomes for the current employment climate
4. The Design and Entrepreneurship Network, or DEN, an entrepreneurial effort in the college that provides incubation space and turnkey support for students to move their ideas to the marketplace

Another key component of our success in building the next generation of engineers and scientists is connecting students with industry partners and research laboratories so that they can take basic research and *translate* it into transformative changes.

This issue highlights a team from industrial engineering — researchers and students who are working with Glen Raven Custom Fabrics on an ongoing project helping the company operate more efficiently (see story, page 18). Similarly, mechanical engineering undergraduates are dividing their time between developing prototypes of new and improved power tools and presenting their work to industry officials for consideration (see story, page 16).

As the manufacturing renaissance moves across the country, we are responding with research and solutions. This issue illustrates how we are producing students who not only have the skills to fill the next generation of jobs but also the skills to create them.

Preparing students to become leaders and entrepreneurs in technology fields is a team effort. Two important members of Clemson's team are alumni. One's contributions have led to two endowed chairs in our School of Computing (see story, page 28), while another has returned as a faculty member in environmental engineering and Earth sciences, where he is exploring avenues for safely storing nuclear waste (see story, page 20).

Also key to the College's team are seven new department chairs who have come to Clemson to share their experiences and visions (see story, page 2). They come from institutions from all over the country.

The economic development race will be won by communities that offer a workforce equipped to solve problems rapidly, maximize new technologies, and adapt to evolving processes and work-organization models. Clemson University's College of Engineering and Science is providing the facilities and faculty needed to prepare the next generation of talent to keep us at the forefront in today's globally changing landscape.

Sincerely,

Anand Gramopadhye, Dean

I D E a S

INQUIRY, DISCOVERY IN ENGINEERING AND SCIENCE SPRING 2015 COLLEGE OF ENGINEERING AND SCIENCE

Professor Brian Powell's $5.25 million grant funds research into safer ways to store nuclear waste.

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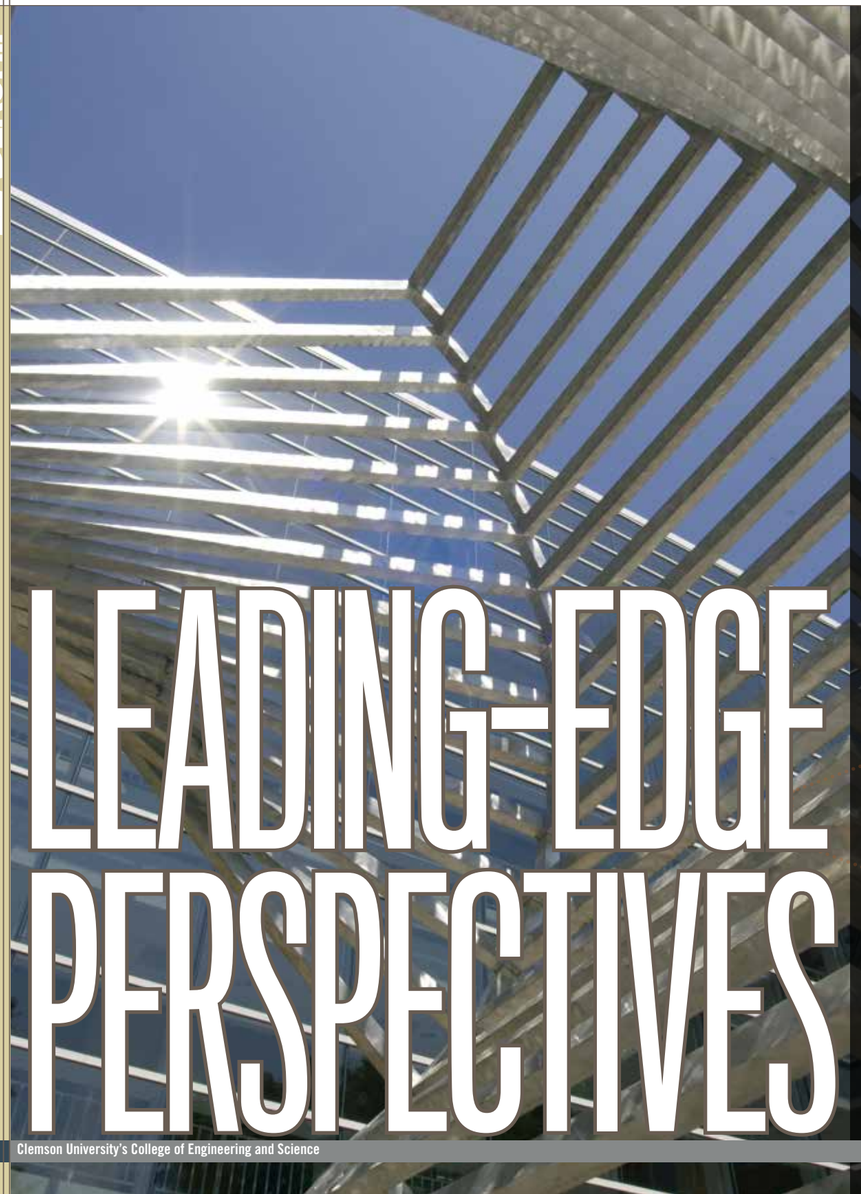

LEADING-EDGE PERSPECTIVES

There's never been a better time to be a part of Clemson University's College of Engineering and Science. In recent months, department chairs from a variety of institutions and geographic locations have become part of the Clemson family. These world-class researchers and innovators are engaging with students and faculty in academic and extracurricular efforts that impact state and global economies. Their leadership and expertise promise to keep Clemson on the forefront of new technologies — now and well into the future.

COLE SMITH

INDUSTRIAL ENGINEERING

B.S., Mathematical Sciences, Clemson University, 1996; Ph.D., Industrial and Systems Engineering, Virginia Tech, 2000

Smith came to Clemson in 2014 from the University of Florida where he was a professor in the Department of Industrial and Systems Engineering.

Why Clemson?

As an alumnus, I have a special affinity for Clemson, so when the opportunity to return as the IE department chair arose, I jumped at the chance. The department is bursting with talent, and the college is structured to facilitate interdisciplinary research. It's an exciting and unique opportunity that I simply couldn't pass up.

What is your vision for professions in your field?

Our students tackle IE challenges in several diverse areas, including supply chain and logistics, transportation, health care, biofuels and national security. IE students collaborate with experts across different fields and build a multifaceted skill set that encompasses theory, application and implementation of engineering principles.

How does IE fit into the state economy?

Clemson IE graduates have increasingly played a role in South Carolina's vibrant economy which embraces a wide variety of industries where our graduates are prepared to make significant contributions. These industries span the manufacturing, automotive, aviation, advanced materials and agriculture fields, just to name a few. Clemson IEs play a vital role far beyond the Palmetto State, though. The department's online Master's of Engineering degree program in supply chain and logistics has been incredibly successful. With expansion efforts in Asia, Clemson is now serving a global market for this specialized, online engineering education.

> *"The department's online Master's of Engineering degree program in supply chain and logistics has been incredibly successful. With expansion efforts in Asia, Clemson is now serving a global market for this specialized, online engineering education."*

World-class research programs are a key component of your department. Talk about some of those.

Our department is probably best known for its success in supply chain and logistics, transportation systems and workforce development. With the growth of our program, Clemson IE researchers have also made vital contributions to health care, information technology, biofuels and national security. These research efforts are resulting in tangible benefits in the field, while simultaneously garnering international recognition for outstanding scholarship. It's an exciting time to be an industrial engineer, and nowhere is it more exciting than at Clemson University.

EILEEN KRAEMER

C. TYCHO HOWLE DIRECTOR OF THE SCHOOL OF COMPUTING

B.A., Biology, Hofstra University, 1980; M.S., Computer Science, Polytechnic University 1986; Ph.D., Computer Science, Georgia Institute of Technology, 1995

Kraemer came to Clemson in 2014 from the University of Georgia where she was associate dean of the Franklin College of Arts and Sciences.

Why Clemson?

Clemson's School of Computing is a dynamic enterprise — the multiple division structure allows the school to be nimble and to develop specializations that set it apart from other computing programs. This allows us to attract top talent and to grow nationally recognized graduate programs.

How does a computing degree translate into jobs?

Computing is integral to nearly every industry, and demand for computing professionals is high and growing. Our graduates will have the opportunity to apply their skills in a wide range of enterprises including retail, finance and insurance as well as government, entertainment, health care and advanced manufacturing.

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How is the state economy affected by the computing field?

Every South Carolina industrial or manufacturing entity needs computer specialists with critical skills from at least one of our divisions: computer science, visual computing and human-centered computing. Consequently, I believe that we're having a significant impact on the state's growth and economic development. I am also confident that our alumni are making regional and national contributions. One example of this is Clemson's presence in the entertainment industry. Many major films produced in the U.S. today carry credits for faculty or alumni from our Digital Production Arts program.

What kind of global impact is your department making?

We have researchers looking at the health care space to apply virtual reality to train nurses and provide occupational therapy for patients, examine privacy implications in the context of electronic health records and develop computational jewelry to support mobile health applications.

Others are working to develop improved models of eye movement for humanoid animation, or improved methods of simulation, or to help young girls learn computational skills through dance. Still others work in cloud technologies or big-data analytics with applications in health, bioinformatics, intelligent transportation and smart electric grids.

It's exciting to be able to work with the excellent faculty and staff in the school to help them reach their goals and to set and achieve new ones.

JOE WATKINS

GENERAL ENGINEERING

B.S., Chemical Engineering, Auburn University, 1983; B.S., Electrical Engineering, Naval Postgraduate School, 1990; M.S., Astronautical Engineering, Naval Postgraduate School, 1991; Ph.D., Mechanical Engineering, Naval Postgraduate School, 2004

Watkins came to Clemson in 2014 from the United States Naval Academy, where he was general engineering program director.

Why Clemson?

I was excited by the vision expressed by the leadership in the College of Engineering and Science. The move from high school expectations to the requirements inherent in technical degree programs can be daunting. General engineering faculty and staff have a passion to educate students in engineering and to make the transition from freshmen to their chosen major as successful as possible.

How does general engineering prepare CES students for success?

It's clear that there is a great need for technical and scientific workers — regionally, nationally and globally. My goal is to help students understand the many career opportunities available to engineering majors. Making an informed choice about a major contributes to student success as they plan and move through their undergraduate courses. Students who have a positive freshman experience are more likely to stay in technology majors and graduate, creating scientists and engineers who'll be ready to assume productive roles in the workforce.

What makes Clemson's general engineering experience unique?

There are several general engineering programs that are having a positive impact in keeping students within technical degree programs. Our Residents in Science and Engineering (RiSE) Living-Learning Community is a unique residential community designed for freshmen in the College of Engineering and Science. RiSE combines the academic and residential experiences in order to foster academic success and facilitate professional development.

For more than 25 years, our Programs for Educational Enrichment and Retention (PEER) office has played a vital role in helping freshman minority students adjust to their new life at Clemson and excel academically in their chosen field of study. PEER helps students develop effective study skills, time-management techniques and self-discipline. Women In Science and Engineering (WISE) is a program that offers mentoring, guidance, counseling and other services that benefit women in the College of Science and Engineering.

> *The move from high school expectations to the requirements inherent in technical degree programs can be daunting. General engineering faculty and staff have a passion to educate students in engineering and to make the transition from freshmen to their chosen major as successful as possible.*

We are also experimenting with some academic innovations to help those general engineering students who encounter difficulties in the freshman courses. A split-semester program offers students the opportunity to retake classes they're finding challenging. In that way, they're able to stay on track with other members of their class. This program also allows students to accelerate their program and actually start their major one semester earlier.

JAMES BARKER COYKENDALL

MATHEMATICS

B.S., Mathematics, California Institute of Technology, 1989; Ph.D., Mathematics, Cornell University, 1995

Coykendall came to Clemson in 2013 from North Dakota State University, where he served as chairman for the Department of Mathematics.

Why Clemson?

When the chair position opened, a member of the search committee contacted me. I thought it such an honor to be considered at Clemson, that I felt obligated to apply.

Before this whole thing with Clemson started, I would have sworn that I would never chair again. I had done it at NDSU and was very, very happy being a professor again and devoting my time (almost) exclusively to my students and my research. As the process continued though, I got more excited about the opportunities and the challenges that this position presented. When offered the job, it was simply impossible to say "no."

What kind of jobs do you see mathematics students pursuing?

Mathematics is the cornerstone for all of science and engineering. The professions that require extensive knowledge of mathematics and mathematical sciences are growing in all directions. There are jobs that did not exist 10 to 15 years ago that require extensive knowledge of the mathematical sciences, and many "traditional" careers are demanding an ever-increasing degree of mathematical sophistication. As time progresses and

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technology advances, we must develop and expand our understanding of mathematics and mathematical sciences in order to move forward in a meaningful way.

World-class research is happening in mathematics. What are you working on?

Our department has an incredibly interesting spectrum of folks working in incredibly diverse areas. We range from some fairly "pure" mathematicians in number theory, analysis and algebra to others in pure and applied statistics, operations research, computational math and applied analysis. We also have researchers studying coding theory, biological mathematics, graph theory and climate change. The college structure encourages interdepartmental collaboration, and our Statistics and Mathematics Consulting Center (SMCC) serves researchers from Clemson University, commerce, industry and government by offering data analysis, statistical guidance and interpretation, problem solving, scientific computing and mathematical modeling.

JAMES R. MARTIN

GLENN DEPARTMENT OF CIVIL ENGINEERING

B.S., Civil Engineering, The Citadel, 1985; M.S., Civil Engineering, Virginia Tech, 1987; Ph.D., Civil Engineering, Virginia Tech, 1990

Martin came to Clemson in 2013 from Virginia Tech where he served as a professor of civil and environmental engineering and director of the Disaster Risk Management Institute.

Why Clemson?

It's an exciting time to be part of the Clemson team. We have an active and engaged faculty that has an outstanding reputation in research and scholarship. As a named department, we have resources to do some very special things.

> *Hardly a week goes by that we're not reminded that our country's infrastructure is beginning to show its age. South Carolina, and really the nation, will need civil engineers well-versed in building sustainable infrastructure.*

Today's civil engineering students will end up with jobs where?

Traditionally civil engineering has been involved primarily with the technical aspects of a project, but nowadays you have to go beyond that. When we talk about sustainable infrastructure, civil engineering has to be part of the big decisions — where a bridge is going to be built, how it's going to be financed, and who will be served by it. Sustainable infrastructure goes beyond just the engineering parameters that govern the design.

How is civil engineering at play in the state economy?

Hardly a week goes by that we're not reminded that our country's infrastructure is beginning to show its age. South Carolina, and really the nation, will need civil engineers well versed in building sustainable infrastructure. Clemson's location along the I-85 corridor, coupled with its academic computing power, offers unique opportunities. Clemson's cyber infrastructure gives us the chance to put together big data for civil systems. We can make a positive global impact with the information and research we can develop.

What kind of world-class research is your department engaged in?

Clemson civil engineering faculty are seeking answers to complex problems related to global sustainability and resiliency, including advanced modeling of hydro-climatic extremes, water and food security analysis, intelligent transportation systems, risk-based decision-making and robust design of engineered systems, sustainable construction materials and big-data analytics.

RAJ BORDIA

MATERIALS SCIENCE

B.S., Mechanical Engineering, Indian Institute of Technology, Kanpur (India), 1979; M.S., Materials Science and Engineering, Cornell University, 1981; Ph.D., Materials Science and Engineering, Cornell University, 1986.

Bordia came to Clemson in 2013 from the University of Washington where he served as chair of the Materials Science and Engineering Department.

Why Clemson?

Over the years, I had developed professional relationships with a number of the faculty members in the department and was impressed with the high quality of research and true spirit of collaboration. If we are going to solve the grand challenges facing the world today, we must make collaboration a core value.

What do you see for the future of your field?

I think that the future is bright for someone entering the materials science field today. Almost all the grand challenges that engineers work on will require new or better materials. The nature of materials science research is changing. Large databases and simulation capabilities are leading to integrated research programs which will accelerate discovery and engineering applications of new materials.

"Almost all the grand challenges that engineers work on will require new or better materials. Large databases and simulation capabilities are leading to integrated research programs, which will accelerate discovery and engineering applications of new materials."

How do advanced materials affect the state economy?

South Carolina is home to scores of advanced manufacturing operations. Virtually all of them make use of advanced materials. Large South Carolina companies with significant materials activities include GE, Boeing, BMW, Michelin and Milliken. Clemson, and more specifically the Department of Materials Science and Engineering, is in a unique position to play a large supporting role through our graduates, research and facilities including those at the Advanced Materials Research Center in Anderson.

What does world-class research look like in your department?

We have researchers exploring new and improved materials for health care, biotechnology, automotive, energy, environment, information technology and defense applications. Their research includes designing materials at different length scales to realize extraordinary electrical, mechanical, thermal and optical properties. The research in the department is primarily supported by NSF, DOE, DoD, NASA and industry.

MELUR RAMASUBRAMANIAN

MECHANICAL ENGINEERING

B.S., Mechanical Engineering, National Institute of Technology Durgapur (India), 1981. M.S., Applied Sciences, Miami University, 1983. Ph.D., Mechanical Engineering, Syracuse University, 1987.

Ramasubramanian came to Clemson in 2012 from the National Science Foundation where he served as lead program director for NSF IGERT, Integrative Graduate Education and Research Traineeship.

Why Clemson?

I saw growth potential and the strategic investments that the administration was making in cutting-edge interdisciplinary research areas.

What does your crystal ball say for the future of the ME field?

I think the future is bright for Clemson mechanical engineers. Our students are prepared to work well in the industry. Experiential education is key. Their depth of understanding on technical topics in the curriculum is achieved through excellent instruction. That is coupled with hands-on experiences through senior design, laboratories and Creative Inquiry programs. Many students take advantage of our outstanding co-op program. The ME Clemson experience makes our graduates top contributors to industry and hence the state.

What will some of those contributions to the state economy be?

Our innovation campuses — the Clemson University International Center for Automotive Engineering, the Clemson University Restoration Institute, the Clemson University Biomedical Innovation Center and the Advanced Materials Research Laboratory — provide a rich collaborative environment where Clemson researchers work with corporate partners. These centers add value through graduate education and research, which serves as an inducement for manufacturers to relocate to the state.

"Our innovation campuses ... add value through graduate education and research, which serves as an inducement for manufacturers to relocate to the state."

Tell me about some of the world-class research programs in your department.

Our faculty members are engaged in a variety of research areas that include energy, advanced materials engineering, biotechnology and nanotechnology. Their efforts are wide-ranging with translational results. One Clemson ME researcher is part of a global interdisciplinary team working to mitigate the issues that arise when children are born with undeveloped heart ventricles. Another is exploring ways to use water droplets to remove particulates from coal mine environments so they don't wind up in a miner's lungs. Their work isn't just life-changing. It is life-saving. ✻

CLEMSON EDUCATORS, MANUFACTURING INNOVATORS

Sustainability, efficiency and innovation: these are hallmarks of the most leading-edge manufacturing and materials research that's underway around the world right now. And they are key components of advanced manufacturing research coming out of Clemson's College of Engineering and Science.

The programs and production advancements that the college's faculty members find themselves spearheading are attracting the support of generous companies and organizations across the state. From computer modeling programs that create a more qualified workforce to safer solutions for storing nuclear waste, the innovations coming out of the college are contributing to prosperity, in the state and beyond.

Manufacturing innovation is widely believed to be what will help South Carolina win the economic development race, locally and abroad. For companies to compete globally, they need a flexible, highly skilled workforce. They must be equipped to maximize new technologies, adapt to evolving production processes and work organization models, and they must be able to solve problems rapidly.

WHAT'S THE SIMULATION?

Clemson's cutting-edge virtual reality programs spread to high schools and technical colleges nationwide.

by Paul Alongi

Virtual reality may have some of its deepest roots in the gaming community, but a growing number of experts at Clemson University and elsewhere believe the field could make its biggest impact in the workplace.

Simulations developed at the Clemson University Center for Workforce Development are helping students in South Carolina and nationwide learn the skills that employers need in a modern manufacturing plant. The simulations range from how an injection-molding machine works, to a demonstration of the forces that keep an airplane aloft.

One simulation the Clemson team has created puts students on the floor of an automotive plant. They navigate the factory from a first-person viewpoint, but instead of zapping zombies, as they might in a video game, they look for safety violations. Members of the team said that virtual reality helps reinforce textbook lessons and can even teach students how to avoid mistakes that could be lethal in real life.

The simulations are spreading to high schools and technical colleges across the country as the falling cost of technology reduces barriers to participation. The Oculus Rift virtual reality headset, for example, is expected to cost about $300 when it hits the market for the general public.

For the Clemson team, virtual reality is the unique part of a broader curriculum that also includes online lectures, textbooks and assessments. More than 1,000 students, about half in high schools, are now using the curriculum.

The team's name is CA²VES, which stands for the Center for Aviation and Automotive Technical Education Using Virtual E-Schools. Anand Gramopadhye, dean of the College of Engineering and Science, says virtual reality is an innovative way to widen the pipeline that supplies the highly skilled workers the nation needs to be competitive.

"Manufacturing remains key to prosperity in our state and across the nation," he says. "By teaching the skills needed in the next-generation workforce, our curriculum is helping shore up the middle class and putting families on the road to success."

Kapil Chalil Madathil, who directs the technology's development, says that interacting with virtual environments helps students retain knowledge.

"This element is adding another level of critical thinking," he says. "The learning curve is shortened when you do these kinds of exercises."

And it's important to shorten that curve when lives could be on the line. One simulation that Madathil and his team have developed teaches students how to remove a battery from a hybrid car. It sounds simple, but doing it incorrectly could lead to electrocution, he said.

The entire curriculum, including the virtual reality simulations, is shared at no cost with high schools and technical colleges.

The focus at Clemson is on the automotive and aerospace industries, but the lessons could apply broadly, explains Kris Frady, who oversees CA²VES as director of the Clemson University Center for Workforce Development.

"We're developing virtual reality for centers across the U.S.," Frady said. "We're at the forefront of a movement that is transforming the educational environment."

All simulations can be done on any computer connected to the Internet, Madathil says.

Each individual college or high school instructor can decide which simulations to use and how to use them. Most simulations are geared toward students studying at home.

"We aimed the curriculum at students who might have trouble making it to a classroom five days a week because of work, family or transportation issues," Frady says. "They can do most of the work from home and come in maybe once a week. The Internet is changing how education is delivered."

The virtual reality and online lessons grew out of a need to create more technicians for manufacturing in the wake of job losses during the Great Recession.

Now that companies are hiring again, economic development officials still see a growing need for workforce education, especially for workers hardest hit by global competition and technological changes.

The research is funded by the National Science Foundation's Advanced Technological Education (ATE) program. Gramopadhye was the principal investigator on the grant, which is now in its fourth year.

The team itself is a collaboration of several departments and includes Dr. Sabarish Babu, an assistant professor in the School of Computing. The team closely works with Babu's research group to incorporate state-of-the-art virtual reality interfaces to enhance the learning outcomes.

CA²VES is part of Clemson's land-grant mission to support economic development in the state. CA²VES also creates a pathway for students with technical-college associate degrees to continue their education by pursuing a bachelor's degree at Clemson.

"This is really important to Clemson's long-term strategic vision," Frady says. ✻

CA²VES is a partnership of the South Carolina Advanced Technological Education National Resource Center, Florence-Darlington Technical College, Greenville Technical College and Trident Technical College.

Students can access the simulations and curriculum through an online portal, which can be found at *educateworkforce.com.*

Right: Endowed chair Marek Urban displays self-healing polymers.

Far right: Urban works with graduate students in a state-of-the-art lab.

HOW SWEET IT IS

With sugar as an energy source, new technology could lead to car paint that fixes its own scratches

by Paul Alongi

The video shows a pair of gloved hands using a razor blade to cut a narrow strip in two and then press together the disconnected pieces. An hour later, the strip is whole again, slightly scarred but strong enough to be bent into an arch.

Marek Urban is using the video to illustrate the latest breakthrough in his research group's work with polymers that heal themselves like skin. The technology holds the hope of creating car paint and cell phones that fix their own scratches, military vehicles that patch their own bullet holes and hip replacements that could repair themselves.

While scientists have been working with self-healing polymers for about a decade, Urban's group has found a new key ingredient: sugar.

An earlier version of Urban's polymers relied on ultraviolet light, which is plentiful from the sun, to fuel the chemical reaction that bonds the pieces. The new version uses sugar as the energy source. The only other ingredients needed are natural levels of carbon dioxide and water in the air.

"It's a huge difference," Urban says. "Before, we needed UV light. Let's say you drive a car in Florida, and it gets hit by a rock. If the sun is shining, it's going to self-heal. But if you drive a car in Michigan or somewhere there is less sun exposure, it will take a long, long time. Now all you need is carbon dioxide and water."

Recognition for the group's work has come from all over the world. Urban and a member of his research group, Clemson doctoral student Ying Yang, described their findings in a paper that was published in the German scientific journal, *Angewandte Chemie*.

Yang also outlined the findings on a poster that won The Royal Society of Chemistry's Soft Matter Poster Prize.

Back home in Clemson, Urban's work with self-healing polymers was cited when he was named the J.E. Sirrine Textile Foundation Endowed Chair in Advanced Polymer Fiber-Based Materials in the Department of Materials Science and Engineering.

Anand Gramopadhye, dean of the College of Engineering and Science, says the foundation's support shows the level of scholarship Urban brings to the University and the global impact his research could have.

"The possibilities are exciting and virtually endless," Gramopadhye says. "I congratulate Dr. Urban on his success. Clemson is lucky to have him."

Urban explains that while others have worked on self-healing polymers, he has focused on making the technology user-friendly for industry.

"Our process is simple and based on the existing materials," he says. "You don't want to build a new factory to make polymers that are self-healing. You would like to take existing technologies to another level. Companies like that because it's an add-on value to already existing markets."

Urban has been working on self-healing polymers for more than five years. In 2009, he co-authored a paper on self-healing polymers with Biswajit Ghosh that was published in the journal *Science*.

Rajendra K. Bordia, chair of Clemson's Department of Materials Science and Engineering, called Urban a pioneer in the area of "stimuli-responsive and self-healing polymers." While Urban's research is exemplary, he is also passionate about creating the next generation of engineers and scientists.

"The students and post-doctoral researchers who work with Marek are learning about the kind of cutting-edge technology that will help keep South Carolina and the nation competitive," Bordia offers. "Their brain power will help fuel the 21st-century economy."

The technology that Urban is developing is also part of a demonstration project under the Department of Defense's corrosion prevention and control program. A polyurethane coating incorporating additives that enable the self-repairing mechanisms is being applied to large hangar doors at the Corpus Christi Army Depot in Texas.

Richard Lampo, a materials engineer with the U.S. Army Engineer Research and Development Center, is helping to evaluate Urban's concepts for self-repairing coatings for use in highly corrosive environments.

"Corrosion of infrastructure and equipment costs the military millions of dollars each year," Lampo says. "Coatings are the first line of defense against corrosion, and a coating that repairs itself when damaged, thus maintaining a barrier to the effects of corrosion, could potentially equate to significant cost savings while maintaining a high level of mission readiness." ✻

Josh Summers

Mechanical Engineering and TTi

DESIGN, BUILD, LEARN

From left to right: ME professor Joshua Summers; Summers' Creative Inquiry team trouble-shoots power tool inefficiencies; results from Fluor-Daniel lab industry-sponsored studies mean student work could one day be used in the marketplace.

Clemson mechanical engineering students benefit from real-world experiences with local industries.

by Heidi Coryell Williams

A lifetime ago, when he was in high school, Clemson mechanical engineering professor Joshua Summers built wind tunnels, and entered them into science fair competitions — successfully winning his fair share of blue ribbons and prize money. He used the cash to help pay for college. More importantly, he developed an appreciation for the practical application of one's studies.

Nearly three decades later, Summers finds himself molding the next generation of engineers, connecting undergraduate and graduate students alike with industry partners and getting them the experience and education they need to be successful in work and in life.

Real-world opportunity

Most engineering programs require a senior capstone project, but the industry-sponsored projects that Clemson's mechanical engineering program makes available, particularly to its undergraduates, are unique.

Summers leads a Creative Inquiry program of about a dozen mechanical engineering undergraduates who divide their time between developing prototypes of new and improved power tools and presenting their work to industry officials for consideration.

"I enjoy getting students the training and the experience of working on real projects," Summers says. "They're working on physical deliverables and making industry connections."

Lately that's meant building and testing power tools — hand sanders, drills and the like — on behalf of Anderson-based Techtronic Industries North America (TTi) to make those tools more portable, more efficient and quieter. "Hands-on" has meant doing design work for NASA, studying traction and resistance issues in the wheels of lunar vehicles. And it's meant working with Greenville-based BMW exploring metal foams for use in their cars' headlights, to improve their efficiency and hold up against harsh road conditions.

"Industry will always have interesting problems to consider," says Melur "Ram" Ramasubramanian, chairman of the mechanical engineering department and the D.W. Reynolds Distinguished Professor. "Our students are able to provide fresh ideas and innovative solutions. And by partnering with business, they gain real-world experience before they even graduate. It's a win-win."

Marketable products

Justin Moylan, a mechanical engineering graduate student from Mount Pleasant, works about 20 hours per week with TTi, but he started with the company last year, while working on his senior design project at Clemson. His study? Designing a solution to the noise emissions of power tools — in other words, to engineer something that would contain the sound but allow heat generated by the mechanism to escape.

"The end goal is coming up with something innovative, something novel," Moylan says, "and ultimately come up with a product TTi can get on the market."

He hopes his product will make its way to the market sometime in the next year or so.

Adam Bidwell, a native of Orangeburg, is a senior mechanical engineering student and is a part of Summers' current Creative Inquiry undergraduate research team. Summers advises the group, but he says the students are the ones actually working in the Fluor Daniel building lab, discussing, designing, writing about and then building the prototypes that will be presented to TTi managers, marketers and engineers.

Those exercises and experiences are setting the stage for a bright future: Adam is already talking to several companies about potential job opportunities.

"I've gotten so much experience. I've been able to take what I've learned and actually apply it to industry," Adam says. "It allows me to get industry experience without having to leave campus." ✻

Scott Mason

by Paul Alongi

ROCK & ROLL

Clemson University researchers team up with fabric maker to help find efficiencies

Industrial Engineering and Glen Raven

Scores of weaving machines created a deafening roar as a Clemson University team watched taut strands of yarn turn into neat rolls of fabric that will become outdoor furniture, convertible tops and a variety of other products. Researchers from Clemson's industrial engineering department were visiting Glen Raven Custom Fabrics' facility as part of an ongoing project that is helping the company operate more efficiently.

The team has developed computer simulations that have helped suggest new equipment purchases and ways of preventing backups. The simulations help the company adapt to changing business conditions, such as an increase in orders or the addition of new inspection machines.

"It's all about improving their manufacturing effectiveness, keeping their costs down and their customers happy," says Scott Mason, the Fluor Endowed Chair in Supply Chain Optimization and Logistics at Clemson.

"It's all about improving their manufacturing effectiveness, keeping their costs down and their customers happy."

— Scott Mason, Fluor Endowed Chair in Supply Chain Optimization and Logistics

Glen Raven is a global company with 3,000 employees and multiple brands, including its flagship, Sunbrella. Markets served include decorative, shade and automotive fabrics.

Clemson's team has focused largely on the manufacturing facility in Anderson, the company's largest, with 650 employees spread over nearly one million square feet.

Randy Blackston, vice president of operations for Glen Raven, says that he connected with Clemson because he wanted to be smart about growing as the company bounced back from the Great Recession of 2009.

"We are becoming a more complex business by entering new markets and offering new products," Blackston says. "This trend increases complexity. The simulation model is helping us manage the complexity. Becoming efficient as complexity increases demands that we use better tools to make decisions."

About $20 million in capital spending in three years has been based on the Clemson research, he says. It includes a robotic warping machine, the only one of its type in the world.

The Clemson team also developed models to test an "off-load table" to make sure that if the company made the capital investment, it would produce the desired result. The table is now part of Glen Raven's operation. As rolls are directed to a packing machine, the table takes the rolls off of a conveyor belt to avoid backups. When fewer rolls are coming down the chute, the rolls return to the line to get bagged.

"We modeled it with simulation and animation," Mason explains. "We could show them the rolls moving."

Several students have been involved in the research project, helping give the next generation of industrial engineers real-world experience. Katie Phillips, a junior from Rock Hill, started working at Glen Raven as part of a co-op program that usually lasts three semesters. She was asked to stay on longer.

"I love it here," Phillips says. "I think it's the perfect application for industrial engineering."

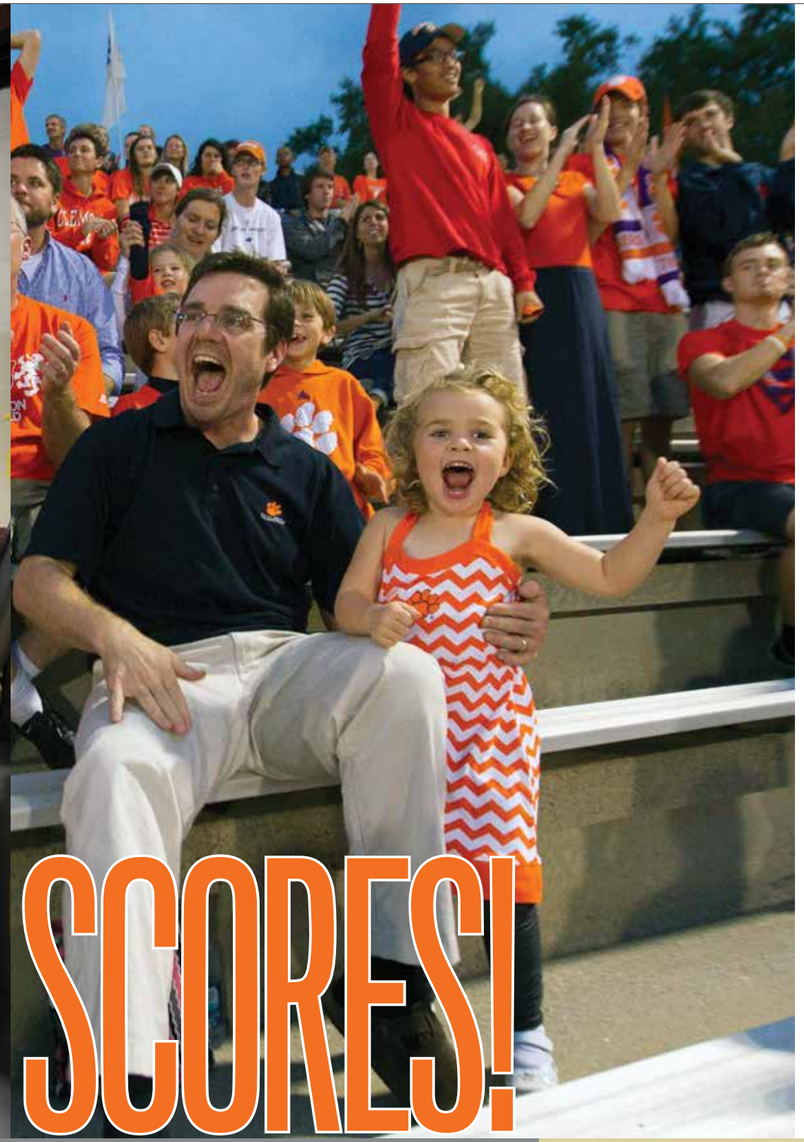
The Clemson faculty members overseeing the project are Mason and Kevin Taaffe, an associate professor and graduate coordinator for the industrial engineering program. The research project is part of the University's involvement in the Center for Excellence in Logistics and Distribution.

The team's focus this year is on the weaving room, but it has also analyzed operations in the yarn manufacturing and warping areas.

Cole Smith, the chair of the Department of Industrial Engineering, says the project is an example of what helps set Clemson research apart from other universities.

"We put a lot of our research into practice with industry," he says. "The Department of Industrial Engineering has made great strides in balancing our research portfolio between analytical development and industrial application.

Says Smith: "This project truly exemplifies how IE researchers improve industrial operations and lead economic development. Just as importantly, the Glen Raven project affords our students an unparalleled experience in applying the lessons they learn in the IE curriculum." ✻



SCIENCE SCORES!

Associate professor Brian Powell leads team that won $5.25 million federal grant to help ensure a cleaner, safer future for all.

by Paul Alongi

The soccer ball thumps off a player's foot, streaks by the goalie and lands at the back of the net. A cheer erupts from the stands of Historic Riggs Field, and the voices of Brian Powell and his four-year-old daughter, Mae, ring out in unison.

Clemson University orange runs in Powell's veins, whether he's watching a soccer game or working in the lab. Powell earned his master's and doctoral degrees from Clemson and is now an associate professor of environmental engineering and Earth sciences, holding the same job that his former adviser once did.

While the men's soccer team was on its way to a 3-1 victory over Wake Forest and the ACC title, Powell had another reason to celebrate.

Just a few hours earlier, he and his research team had finished an on-site review with officials from the U.S. Department of Energy. They knocked out the final details of a $5.25 million grant — one that will pay for three years of research toward finding the safest ways to store nuclear waste.

As principal investigator on the grant, Powell leads a team of more than 20 researchers from across the state. His co-principal investigators are Travis Knight of the University of South Carolina and Zheng Chang of South Carolina State University.

Experiments have been done on a small scale in labs, but a new "testbed" at Clemson will allow researchers to test underground storage methods on an intermediate scale in real-world conditions. The project also includes new instrumentation to collect 3-D data examining radionuclide behavior in experimental systems.

"If we can do that, then our confidence in these waste disposal scenarios will be much, much higher," Powell says. "This stands to be a premier research team and test site in the country."

The study is funded by the DOE's Experimental Program to Stimulate Competitive Research.

Powell has enjoyed soccer all his life, and he's enjoyed the way it connects him to his alma mater and his field. He used to play pickup games with Ara Amirkhanian, who recently finished his senior season with Clemson. Amirkhanian is the son of former Clemson civil engineering professor Serji Amirkhanian.

Powell values his time with family, as well, taking Mae to her first Clemson soccer game when she was three weeks old. The lively preschooler is also on his mind when he goes to the lab.

"I think for everybody in the department, there's a reason we do environmental research," Powell offers. "We want to make a cleaner, safer environment for our kids, for everybody's kids." ✻

Brian Powell

News from Around the College

(Center) Assistant Professor of Bioengineering, Frank Alexis

CES assistant professor makes national list of top researchers

Frank Alexis, a Clemson University assistant professor of bioengineering, is on a new national list of top junior faculty researchers who were chosen based on their number of patents. Alexis has six patents to his credit, the third most on a list of five "top translational junior faculty in 2013," according to the journal *Nature Biotechnology*.

Alexis developed new ways of delivering drugs in nanoparticles that are 10,000 times smaller than the cross-section of a human hair. Alexis' nanoparticles deliver drugs directly to the part of the body where they are needed. The technology helps make drugs less toxic, which is especially helpful for cancer patients.

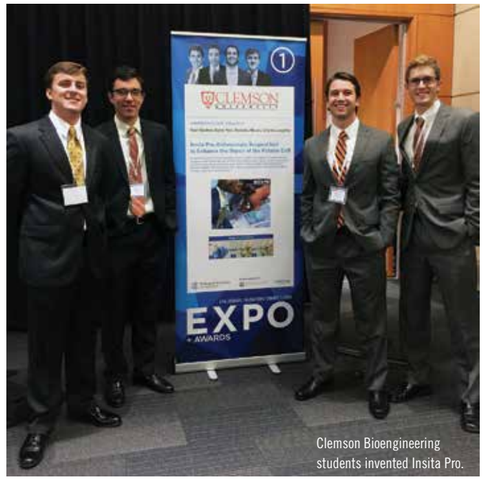
Inspirational professor honored by peers

A six-time professor of the year who has been credited with inspiring an entire generation of Clemson University industrial engineering students was honored by the Human Factors and Ergonomics Society. Professor Joel Greenstein's elevation to fellow recognizes outstanding achievement, consistently superior professional performance, exceptional contributions, personal service to the society and other meritorious accomplishments. Anand Gramopadhye, dean of the College of Engineering and Science, says Greenstein was instrumental in creating one of the country's most successful human factors and ergonomics programs. "Clemson University now boasts one of the most significant human factors programs nationally," he says. "I congratulate Joel on being named fellow. It confirms what we have long known: He is among the best of the best in his field."

(Left) Professor Anthony Guiseppi-Elie

Professor recognized for outstanding contributions to the chemical sciences

Anthony Guiseppi-Elie's work in bioelectronics, biosensors and biochips has been recognized by the Royal Society of Chemistry. The London-based professional society admitted him as a fellow. One of Guiseppi-Elie's projects that helped secure this prestigious honor could allow doctors to inject chips into the muscle of trauma victims to determine whether blood loss is life-threatening. The "biochip" is one of many innovations that Guiseppi-Elie has advanced in an accomplished career spanning nearly four decades, including eight years at Clemson.



Clemson Bioengineering students invented Insita Pro.

The GlucoSense diabetes product has been led by doctoral student Kayla Gainey

Bioengineering student team named finalist in national inventors competition

A team of Clemson University undergraduate students is among seven finalists for the 2014 Collegiate Inventors Competition, honoring the latest in student creativity and innovation. The team includes bioengineering students Ryan Gedney of Daniel Island, South Carolina; Charles Laughlin of Greensboro, North Carolina; Nicholas Marais of San Diego, California; and Taylor Pate of Kingsport, Tennessee. They were recognized for Insita Pro, an arthroscopic surgical tool that enhances the repair of the rotator cuff.

First Bosch fellow named

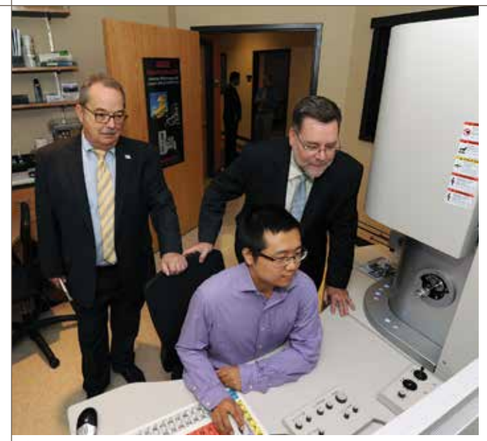
Vismita Sonagra

Clemson University's first Bosch fellow, Vismita Sonagra, is an automotive engineering graduate student who shares her knowledge of engines and love of learning from the classroom to the NASCAR track. Sonagra will receive $20,000 and will be encouraged to continue her outreach to boost K-12 education in science, technology, engineering and math. The award was made possible by a $500,000 grant from the Bosch Community Fund, which established an endowment in perpetuity for automotive engineering fellowships. The Bosch Community Fund is the charitable foundation of Robert Bosch LLC.

Research project evolves into a global business

What started as a Clemson University research project is turning into a global business that could supply diabetics with the low-cost testing equipment they need to manage their blood sugar. The product, GlucoSense, is aimed at helping diabetics in developing countries and other resource-poor settings do the daily testing that can help them prevent potentially fatal complications. The student-led GlucoSense team has started a company, Accessible Diagnostics, with doctoral student Kayla Gainey serving as chief technology officer.

News from Around the College



Yunsong Zhao works at an electron microscope. Behind him are Doug Griffith (left) and Phil Bryson, both of Hitachi High Technologies America Inc.

Laser focus on electron microscopes helps doctoral student win first fellowship

Yunsong Zhao, a doctoral candidate in electrical and computer engineering, is the first recipient of the Hitachi High Technologies America Electron Microscopy Annual Fellowship. The fellowship is available to Clemson University graduate students who use electron microscopes that magnify with atomic resolution. The fellowship strengthens ties in a longstanding partnership that has resulted in a cutting-edge Clemson University lab packed with Hitachi microscopes. Zhao's work focuses on making semiconductor lasers powerful while maintaining good beam quality for use in research and industry.

Tiger entrepreneurs prowl 'The DEN'

The College of Engineering and Science's Design and Entrepreneurship Network (The DEN) brings together students, faculty members and industry experts to explore ways to commercialize Clemson research. Partners range from venture capitalists to patent attorneys who help students move new technologies from the lab to the marketplace.

Students and partners gather in weekly meetings across campus, where students pitch their ideas so that the group can brainstorm ways to make them better and take them to market. "What was sown as a seed in the Department of Bioengineering has blossomed into a full-fledged entrepreneurship initiative across the College of Engineering and Science," says Dean Anand Gramopadhye. "The DEN is a nurturing entrepreneurial ecosystem that prepares engineers and scientists not only to take the next generation of jobs but to create the next generation of jobs. This is a major campus initiative by the College of Engineering and Science."

Clemson University signs pact with China's top civil engineering program

Clemson and Tongji universities will exchange civil engineering doctoral students as part of a new agreement that allows participants to earn a dual Ph.D. degree from both universities. The partnership marks the first dual Ph.D. program in civil engineering that Tongji has established with a U.S. university.

Doctoral candidates will be exposed to cultures and work practices from the world's two largest economies and position them for strength into the future. For Clemson's doctoral students, the agreement will open the door to a university that was ranked No. 1 in civil engineering by China's Ministry of Education. Candidates will also be immersed in the culture and language of a rapidly growing nation that has enormous civil engineering needs, ranging from roads, tunnels, and bridges to earthquake-resistant buildings.

The DEN

Floor plans and a footprint of the Solar Decathlon house Clemson students are building were recently unveiled.

Students unveil solar-powered, zero-energy home designed for South Carolina families

The Clemson University team participating in the U.S. Department of Energy Solar Decathlon 2015 recently unveiled its highly innovative, affordable design and construction methodologies that could revolutionize homebuilding in South Carolina and other southern states. Clemson and 16 challengers from colleges and universities across the country have begun the nearly two-year process of building solar-powered houses for the competition. It helps demonstrate technologies and designs that save money and energy while protecting local communities and boosting economic growth. The Clemson team includes more than 100 students and faculty from across the University collaborating on the design, construction and promotion of a prototypical, three-bedroom, 1,000-square-foot, low environmental-impact solar house that is cost effective in today's market and comfortable in South Carolina's climate.

Clemson math experts offer helping hand to researchers

A group of Clemson University math experts has begun working to expand a center that helps researchers analyze the massive amounts of data they collect as they study everything from energy use to the prevalence of canine heartworm in the U.S.

The Statistics and Mathematics Consulting Center serves researchers at the University, as well as in commerce, industry and government. Researchers whose expertise lies outside math and statistics bring their data to the center for help. The center is open to researchers from a broad range of disciplines. Services offered include data analysis, statistical guidance and interpretation, problem solving, scientific computing and mathematical modeling.

The center's mission is to boost research on campus, but it also offers help to outside agencies and businesses on a consulting basis.

Farmers use math to save water, as drought grips California

The "virtual farm" models that a Clemson University associate professor helped develop are taking on heightened importance as California's strawberry and raspberry growers cope with an unprecedented drought.

Lea Jenkins was part of a team sponsored by the American Institute of Mathematics that created models to help farmers in California's Pajaro Valley make best use of their land and water.

Jenkins said the models she helped develop could apply broadly beyond California and that she is looking for opportunities to use them in South Carolina. They could be used for farms of any size, she said.

Traveling program urges students to Emagine! future engineering careers

The College of Engineering and Science recently kicked off its 2015 Emagine! tour with a stop at the Clemson University Restoration Institute in North Charleston. Some 200 middle school students learned about engineering and science careers through a series of hands-on activities, including programming driverless vehicles, creating an air-powered car and using advanced materials to design a shatter-resistant plate. Over the next three months, the Emagine! team will visit four additional South Carolina cities to show students how the science and math they are learning in middle and high school apply to engineering in the real world. Now in its fourth year, Emagine! has reached nearly 5,000 students and parents across the Palmetto state.

Emagine! in Charleston, S.C.

News from Around the College

CU-ICAR students are required to create and manufacture a new vehicle prototype as part of their studies.

CU-ICAR students unveil Deep Orange 4 concept vehicle

The Clemson University International Center for Automotive Research (CU-ICAR) unveiled its latest concept vehicle at the Center for Automotive Research Management Briefing Seminar. Deep Orange 4, the concept vehicle program's fourth generation, is a BMW Manufacturing Co.-sponsored vehicle. The project focuses on product design and manufacturing innovations. The vehicle is based on the BMW X3 and is defined as a versatile vehicle that targets the niche market of performance-oriented SUV customers who want both best-in-class utility and space and an aggressive, sporty design. Students in Clemson's graduate automotive engineering program are required to create and manufacture a new vehicle prototype. 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 and is sponsored by a major manufacturer and a number of suppliers.

Serita Acker and her Women in Science and Engineering students.

WISE director collects award at magazine's STEM conference

The director of a Clemson University program that supports female engineering and science majors has been recognized by *Women of Color* magazine. Serita Acker, the director of Women in Science and Engineering (WISE), won the magazine's College-Level Promotion of Education award. WISE offers mentoring, networking, tutoring, professional development opportunities as well as a living-learning community for sophomore students (WISER). Acker also oversees several academic summer camps and outreach programs for students in the K-12 system.

President Clements joined Anita Zucker and Jonathan and Laura Zucker and scores of future scientists and engineers to celebrate the groundbreaking of a new, graduate education center in Charleston.

Clemson breaks ground for Zucker Family Graduate Education Center

Clemson University officials broke ground for a $21.5 million building that will help shape the future of the state's engineering landscape for generations to come.

President James P. Clements joined Anita Zucker and Jonathan and Laura Zucker for the ceremony celebrating the commencement of work on the 70,000-square-foot Zucker Family Graduate Education Center. Located at the Clemson University Restoration Institute in North Charleston on the former naval shipyard, the center will offer master's degrees and Ph.D.s in engineering. The program will eventually grow to approximately 250 students, 20 faculty, 40 researchers and staff. Office space in the center will be leased to industry looking to engage with faculty, students and researchers. The doors are expected to open in 2016.

Filipi to lead Clemson automotive engineering department

Zoran Filipi has been named automotive engineering chair and executive director of the Carroll A. Campbell Graduate Engineering Center at the Clemson University International Center for Automotive Research (CU-ICAR). He is the second chair in the department's history. He takes over for Imtiaz Haque, who helped create CU-ICAR and is retiring.

The automotive program is in the College of Engineering and Science. It started with three graduate students in 2006 and grew to more than 200 last year. All students study at the graduate level, pursuing master's and doctoral degrees. Nearly 20 faculty members, most based at CU-ICAR, are part of the department.

Filipi began work in Clemson's automotive engineering department in 2012. He is the Timken Endowed Chair in Vehicle System Design and a leading expert in advanced engine concepts and alternative powertrains, including electric and hydraulic hybrids. Filipi received his Ph.D. in mechanical engineering from the University of Belgrade in 1992 and joined the University of Michigan in 1994. There he was the director of the Center for Engineering Excellence through Hybrid Technology and the deputy director of the Automotive Research Center. He is a fellow in the Society of Automotive Engineers. ✻

(Center) New CU-ICAR director Zoran Filipi

LEGACY OF GENEROSITY

C. Tycho Howle gives back to his alma mater in appreciation of a great education

By Paul Alongi

A medallion hung from an orange and purple ribbon around C. Tycho Howle's neck as he stepped up to the microphone and told a room full of Clemson University faithful, "I'm glad to be home." The stage at his alma mater was a long way from his humble beginnings in a small South Carolina town, but Howle has never forgotten how important education has been in his success.

Howle, who has two degrees from Clemson and one from Harvard, became a pioneer in the e-business world and is an Atlanta philanthropist. A company he founded in 1983, Harbinger Computer Services, grew to having more than 40,000 active customers, 1,000 employees spread across eight countries and annual revenues exceeding $155 million.

"All along the way, a quality education has been the ticket for me to be able to move on to the next stage of life," he says. "I think most people know how important education can be to a successful career, but I take every chance I can to reinforce that notion with the young people I encounter."

Now retired, Howle was back at Clemson in October to help recognize Eileen Kraemer as the C. Tycho Howle Director of the School of Computing. Her directorship was the second endowed chair his family has supported. As part of his investiture ceremony, Clemson President James P. Clements gave both Howle and Kraemer endowed chair medallions.

"Tycho, we are grateful," Clements said during the presentation. "The two endowments from your family are important to preparing students to become leaders and entrepreneurs in technology fields."

Howle began life in Lancaster, a small city about 40 miles south of Charlotte. The son of a mechanic and seamstress, he was the youngest of eight brothers and sisters. Howle played football and ran track for Lancaster's countywide high school and did well on his SATs. He needed to pick a state-supported school and, as a Tigers fan, preferred Clemson.

Howle graduated with honors in physics and went on to get his master's degree in systems engineering, which was then in the electrical and computer engineering department. He worked at the consulting firm Booz Allen Hamilton for a few years before going to Harvard Business School to get a master's of business administration.

Howle served as both chairman and CEO for most of his 17 years with Harbinger.

In 2001, Howle founded nuBridges Inc., a firm that provided security and managed services to help businesses protect sensitive information. It was acquired by Liaison Technologies in 2011.

Howle lived most of his professional life in Atlanta and gave back generously to the city's causes ranging from the arts to programs that help the homeless, while also supporting Clemson.

"When someone is given a lot, it seems to me that you're also responsible for giving back," he says. " It seems the more generous we have been, the more good fortune we've had in our life. Some might think that is a cliché, but in our case, it's true."

Howle now lives in Naples, Florida, and also enjoys spending time at his home on Lake Burton in Georgia. He and his wife, Marie, have two daughters and six grandchildren.

"When I think about the people and organizations who have played a major role in my life, Clemson is in the top tier," he said. "It prepared me not only with a great education, but also with a good set of values and lasting friendships." ✻

CES Dean Gramopadhye, C. Tycho Howle and Eileen Kraemer, the C. Tycho Howle director of the School of Computing

Departments

Automotive Engineering

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Fast Facts

Tenured/tenure-track faculty: 13

Enrollment: (Fall 2014)

Undergraduate	N/A
Master's	143
Doctoral	61

Degrees awarded: (12/13; 5/14; 8/14)

Undergraduate	N/A
Master's	72
Doctoral	5

Research expenditures: $3,417,369 (FY14)

Research thrusts: systems integration, vehicle manufacturing, vehicle design and development, vehicular electronics

Bioengineering

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Fast Facts

Tenured/tenure-track faculty: 22

Enrollment: (Fall 2014)

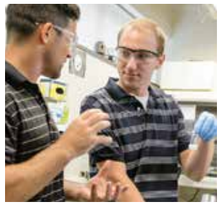
Undergraduate	309
Master's	44
Doctoral	82

Degrees awarded: (12/13; 5/14; 8/14)

Undergraduate	96
Master's	23
Doctoral	15

Research expenditures: $4,667,874 (FY14)

Research thrusts: biomaterials engineering, bioelectrical engineering



Chemical and Biomolecular Engineering

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Fast Facts

Tenured/tenure-track faculty: 12

Enrollment: (Spring 2014)

Undergraduate	227
Master's	1
Doctoral	33

Degrees awarded: (12/13; 5/14; 8/14)

Undergraduate	45
Master's	1
Doctoral	7

Research expenditures: $1,340,704 (FY14))

Research thrusts: advanced materials, kinetics and catalysis, energy, chemical and biochemical separations, molecular modeling and simulation, biosensors and biochips

Chemistry

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Fast Facts

Tenured/tenure-track faculty: 22

Enrollment: (Fall 2014)

Undergraduate	146
Master's	1
Doctoral	92

Degrees awarded: (12/13; 5/14; 8/14)

Undergraduate	28
Master's	4
Doctoral	12

Research expenditures: $2,785,383 (FY14))

Research thrusts: analytical, inorganic, organic physical chemistry, chemical education, interdisciplinary and nontraditional areas: polymer and materials chemistry, solid-state chemistry, bioanalytical chemistry, bioorganic and medicinal chemistry, computational chemistry, chemical physics

Glenn Department of Civil Engineering

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Fast Facts

Tenured/tenure-track faculty: 23

Enrollment: (Fall 2014)

Undergraduate	358
Master's	72
Doctoral	71

Degrees awarded: (12/13; 5/14; 8/14)

Undergraduate	152
Master's	41
Doctoral	13

Research expenditures: $3,050,794 (FY14)

Research thrusts: sustainable and resilient infrastructure

School of Computing

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Fast Facts

Tenured/tenure-track faculty: 31

Enrollment: (Fall 2014)

Undergraduate	581
Master's	138
Doctoral	86

Degrees awarded: (12/13; 5/14; 8/14)

Undergraduate	73
Master's	66
Doctoral	3

Research expenditures: $5,606,262 (FY14)

Research thrusts: computing foundations, data analytics, software engineering, cyberinfrastructure, networking, bioinformatics, computer graphics and animation, eye tracking, visualization, digital arts, intelligent and interactive systems, identity science and affective computing, virtual environments, human/computer interaction, pedagogical tools using tablet PCs and handheld devices

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Fast Facts

Tenured/tenure-track faculty: 29

Enrollment: (Fall 2014)

Undergraduate	533
Master's	91
Doctoral	99

Degrees awarded: (12/13; 5/14; 8/14)

Undergraduate	116
Master's	36
Doctoral	15

Research expenditures: $5,743,314 (FY14)

Research thrusts: optoelectronics, cyberinfrastructure, wireless communications, computer networks, nanoelectronic materials processing, biochips, semiconductor lasers, optical systems, integrated circuit design, high-performance computing, computer security, robotics, image processing, biological modeling, situation and threat assessment, power systems

Engineering and Science Education

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Fast Facts

Tenured/tenure-track faculty: 2

Enrollment: (Fall 2014)

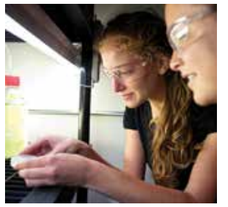
Undergraduate	0
Master's	0
Doctoral	10

Degrees awarded: (12/13; 5/14; 8/14)

Undergraduate	0
Master's	0
Doctoral	2

Research expenditures: $491,199 (FY 14)

Research thrusts: student motivation, problem solving, equity and gender issues in STEM disciplines, physics identity development, modeling of large-scale data, social capital, students' academic and career development and success



Environmental Engineering and Earth Sciences

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Fast Facts

Tenured/tenure-track faculty: 22

Enrollment: (Fall 2014)

Undergraduate	195
Master's	73
Doctoral	30

Degrees awarded: (12/13; 5/14; 8/14)

Undergraduate	60
Master's	28
Doctoral	7

Research expenditures: $3,184,441 (FY14)

Research thrusts: environmental chemistry, environmental fate and transport, hydrogeology, nuclear environmental engineering and science, biosystems engineering, process engineering, sustainable systems

Industrial Engineering

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Fast Facts

Tenured/tenure-track faculty: 13

Enrollment: (Fall 2014)

Undergraduate	315
Master's	200
Doctoral	31

Degrees awarded: (12/13; 5/14; 8/14)

Undergraduate	70
Master's	63
Doctoral	9

Research expenditures: $1,855,477 (FY14)

Research thrusts: supply chain optimization and logistics, human factors and safety in health care and in technologically complex environments, education and learning systems

Departments

Materials Science and Engineering

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Fast Facts

Tenured/tenure-track faculty: 15

Enrollment: (Fall 2014)

Undergraduate	114
Master's	13
Doctoral	49

Degrees awarded: (12/13; 5/14; 8/14)

Undergraduate	28
Master's	4
Doctoral	8

Research expenditures: $2,734,013 (FY14)

Research thrusts: manufacturing, characterization and structure/property/performance relationships of ceramics, glasses, polymers, photonics/optics, fiber-based materials, thin films, metals

Mathematical Sciences

James Coykendall, Ph.D.
Department Chair

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Fast Facts

Tenured/tenure-track faculty: 47

Enrollment: (Fall 2014)

Undergraduate	188
Master's	22
Doctoral	98

Degrees awarded: (12/13; 5/14; 8/14)

Undergraduate	40
Master's	31
Doctoral	14

Research expenditures: $1,352,751 (FY14)

Research thrusts: algebra and discrete mathematics, applied analysis, biomathematics, computational mathematics, experimental statistics, operations research, probability and statistics

Mechanical Engineering

M.K. "Ram" Ramasubramanian, Ph.D.
Department Chair

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Fast Facts

Tenured/tenure-track faculty: 29

Enrollment: (Fall 2014)

Undergraduate	712
Master's	134
Doctoral	58

Degrees awarded: (12/13; 5/14; 8/14)

Undergraduate	174
Master's	47
Doctoral	10

Research expenditures: $2,053,276 (FY14)

Research thrusts: transportation, energy, design, materials, manufacturing, fluids, complexity, multi-scale modeling

Physics and Astronomy

Mark Leising, Ph.D.
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Fast Facts

Tenured/tenure-track faculty: 25

Enrollment: (Fall 2014)

Undergraduate	75
Master's	4
Doctoral	58

Degrees awarded: (12/13; 5/14; 8/14)

Undergraduate	26
Master's	1
Doctoral	5

Research expenditures: $2,941,980 (FY14)

Research thrusts: astronomy and astrophysics, atmospheric and space physics, materials physics, surface physics, theoretical quantum physics

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U.S. Secretary of Commerce Penny Pritzker (center) visited South Carolina to take part in a roundtable discussion hosted by the Clemson University Center for Workforce Development. Her participation highlighted public-private partnerships that help create the next generation of engineers, scientists and technicians America needs to remain competitive. Clemson University President James P. Clements (left) co-chairs the U.S. Department of Commerce's National Advisory Council on Innovation and Entrepreneurship (NACIE); he recently was named chairman of the board of directors for the Association of Public and Land-grant Universities.