FOCUS

UAH Research Magazine // Spring 2017

FLYING RIGHT

UAH works with FAA to ASSURE drone safety

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NEW INCUBATOR

Bridging the gap from invention to innovation

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THE UNIVERSITY OF ALABAMA IN HUNTSVILLE

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Growth at UAH

Welcome to this edition of FOCUS, UAH's research magazine. Since my arrival at UAH nearly four years ago, I have been amazed at the continuous growth of the university. This growth can be measured in many ways to include student enrollment, introduction of new programs, hiring of faculty and research staff, and infrastructure improvements. I am often reminded, by those I meet in the Huntsville community, of how far UAH has come over a relatively short period. It is most certainly a privilege to be a part of this growth and to work alongside an exceptionally supportive group of community leaders – many of whom are UAH graduates.

This issue of FOCUS includes an article on the planned D.S. Davidson Invention to Innovation Center (I^2C) that is to be constructed adjacent to our College of Business Administration. We expect construction to begin this summer and completion about 15 months afterward. This 45,000 square foot facility will service a 15-county region and promote science and engineering startups. We believe the synergy between our College of Business Administration and the entrepreneurs that will reside in the facility will be a very positive force for the community. We are deeply grateful for the generosity of Dr. Dorothy Davidson in supporting this project.

Other articles in this edition speak to the strong collaborations between UAH and the community. For the past two years, we have been heavily engaged in the Federal Aviation Administration's Center of Excellence for Unmanned Aircraft Systems (UAS) research (known as the ASSURE program) which is led by UAH's David Arterburn through the Rotorcraft Systems Engineering and Simulation Center. Details of our contributions through this program are included in this issue's cover story. Our Student Focus feature is about a senior design class working with Northrop Grumman Corp. on UAS cybersecurity research.

We have included several articles that we consider research highlights of interest at UAH. They all involve collaboration within our community and serve as testaments to the community focus that UAH has historically provided. Such collaboration can be seen in our recent partnership with HudsonAlpha Institute for Biotechnology on a $31.5 million National Institutes of Health project, our strong partnership with Marshall Space Flight Center in atmospheric research, our internationally known work within our Center for Applied Optics, and our highly capable Center for Cybersecurity Research and Education. I hope you will take the time to look over these stories and I would appreciate hearing from you afterward.

It is our hope that this magazine helps to maintain our connection with the Huntsville community and our many sponsors. We are so privileged to do the work that we do and at the same time, we are proud of the accomplishments that our faculty, staff, students and alumni have achieved. My office is available to provide information on the efforts featured in this magazine or any other research project ongoing at UAH. ■

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COVER: Dave Arterburn, director of the Rotorcraft Systems Engineering and Simulation Center, with some of the center's drones.

THE UNIVERSITY OF ALABAMA IN HUNTSVILLE

A Tier 1 research university that is located within the second largest research park in the United States, UAH is considered one of the nation's premier research universities.

IN ALABAMA

1ST IN ALABAMA

- environmental sciences including atmospheric sciences
- math & computer sciences
- physical sciences

2ND IN ALABAMA
federally funded research expenditures

NATIONALLY

- **6TH** Federally financed Aeronautical/ Astronautical engineering research
- **11TH** Federally financed Atmospheric Sciences research expenditures
- **11TH** Federally financed Computer Sciences research expenditures
- **14TH** NASA R&D expenditures
- **18TH** Federally financed Business & Management research expenditures
- **17TH** Federally financed Astronomy research expenditures
- **25TH** Department of Defense R&D expenditures

RESEARCH

$441.9 million
Five-year contract and grant research total

$88.4 million
Fiscal 2015 research total

$5 million
Five-year license and royalty revenue total

ISSUED PATENT TOTAL – 68

SOURCE: National Science Foundation

ASSURE safety

Rotorcraft Center on leading edge of new FAA drone standards

A sunny future lies ahead for the unmanned aviation systems (UAS) industry once it has become fully integrated with all the rest of the aviation field, but for now safety concerns cloud the view, which is why the Federal Aviation Administration (FAA) currently does not allow operators to fly craft directly over people.

When it comes to drone safety, there are many questions. What happens when a drone falls out of the sky? What happens if the drone hits a person, a building or a car? And how likely are the people below it to be injured or killed? How serious will those injuries be? What safety devices might mitigate those injuries?

In safety, today's unmanned aviation systems industry (UAS) is akin to the auto industry in the early 1960s, as the federal government began gathering more information about vehicle crashes and the injuries they caused. Seat belts and air bags evolved from these studies and roads and vehicles became much safer. Drones are at the beginning of this evolution. Safety is a major concern of the FAA and insurers and the mechanisms and standards required to foster safety for the general public are being carefully developed.

The Rotorcraft Systems Engineering and Simulation Center (RSESC) at the University of Alabama in Huntsville (UAH) is working as part of the Federal Aviation Administration (FAA) Unmanned Aerial System (UAS) Center of Excellence and the Alliance for System Safety of UAS through Research Excellence (ASSURE) to develop those safety standards.

ASSURE is a collaboration of 23 leading research institutions and a hundred leading industry and government partners. ASSURE operates the FAA UAS Center of Excellence, which is dedicated to providing the agency and industry with research to maximize the potential of commercial unmanned systems.

UAH's RSESC has a unique skill set for a university research center in that its expertise applies to the engineering design, analysis, fabrication, integration and flight testing of a wide variety of vehicles, including aircraft, rotorcraft, satellites, spacecraft and unmanned systems.

The FAA has continued to evolve the standards for UAS entering the national air space, and flight over people standards are evolving as more research is collected. RSESC Director Dave Arterburn believes the evolution of these standards for flight over people will become

a touchstone for the burgeoning UAS industry to engineer better aircraft to keep people on the ground safer should a mishap occur.

"We've already done ballistic modeling and impact testing to show that small UAS collision dynamics are very different than that of metals found in manned aircraft. Over the last year we have collected a tremendous amount of data and conducted analysis to assist the FAA in their development of rule-making," Arterburn says, reaching for a tungsten ballistics test rod in his office and tapping it in the palm of his other hand. "This rod weighs half the weight of a typical UAS, but you would have substantially less injury with the drone than with this metal rod for the same impact energy."

INDUSTRY CRIMP

Not being able to fly over people without a formal FAA waiver has put a crimp in the expanding role of UAVs, an industry that is expected to generate 100,000 new jobs and $82 billion in economic impact once fully integrated.

"It's already a huge industry," Arterburn says. "You're starting to see the FAA be a little more streamlined as far as approving waivers now, and the commercial sector is coming along, but there's still a vast amount of airspace that's yet to be open to UAS because of the concerns over flying over people."

FAA Part 107, which covers unmanned aerial vehicles (UAVs) – commonly called drones – weighing less than 55 pounds, says operators must keep the craft within their line of sight and cannot fly over people who are not directly participating in its operation.

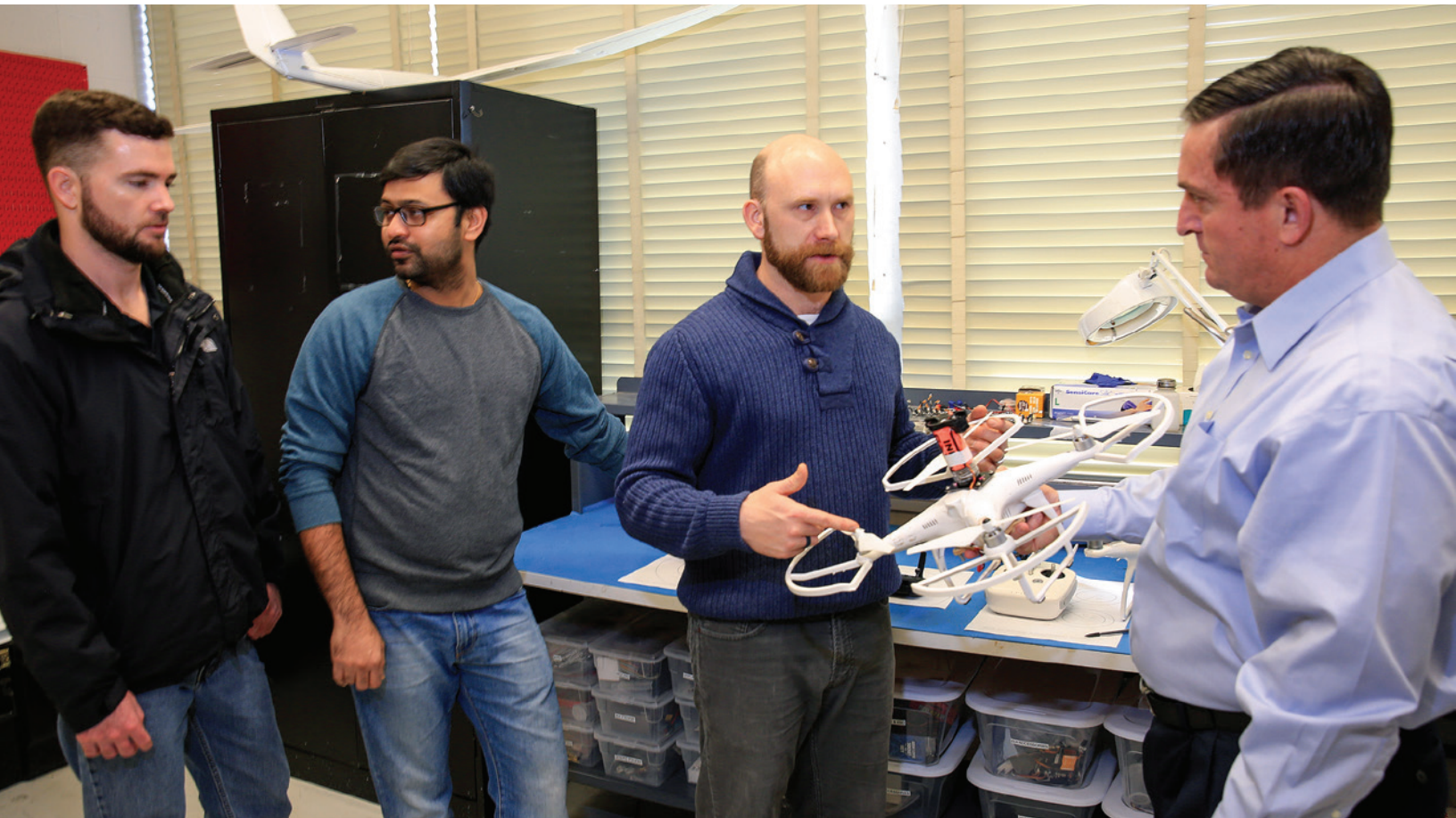
The major collision concerns regard possible injuries or fatalities arising from a direct drone strike of someone on the ground, and the possibility of lacerations from contact with the blades.

"The research we've been doing is looking at the severity of the injuries by the drones and into the probability that someone on the ground would be struck by a drone," Arterburn says. RSESC personnel are also performing tests for the drone industry and doing their own experiments with various technologies to lessen the probability of blunt force trauma from impacts and lacerations injuries from drone blades spinning at 7,000 rpm.

"The FAA's question is, what is the acceptable risk?" Arterburn says. That involves evaluating the severity of an impact when the collision occurs, as well as calculating the probability of someone being in a specific place at a specific time as the drone is coming down in that exact spot. "We have done the initial severity calculations and now we need to address the probability side of the equation as we continue to explore additional failure modes and their severity as part of future research."

Knowing the probability of human injury or death is essential to FAA rule-making for drone flight over people.

"Until we get the injury mechanics



defined, it's very difficult to make a case to the FAA to allow you to fly over people, especially in areas with crowds of people," Arterburn says. "The use of drones over people has a large number of applications that are beneficial to society once we have the right understanding of the risk." Use of drones for news coverage, protection for fire fighters and law enforcement and study of human traffic patterns in public are a few examples of what drones can provide while operating in and around the public.

The RSESC is using computer modeling, computational fluid dynamics, vehicle aerodynamics analysis and ballistics calculations to determine the severity of these impacts and evaluate various configurations of drones. Then, RSESC personnel use flight tests to verify their analyses and to gather real-world aerodynamic drag numbers to validate the modeling.

"We've made it possible for people to understand how the aerodynamics and ballistics of the vehicle affect how the drone falls," Arterburn says.

CRASH DUMMIES

Some of the safety research borrows from methodologies used by the U.S. Dept. of Transportation's National Highway Traffic and Safety Administration (NHTSA) and its vast accumulation of crash and injury data. Researchers have dropped 27 drones on crash dummies normally used in auto and aircraft crash tests and gathered data on the resulting damage to the dummies, with heightened focus on head and neck injuries. That data was compared with NHTSA standards to help determine safety margins and probabilities for various injuries from a falling drone strike.

◂ **Nick Balch**, **Nisanth Goli** and **Chris Dulling** in an RSESC lab with **Dave Arterburn**, director of RSESC.

"We've made it possible for people to understand how the aerodynamics and ballistics of the vehicle affect how the drone falls."

- Dave Arterburn

"What we found is that the impact energy of a drone would be defined as having a 70-90 percent chance of a fatality using old injury standards for metallic debris, while the test showed that the drone impact was actually a 12 percent chance of severe injury according to the Abbreviated Injury Scale," Arterburn says.

The Abbreviated Injury Scale (AIS) is an anatomical coding system created by the Association for the Advancement of Automotive Medicine to classify and describe injury severity. The scale is derived from actual automotive injuries with input from medical professionals treating those injuries. The AIS criterion helps form federal vehicle safety standards.

"We found that the injury potential of those vehicles is not as high as determined by traditional casualty methods of evaluation used by the National Test Ranges and Air Force Space Command," Arterburn says. "At impact, the drone made of plastic absorbs a substantial amount of the energy as it flexes, rather than transferring that energy to a person." The RSESC is working to quantify the degree of that flex to develop simplified test standards for different drones.

As the data has come in, Arterburn has made numerous trips to Washington, D.C., to brief the FAA on the evolution of collision research. RSESC has also communicated the results with the European Aviation Safety Agency (EASA), which is considering the data for use in formulating its own rules.

"Now we need to continue to develop the research to where the FAA can formulate their own rules for flight over people," Arterburn says. "Once the FAA standard is available, then the industry itself will begin to redesign its vehicles to be safer."

That's an evolutionary pattern that's evident in the automotive industry, and the RSESC is doing engineering, testing and research at the request of the drone industry to evaluate vehicle designs and propose mitigations such as blade guards and other methods for improving safety.

◂ **Dave Arterburn** and foreground drones intentionally crashed during FAA research.

"We are constantly asked by industry to evaluate mitigations such as blade guards," Arterburn says. "How do you make blade guards so that they are safe but they also don't affect the performance of the vehicle?"

RSESC research indicates the best way to do that might be to design in the guards or ducts, rather than using an add-on device later. "We are trying to lead the industry into integrating the guards into the design phase from the beginning," says Arterburn.

In RSESCs UAS lab, a test stand is dedicated to gathering aerodynamic data on integral blade ducts. The research looks promising, showing improved vehicle performance while preventing laceration injuries.

Researchers also are probing whether they can design drones to mitigate the possibility of injury by using deployment and deceleration devices like parachutes to help bring the vehicle down with less velocity and increase its inherent safety in crash situations. These devices also require the development of clear standards to ensure they can deploy properly under all conditions.

The use of drones to make deliveries raises its own set of safety questions.

"The interesting thing about delivery is that it's not just the vehicle, it's the payload that can also become a hazard," Arterburn says. "Once that payload is released or drops inadvertently, there's no way you can control how it will fall."

Research on hazards and safety is also informative for the insurance industry, which must write the policies that cover the costs of potential accidents.

"The analytics being done at present are widely varied and so the cost of the policies is higher," Arterburn says. "As we learn more about drone collisions and become more precise in our analytics, then you'll see insurance costs begin to come down."

DRONE BOOSTER

A major proponent of the value of drones to society and a booster of the industry, Arterburn has also been working with an Alabama Dept. of Transportation task force and the State Legislature on in-state drone legislation. He works with the Association for Unmanned Vehicle Systems International (AUVSI) through its Pathfinder Chapter and through UAH's largest in the nation, 27-student AUVSI student section, as well as with the U.S. Space & Rocket Center and GEO Huntsville to promote the use, safety and capabilities of drones, and especially their use by first responders.

"There's been a lot of work done to promote this industry, both in Alabama and nationally," Arterburn says. "We are seeing an increasing interest from people who are asking how this industry can help their own businesses.

"There's a real opportunity to see drones become commonplace, where they become a valuable tool that benefits business and society, and not just something to be feared," he says. "We need to focus on how drones can benefit business and society and how they can be used most effectively and safely in a wider segment of society." ■

EXPLORING HOW CELLS WORK

Dr. Eric Mendenhall, a UAH assistant professor of biological science and adjunct faculty member at Huntsville's HudsonAlpha Institute for Biotechnology, has teamed with Dr. Richard Myers, HudsonAlpha president, science director and faculty investigator, as co-principal investigators in genetic research using a procedure they developed. The research will help scientists better understand how cells function. Conducted at HudsonAlpha, it is part of a four-year, $31.5 million National Institutes of Health (NIH) Encyclopedia of DNA Elements (ENCODE) Project to further the construction of a comprehensive parts list of functional elements in the human genome. Dr. Mendenhall and Dr. Myers will study more of the approximately 1,500 transcription factors in our genes, of which only about 300 are currently characterized.

"We want to find out where the transcription factors bind on the DNA," says Dr. Mendenhall. That's important because the genome in each of our cells is identical. "The same blueprint is in virtually every cell of our body," he says. It's the transcription factor proteins that act as switches to turn on or off genetic functions that can turn a cell into a heart cell, a liver cell, or even a disease cell. Their location along the DNA strand, or genome, is critical to what role a cell will play during its lifetime. Developed by the pair at HudsonAlpha, a procedure called CETCh-seq first uses a genetic editing technique called CRISPR/Cas9 to design a reagent to modify a genome in liver cells. "Then we can genetically engineer them, and flag the transcription proteins," Dr. Mendenhall says. Then in the second part of the CETCh-seq method, a protocol called ChIP-seq tells them where the switches are located. Like an electrician testing circuitry, once researchers know where the switches are they can then test them to see which circuits they control, revealing new information about how the genome works – an area of science known as gene regulation. "For example, you can begin to ask what transcription factors are found near the gene that is causing disease," Dr. Mendenhall says. "This research helps to set the future for gene regulation." ■

ARMY SPACE AND MISSILE DEFENSE LEADERSHIP

As the senior civilian at U.S. Army Space and Missile Defense Command/Army Forces Strategic Command, James B. Johnson Jr., deputy to the commander, provides leadership for the command's space and missile defense programs, acquisition, personnel and resource management. He is one of only two three-star equivalent civilians on Redstone Arsenal.

"I see my job as enabling the commanding general to focus on the operational aspects of the command. At the end of the day my priority is making sure the entire command is laser focused on taking care of our soldiers."

Charged with defending the United States against ballistic missile attack, USASMDC/ARSTRAT space and missile defense professionals also provide data gathered from space to users in organizations across the Department of Defense, conduct operational missions, develop future capabilities, and conduct scientific research and technology development.

Johnson graduated with a bachelor's degree in electrical engineering and a master's degree in systems engineering from The University of Alabama in Huntsville.

"Earning two engineering degrees from UAH has opened so many doors for me over the years and helped prepare me to always be ready to take on more challenging assignments. I especially benefitted from and enjoyed learning about radar systems, simulation methods, the systems engineering process and engineering management."

Johnson has maintained many collaborative relationships with UAH in the years since graduating. SMDC works closely with UAH research organizations such as the Center for Cybersecurity and Research and Education, the Research Institute and the Systems Management and Production Center.

"UAH does a great job staying in tune with the needs of Redstone Arsenal."

Johnson began his government career with the Aviation and Missile Research, Development and Engineering Center located at Redstone Arsenal and served in engineering, test and program manager roles across the Dept. of Defense. He was selected for the Senior Executive Service in 2007. Johnson served as director of the SMDC Future Warfare Center before assuming his current position. ■

CREATING A DRONE BARRIER

Northrop Grumman Corp. challenged a UAH senior design class to electronically capture or disable an Unmanned Aircraft System (UAS), or drone, to keep it out of a designated zone. The challenge awards the class points based on how far the drone can be kept from the target. It spawned a cross-campus collaboration between the College of Engineering; the College of Arts, Humanities and Social Sciences; and the Systems Management and Production (SMAP) Center. A live demonstration to show the solution to Northrop Grumman officials was planned this spring at a farm near Gurley. Solving the problem required a diverse team. "Because we have mechanical engineers, computer programming engineers and industrial and systems engineers, we all have different areas of expertise, and thus are working on different tasks," says project lead William Klingbiel, a mechanical engineering major. It is hoped that the collaboration can expand in the future to include multiple competing teams. From left are advisors Dr. Brian Landrum, Dr. Earl Wells and Dr. Phillip Farrington; students Alyse Adams, Tevon Walker, Daniel Bernues, William Klingbeil, Zack Horvath and Faith Buckley; and Northrop Grumman employees Bob McCaleb, Britton Bush and Lawanda Reynolds. ■

BUILDING 'THE BRIDGE'

Business college, D.S. Davidson I²C team to support startups

The $14 million Dorothy S. Davidson Invention to Innovation Center (D.S. Davidson I²C) on the UAH campus brings evolutionary opportunities for the community in general, the business community, the evolving university and the College of Business Administration (COBA), according to the center's new director, the new COBA dean and business professors.

"The D.S. Davidson I²C is all about delivering a positive impact on accelerating technology development and new venture creation for students, founders, investors, mentors and other related parties," says its new director, Rigved Joshi, who comes to UAH after career experience in venture capital, private equity, startup incubation and intellectual property monetization, and who recently managed new ventures, strategy and innovation at Vanderbilt University.

"The D.S. Davidson I²C is truly a springboard for all students and faculty to collaborate in an interdisciplinary manner and benefit from UAH's network of research and corporate partners, the greater Huntsville entrepreneurial community and beyond."

Collaboration between the incubator and the COBA will include three key areas: entrepreneurial curriculum development, experiential learning and entrepreneurship events.

"The D.S. Davidson I²C's relationship with the COBA will be highly strategic and symbiotic," says Joshi. "The incubator will provide support for entrepreneurs who are interested in developing early-stage business ventures by providing them faculty and student support, office space, access to mentors and subject matter experts."

Additionally, Joshi says the incubator will leverage deep domain knowledge that COBA faculty bring to the table to further support and champion the efforts of incubator participants looking to launch their businesses.

The addition of a startup incubator brings widely diverse benefits and opportunities for UAH, says Dr. Jason Greene, the new dean of the COBA.

"I think it will help us as we transition as a university and we become more of a destination campus," says Dr. Greene, who came to UAH in July after serving as interim dean of the College of Business and the Henry J. Rehn Professor of Finance at Southern Illinois University. "We've transitioned from being a commuter type of environment to a more traditional environment, and that is especially so for the business college."

Dr. Greene says the D.S. Davidson I²C building's architectural plans provide a visual clue to how real-world entrepreneurship will be wedded to the academic world of studying and helping those businesses.

"When I look at the plans, I see a physical bridge designed in there that is connecting us. I've literally taken to calling it The Bridge," he says. "The Bridge is both symbolic and quite literal.

"It's brilliant to have the connection between the two buildings to facilitate the development of relationships between the two entities," Dr. Greene says. "It's going to bring benefits to the college, and the college is going to bring benefits to the businesses who are D.S. Davidson I²C clients."

Groundbreaking for the new building is scheduled in July. Dorothy Davidson, chief executive officer and chairman of the board of Davidson Technologies Inc.

▸ An artist's rendering of the **Dorothy S. Davidson** Invention to Innovation Center shows "The Bridge" between the center and the College of Business Administration building.

Rigved Joshi, Dorothy S. Davidson Innovation to Invention Center director, says the center is focused on "delivering a positive impact on accelerating technology development."

(DTI), provided a $5 million gift and the D.S. Davidson I2C has received a $3 million grant from the U.S. Dept. of Commerce Economic Development Administration (EDA). Funding was also provided by the UAH Foundation and the State of Alabama to make the incubator a reality.

The incubator will provide up to 40 start-up businesses with office and laboratory space in a 45,000-square-foot building projected to be complete in 2019. With a $500,000 EDA grant, the university is jump-starting the D.S. Davidson I²C through a Virtual Proof of Concept Center that is beginning to create functions that will be housed in the incubator building.

Utilizing resources at UAH to bring "shelved" technologies into the marketplace through identification and funding of entrepreneurs in a 15-county region and at UAH, the incubator will provide a range of services to convert ideas, research and prototypes into viable commercial products. The resulting startups will reside there for about three to five years before launching on their own.

Two business college centers, the Small Business Development Center (SBDC) and the Center for Management and Economic Research (CMER), will be immediately valuable to D.S. Davidson I²C clients, offering expertise in comprehensive business counseling, financing and business processes, according to Dr. Greene. In addition, the business college's primary educational objective can be a boost for entrepreneurs.

"We can customize our business education product to bring value to the business clients at the D.S. Davidson I²C," Dr. Greene says. Workshops and lunch-and-learn experiences can serve as quick learning tools for those new to the business world.

The new incubator arrives as an increasing population of traditional students who

stay on campus longer opens the COBA to new possibilities to help students better build important university and business networks, Dr. Greene says.

An example is the Executive Scholars Mentoring Program of Dr. William MacKenzie, the COBA's interim associate dean and an associate professor.

"The program is in its third year and has been very well received by both mentors and our students," says Dr. MacKenzie. "The purpose of the program is to pair some of our best and brightest business students with community leaders.

"We wanted to develop an experience that would be unique for these students and help them jumpstart their careers,"

he says. "This program connects our students with senior managers from established companies to help provide a unique learning experience."

Students are nominated for the program by faculty and then must apply to be selected to participate. This year, 17 students are paired with 17 mentors.

The incubator will provide all business students the chance to work closely with entrepreneurs, says Chakri Deverapalli. An entrepreneur himself, Deverapalli is the COBA's director of information technology and a lecturer.

"The D.S. Davidson I²C has the potential to generate the next 'unicorn' for our economy, with so many talented people within the university and the area," Deverapalli says. A unicorn is a private company valued at $1 billion or more.

He sees the D.S. Davidson I²C as becoming integral to the college's entrepreneurship development efforts.

"Currently, there are more than half a dozen courses in our business program that teach entrepreneurship, new product development and various aspects of entrepreneurship. Our students are taking these ideas to local and regional competitions," Deverapalli says. "With the help of the D.S. Davidson I²C, they get to test out the viability, or take the first steps of commercializing their ideas in business and technology."

Dr. Laird Burns, associate professor of management science, says UAH students from all colleges approach him often with intriguing ideas they are interested in pursuing, and the D.S. Davison I²C may offer them that opportunity.

"The D.S. Davidson I²C will provide many engagement opportunities for students in our colleges, including class and extracurricular projects, engagement in discussions and interviews with innovators about product and service development ideas, and learning how a good idea alone does not ensure success," says Dr. Burns.

"Graduate and undergraduate student projects that come to mind may include design and engineering support, hardware design, materials research, computer programming projects, developing a pitch to help sell an innovation, analyzing economic viability, developing a marketing plan to sell investors and customers, writing business plans, developing human resources plans, enhancing communications strategies, graphic arts support, writing student papers on the benefits and challenges arising from developing innovations or of being an innovator, surveys of product acceptance and competitive positioning and many other opportunities."

Likewise, the D.S. Davidson I²C should encourage faculty research.

"Faculty may, for example, work with innovators and students to enhance material properties, study the efficacy of senior design projects, or work with innovators in a longitudinal study to see how innovations and supply chains evolve over time," Dr. Burns says. "Faculty may study firsthand the applied 'science' of innovation, and study how innovation centers thrive and adapt over time to sustain viability."

There will also be an important opportunity to study economic development in Huntsville and the surrounding counties, Dr. Burns says, as well as an opportunity to directly engage regional communities in economic research.

"Huntsville has many companies that arose from opportunities for innovation,"' he says, "and the sharing of future innovation opportunities with our friends in surrounding communities can help improve economic success for all of North Alabama."

> "It's brilliant to have the connection between the two buildings to facilitate the development of relationships between the two entities."
> - Dr. Jason Greene

Dr. Greene calls those kinds of opportunities purposeful interactions.

"It's my hope that those kinds of purposeful interactions will bring about accidental interactions that will also be beneficial to both the college and the D.S. Davidson I²C clientele," he says, pointing out that the coming arrival of the incubator has already piqued increased business student interest. Once built, its physical presence on campus should generate even more.

"Over time, I think we'll see a culture get embodied in the college of working with the D.S. Davidson I²C clients," say Dr. Greene. "I think we'll play a big role in supporting and championing entrepreneurship, and in the university as a whole becoming more entrepreneurially active." ■

GLOBAL IMPACT

UAH, NASA partner in climate research that's essential here and abroad

Developing countries count on a solid partnership between The University of Alabama in Huntsville (UAH) and NASA to manage climate risks and land use.

To help make these decisions, they use SERVIR, a joint development initiative of NASA and the U.S. Agency for International Development (USAID). Partnering with regional organizations at SERVIR's global hubs, the agencies help developing countries use information provided by Earth observing satellites and geospatial technologies. SERVIR's goal is to help countries improve environmental management and resilience to climate change.

"UAH is a key partner and contributor to SERVIR, coordinating science activities at the SERVIR hubs and helping hub regions access and use the best of NASA science to address issues such as droughts, floods, weather forecasting, land use and food security," says Daniel Irwin, SERVIR director.

"Atmospheric Science and NASA's MSFC Earth Science Office collaborate closely on a wide variety of basic and applied research topics in the earth and atmospheric sciences," says Dr. Larry Carey, chair of UAH's Atmospheric Science Department and associate director of the Earth System Science Center. "It works well because we have a shared research vision to improve our understanding of the Earth/atmosphere system, to develop new technologies to observe and model weather and climate and to transition our research to operations for maximum societal benefit."

Home to the ESSC and the National Space Science and Technology Center (NSSTC), UAH's Cramer Hall provides a unique collocation strength that helps maintain a productive relationship, Dr. Carey says.

"Face-to-face interaction on a day-to-day basis promotes active collaboration, strong ties and an entrepreneurial spirit that benefits all equally," he says. "We can get more done when working together, which leads me to the next key element of our success – people."

The effort succeeds, Dr. Carey says, because of the unique capabilities, ingenuity and hard work of NASA scientists and UAH faculty, staff and students. Irwin agrees.

"The UAH Department of Earth System Science and Department of Atmospheric Science are incredibly valuable to SERVIR because the focus of each closely aligns with our objective to provide better knowledge of the Earth as a system and use Earth observations and geospatial technology for environmental decision-making," says Irwin.

"This collaboration enables us to tap into the expertise of UAH scientists and researchers and also provides us graduate research assistants that are well trained and aligned to our needs," he says.

On the other hand, he says SERVIR provides an opportunity for UAH researchers to work on a high-energy program to apply their research and expertise to real world problems in the developing world related to water and water-related disasters, food security and agriculture, weather and climate, and land use and ecosystems.

SERVIR hubs are located in Nairobi, Kenya, to serve Eastern and Southern Africa; in Kathmandu, Nepal, for the Hindu Kush-Himalaya region of Asia; at the Asian Disaster Preparedness Center in Bangkok, Thailand; and its newest hub at SERVIR-West Africa, launched in 2016.

"As a result," Irwin says, "SERVIR has a global impact."

A UAH champion to strengthen the NASA and UAH relationship is Dr. Robert Griffin, assistant professor of atmospheric science and director of the Alabama Remote Sensing Consortium (ARSC).

"Without Rob's leadership from the UAH side, we would not be where we are today," Irwin says. "He has helped in so many areas, such as supporting research, helping to build and coordinate a great UAH team of researchers that support SERVIR and identifying top notch graduate research assistants (GRAs). UAH GRAs Susan Kotikot, Kel Marker and Casey Calamaio have done excellent work for SERVIR and provided us with valuable knowledge through their research."

A native of Kenya, Kotikot came to the U.S. to work with SERVIR and is working to help mitigate crop damage by frost in Kenya to protect livelihoods.

Markert helped SERVIR to process imagery from ISERV, SERVIR's Earth-observing camera aboard the International Space Station, and is now a regional science associate for the program.

An expert in unmanned aerial vehicles, Calamaio researched forest mapping in Guatemala in collaboration with the Guatemalan Park Service, known as CONAP.

"I am the principal investigator at UAH for the science support we provide to SERVIR and I couldn't be more proud of the dozen-plus UAH researchers and graduate students that support SERVIR full-time," says Dr. Griffin. "It is truly impressive the global network and societal impact that Dan Irwin and his team have built up over the past decade."

There are only a handful of places in the U.S. where a NASA Earth science research office is co-located with a university, Dr. Griffin says. "Dan's and the SERVIR team's offices are quite literally right down the hall and this is a terrific resource for us in terms of developing collaborative research proposals and fostering ideas."

UAH collaborates with SERVIR by providing expertise in geospatial analysis, satellite remote sensing, environmental modeling, disasters, hydrology, land use and land cover and atmospheric science. The relationship partners UAH scientists and engineers, faculty and graduate students with NASA civil servants, contractors and program leads.

"Graduate students from all over the world come to UAH to be part of this exciting project, developing research projects and theses that help solve pressing environmental needs around the world," says Dr. Griffin.

Undergraduate students also get involved, learning about SERVIR and MSFC Earth science through guest lectures in their 100-level Earth system science courses.

"Because of our relationship with NASA projects like SERVIR, and the cooperative agreement that makes them possible, the UAH programs in Earth and Atmospheric Science are growing and our graduates are in high demand," Dr. Griffin says.

Besides SERVIR, Dr. Carey says the Earth Science Office also houses NASA's Short-

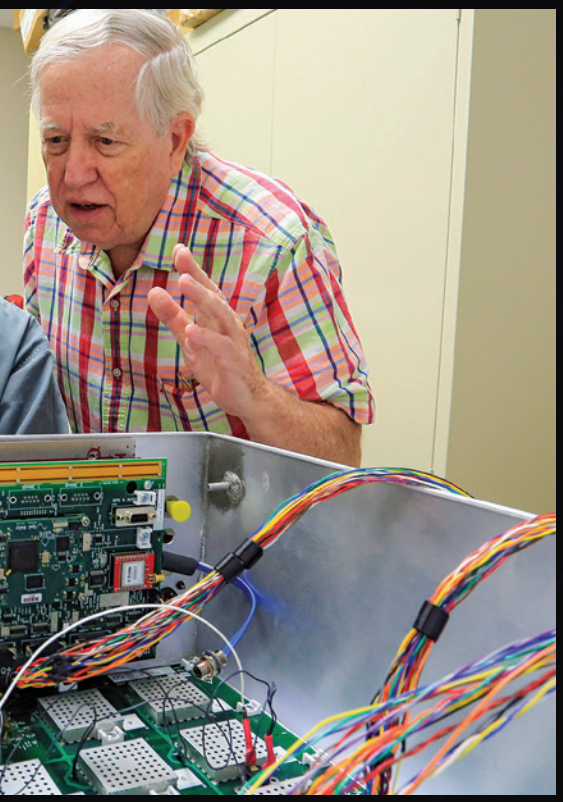
term Prediction Research and Transition (SPoRT) Center and the Global Hydrology Research Center (GHRC).

"Each center has a unique research mission and capabilities," Dr. Carey says. "UAH students, staff and faculty can be found actively participating in all of them. Assisting NASA with their various goals increases the research enterprise at UAH and provides the opportunity to jointly develop new ideas and compete for new research funding collaboratively with NASA."

There is purposeful overlap in UAH's research interests and those of NASA MSFC.

"In fact, we always include a NASA scientist on our faculty hiring committees to insure that we are pursuing excellence in areas that help maintain the vigor of our collaborative research enterprise," says Dr. Carey. "NASA benefits by working with multiple UAH research teams that provide unique knowledge, research capabilities and facilities."

UAH and NASA use ESSC research



▲ Mike Stewart, left, and Hugh Christian work at the NSSTC on wiring the Fly's Eye GLM Simulator (FEGS) shortly before shipment. FEGS has 30 photometers set to specific wavelengths of light and a wide-spectrum camera. It's flown on an aircraft above the cloud tops and was first used to validate GLM's performance.

labs in severe weather, radar, satellite remote sensing, atmospheric chemistry and lightning, as well as a large multi-processor computer system for climate and weather modeling and data assimilation. A new UAH facility is the Severe Weather Institute Radar & Lightning Laboratory (SWIRLL) that provides unique mobile and fixed research infrastructure within five high bays for mobile platforms, several interior labs, fixed roof top platforms and an operations center for studying severe and hazardous weather, radar meteorology, lightning physics and air quality.

UAH has worked closely with MSFC to design, fabricate and test the Geostationary Lightning Mapper (GLM), a new instrument launched in November on the National Oceanic and Atmospheric administration (NOAA) GOES-R satellite series. GLM is a single channel, near-infrared optical transient detector that can detect the presence of lightning continuously over the Americas and adjacent ocean regions with near-uniform spatial resolution of about 8-10 km.

GLM's hardware and software systems are based on legacy lightning instrumentation also developed jointly by UAH and NASA MSFC, including the NASA Optical Transient Detector (OTD) and Tropical Rainfall Measuring Mission (TRMM) Lightning Imaging Sensor (LIS).

"LIS and GLM provide unique observations for NASA and UAH to study fundamental processes in atmospheric convection, cloud electricity, climate, tropical cyclones, severe storms and other high impact weather," says Dr. Carey.

GLM observations will provide new tools for meteorologists to diagnose and forecast severe and tornadic storms. One such tool being transitioned to the NOAA National Weather Service (NWS) is the lightning jump algorithm, jointly designed and tested by UAH and MSFC. It provides valuable added severe storm warning time with high probability of detection and relatively low false alarm ratio.

"The transitioning of the lightning jump from research-to-operations (R2O) was greatly facilitated by the UAH-NASA staff and students working in the NASA SPoRT center with the feedback of NOAA NWS forecasters," Dr. Carey says. "A similar R2O paradigm has been successfully used by NASA and UAH with convective initiation and lightning forecasting tools based on the upcoming GOES-R Advanced Baseline Imager (ABI) instrument."

NASA's SPoRT Center and the NASA/MSFC Earth Science Office have benefitted from such cooperation, says Dr. Gary Jedlovec, who from 2002-2014 was the project lead and principal investigator for SPoRT and currently manages NASA/MSFC's Earth Science Office.

SPoRT transitions unique observations and research capabilities to the operational weather community to improve short-term weather forecasts on a regional and local scale.

"Through the SPoRT program, NASA and UAH provide unique research capabilities in support of NOAA and the NWS across the country," says Dr. Jedlovec. "Each organization provides complementary expertise, making the joint research effort stronger than most other collaborations.

Through this collaboration, the UAH faculty, staff and students have access to NASA equipment such as lab space and tools, hardware such as airborne instruments, data, and models, software and other resources, says Dr. Jedlovec.

"Students get to participate in cutting-edge NASA research that students at most other universities don't routinely have access to. The ability to partner with NASA scientists on peer-reviewed proposals boosts the research opportunities for faculty and staff," he says.

NASA partnerships provide UAH scientists with stronger connections with end users, Dr. Jedlovec says.

"Many Marshall scientists are adjunct faculty members and they mentor students, provide Graduate Research Assistant (GRA) opportunities and occasionally teach academic courses in areas of their unique technical expertise," he says. "Partnering with the faculty and research staff at the university brings technical expertise that MSFC does not have, making the joint proposals more competitive in the peer review process."

Collocation at the NSSTC builds strong partner teams that increase productivity and the value of the outcomes from research, he says.

"UAH scientists form a key component

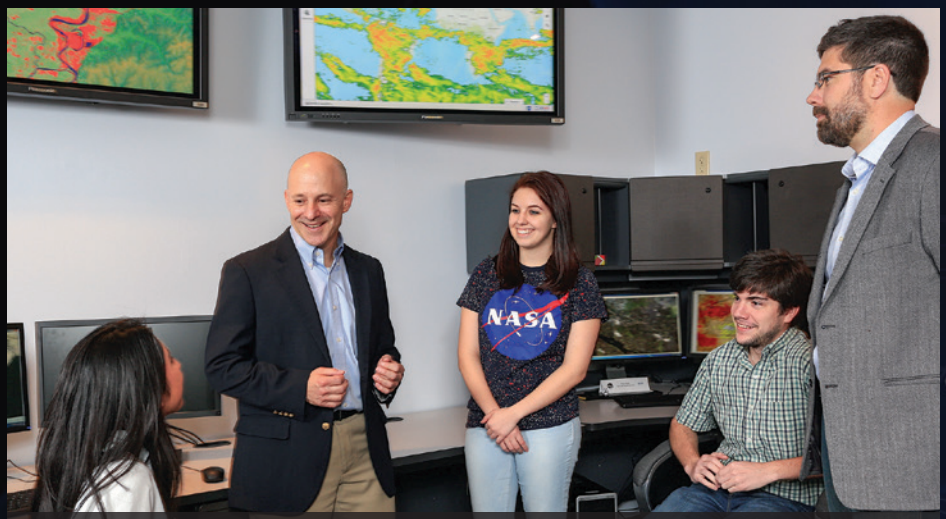
of our team by providing the expertise to analyze and process satellite data, derive geophysical parameters, develop and implement product training, and help transition products into end-user decision support systems," says Dr. Jedlovec. "These capabilities complement those of NASA and form a strong research team."

The lightning data archive for all of NASA, the GHRC was collaboratively founded between MSFC and UAH, says Dr. Sara Graves, director of UAH's Information Technology and Systems Center (ITSC) and professor of computer science. GHRC also houses many other types of NASA satellite and field campaign data that are received, managed and distributed by ITSC.

"Scientists worldwide come to the GHRC to get data, as well as tools to help them use the data," says Dr. Graves. "We also have many other projects for creating various tools and technologies. Some have been collaborative through MSFC and UAH, but a very important contribution that UAH is making to this is that UAH will bring in the National Science Foundation (NSF) and other sources of funding, such as the Dept. of Defense. We then incorporate those back into the GHRC and into other NASA projects."

ITSC is involved with MSFC in disaster and hazard work, as well, including using data to help during weather-related emergencies such as hurricanes and tornados and in other emergency situations such as earthquakes. UAH applies its data mining tools to help make the NASA data useful and relevant.

Internationally, UAH and MSFC work with the European, Japanese and German space agencies.



▸ MSFC's **Dan Irwin**, left, and UAH's **Dr. Rob Griffin** work together in NASA's SERVIR program to assist in integrating remote sensing and geospatial analyses into more effective decision-making for environmental management.

"We have a lot of partners that Marshall doesn't have, and vice versa," Dr. Graves says. "It broadens our community, from a computer science standpoint as well as the Earth science involved."

UAH and MSFC also worked together to relocate the Sally Ride EarthKAM to the U.S. Space & Rocket Center in Huntsville from the University of California-San Diego, providing grade school and high school students with the ability to capture Earth images from the camera aboard the International Space Station.

"It's been a fantastic and very productive professional relationship, but it has also provided for a lot of personal relationships," says Dr. Graves. "That always helps when you are trying to do collaborations on research or operating a data center."

The relationship has been durable, lasting over 20 years, she says. The two institutions support each other in research.

"Sometimes we write proposals together," Dr. Graves says. At other times, UAH will propose research and ask MSFC to collaborate.

Having the other weather agencies and organizations involved located at Cramer Hall is a plus, says Cindy Upton, MSFC Science and Technology Office operations lead and NSSTC facility manager.

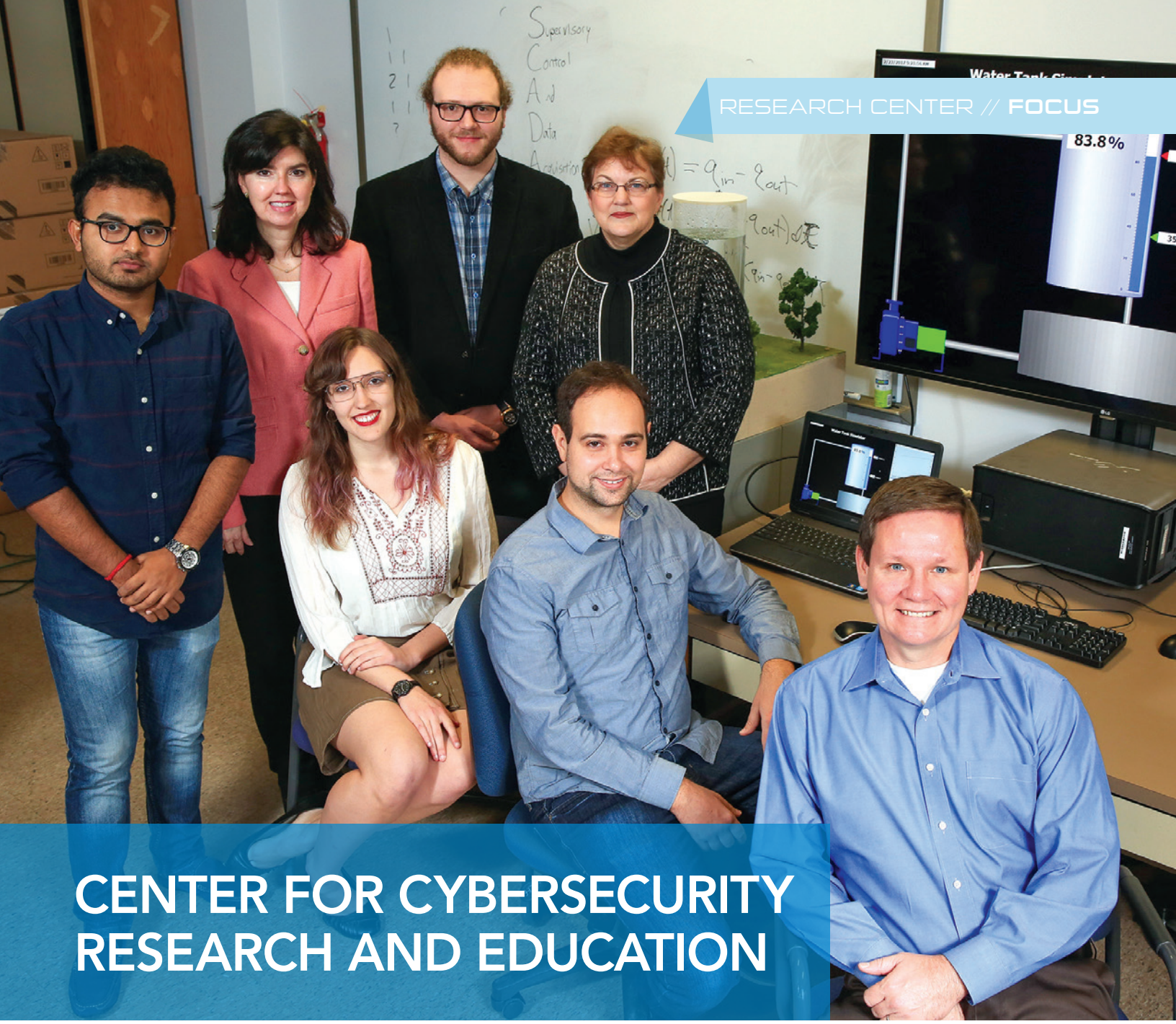
"In addition to NASA and UAH, we have the regional NWS office, which is part of NOAA; the Universities Space Research Association (USRA); and other partners who mutually benefit from the research done here," says Upton, whose roles include managing the UAH-MSFC cooperative agreement, federal and state regulations compliance and managing the workings of the partnership. "The National Weather Service uses some of the NASA models in their weather forecasting."

For UAH students, being exposed to NASA as they learn is invaluable to their future careers.

"It's great for our faculty and staff, but it is particularly excellent for our students," says Dr. Thomas Koshut, a UAH associate vice president for research and economic development. "When they walk into Cramer Hall, they don't see UAH people and NASA people, they see it as one critical mass of researchers working together."

NASA scientists teach classes and are involved in student qualifying examinations and the dissertation process for masters and doctoral degrees.

"In return," Dr. Koshut says, "NASA gets our students, with all of their youth, energy, exuberance and new ideas." ■



CENTER FOR CYBERSECURITY RESEARCH AND EDUCATION

▲ Center for Cybersecurity Research and Education in the SCADA Laboratory in UAH's Engineering Building. Standing, from left: **Rishabh Das**, **Sharon Johnson**, **Jesse Hairston** and **Kim Galkowski**. Seated: **SueAnne Griffith**, **Thiago Alves** and Director **Dr. Tommy Morris**.

Protecting vital systems and building future workforce

Work being done in cyber physical systems at The University of Alabama in Huntsville (UAH) Center for Cybersecurity Research and Education (CCRE) is grabbing attention in the broader cyber world.

Part of CCRE's mission is to research and develop cutting-edge protections for cyber physical systems that are lower-level computing workhorses found in industrial systems, civil infrastructure, medical devices and anywhere a computer interacts to monitor and control objects in the physical world. Cyber physical systems do many of the more mundane tasks involved in keeping our lights on, our water clean, our cars running and, for some, our medicine pumping or hearts beating.

Another part of CCRE's mission is to educate and develop the growing workforce needed to create, maintain and improve these systems.

In cyber physical systems, the center focuses particularly on supervisory control and data acquisition (SCADA) systems. These systems are the backbones that run operations in

everything from power plants to hospital elevators to hydroelectric dams. These systems are critical to a functioning society and are often overlooked and therefore can be vulnerable to attacks from hackers.

That's how at the end of 2015, for example, hackers broke in to SCADA systems at electric utilities in the Ukraine and turned off power serving 250,000 utility customers. And in early 2016, the U.S. Justice Department filed charges against seven hackers who hacked the SCADA system managing a flood control dam in Rye, N.Y. Luckily, there was no water behind the sluice gate at the time of the attack.

Against that backdrop, CCRE's efforts to improve cyber physical system protections and to find ways to bring security measures into the very beginning of the design and manufacturing processes, rather than to add them later, have attracted great notice. The center is expanding rapidly since Dr. Tommy Morris became its founding director in August 2015.

An associate professor in the Department of Electrical and Computer Engineering, Dr. Morris came to UAH after seven years at Mississippi State University, where he was director of the Critical Infrastructure Protection Center and associate director of the Center for Computer Security Research, among other posts, and worked with some organizations on Redstone Arsenal.

Now he finds his efforts accelerating in a more cybersecurity conscious world.

"We've had a tremendous amount of success with grants and contracts," Dr. Morris says. In February 2017 alone, the center won a $198,000 grant from the National Security Agency and was notified it is on track to receive a $243,000 grant from the U.S. Army Engineer Research and Development Center in Vicksburg, Miss. Both grants pertain to the center's SCADA cyber physical systems research, and Dr. Morris expects CCRE staff will increase again with the new work.

▸ Testing in the SCADA Laboratory are, from left, **SueAnne Griffith**, **Thiago Alves** and **Dr. Tommy Morris**.

The staff has already grown to include two research scientists and a staff assistant specific to the center, which also involves UAH faculty across computer science, information systems and engineering disciplines in its research and programs.

"The largest portion of our research is in SCADA," Dr. Morris says. Working with the CCRE, UAH faculty research the development of secure architectures for cloud computing and for systems embedded into a product in order to make security integral to the device itself.

The center collaborates with the U.S. Army's Aviation and Missile Research, Development and Engineering Center (AMRDEC) on Redstone Arsenal, as well as the National Science Foundation (NSF) and others. One NSF-funded project is to develop virtual SCADA systems, a full SCADA system simulation running on a computer from which researchers and students can safely mount cyber-attacks and test defenses.

That project also touches on CCRE's role in developing the cyber physical systems security workforce. The virtual SCADA systems will be used to provide hands-on cybersecurity education to students in four different engineering disciplines – civil, chemical, electrical and mechanical.

"We wanted to find a way students could continue learning their discipline, but at the same time be exposed to cybersecurity issues and training," Dr. Morris says. "These virtual SCADA systems are relevant to their degree. For example, we're creating a distillation tower like you would find at a refinery for chemical engineering, a mass damper used to steady tall buildings for civil engineering, a robotic arm like those on factory floors for mechanical engineering and an electric generator for electrical engineering students."

▲ Discussing a water tank simulator in the SCADA Laboratory are, from left, **Rishabh Das**, **Sharon Johnson** and **Jesse Hairston**.

Important components of the education and training function are the NSF CyberCorps Scholarships for Service (SFS) program and the U.S. Army Reserve's Private Public Partnership Initiative, or P3I, program.

A National Center of Academic Excellence in Information Assurance Education, a National Center of Academic Excellence in Cyber Defense and a National Center of Academic Excellence in Cyber Defense Research, UAH is in the fourth year of its five-year, $4.2 million NSF CyberCorps SFS program.

In the program, full-time scholarship students studying cybersecurity are provided full tuition, fees, books and a salary. In return, after graduation they work for the government one year for every year of scholarship.

"We have 23 students on NSF scholarships at the moment, and will award about 10 more this year," he says. "It's a really great program."

The CCRE is one of the largest P3I program participants in the country, with 22 reservist students who have scholarships to pursue cybersecurity degrees.

"The Army is trying to build a cadre of cyber-trained reservists," Dr. Morris says, "and we're helping do that for them."

Grants are also helping the center recruit new students to UAH, such as summer cybersecurity camps that have been held for eighth, ninth and 10th graders and teachers. The camps are funded by the joint NSA/NSF GenCyber program, which is allowing CCRE to offer a unique camp this year.

"We are partnering with the Alabama School for the Deaf and the Rochester Institute of Technology's National Technical Institute for the Deaf to offer a GenCyber camp for about 20 deaf or hard of hearing high school students in July, here on campus," Dr. Morris says.

The university's genuine commitment to cybersecurity has been key to the growth of the CCRE, he says.

"I've been enthused by the support from the faculty, staff, administration – everyone is on board," says Dr. Morris, "and that makes it fun and easier to be successful."

For Dr. Morris, the best is still on the horizon, as he leads a committee charged with establishing a bachelor of science degree program in cybersecurity and hopes it can be offered to students as soon as the fall of this year.

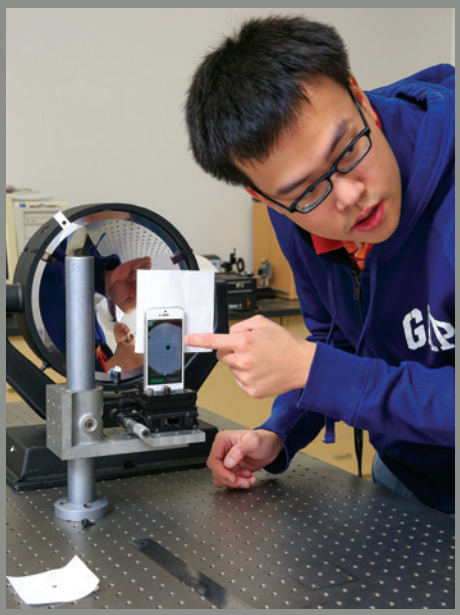
"The thing that excites me most is creating a bachelor of science in cybersecurity," Dr. Morris says. "It's going to have an impact for a long, long time." ■

CENTER FOR

APPLIED OPTICS

Puts cutting-edge research to work in the world

Associate Director of the Center for Applied **Optics Dr. Patrick Reardon** and graduate student **Bojun Zhang** use a cell phone app in conjunction with a Hartmann screen to check the curvature of a mirror.



Since its creation in 1985, the UAH Center for Applied Optics has been firmly established at the intersection of science and engineering, putting cutting-edge theory and research to use in everything from unique orbiting observatories to ubiquitous cell phones.

"We take concepts to creation," says Dr. Patrick Reardon, associate director of the center and an assistant professor in the Electrical and Computer Engineering Department. "We look at every phase in development including design, fabrication, test, assembly, alignment, calibration and even deployment of the optical systems."

Part of the growing appeal of optics research is the broad spectrum of applications, from cosmic to deceptively mundane. He points out that researcher Dr. James Hadaway makes regular trips to Houston in support of tests on NASA's next great space-based observatory, the James Webb Space Telescope, set for launch in 2018. Previously, Dr. Hadaway led the team that worked with the X-ray Calibration Facility at NASA's Marshall Space Flight Center in Huntsville to measure the performance of the telescope's 18 primary mirror segments in a simulated space environment.

But other CAO projects are decidedly down-to-Earth.

"We've been supporting a company in the Atlanta area that produces clear plastic domes to cover security cameras," Dr. Reardon says. "The optics and the cameras themselves have been getting better, so the protective domes they see through have to improve, too."

The center is developing instrumentation that will allow the company to rapidly test and then tune their injection molding system, so they can quickly produce domes and parts that meet customer expectations, he says. But the CAO goes further by helping educate those customers about dome designs and ways of optimizing their camera's capabilities.

It's the same kind of attention the CAO provides scientists needing custom equipment or expertise.

"We are often the bridge between researchers and the data that they want to obtain or measure. We develop the deployable optics that will get them the data they want to see," Dr. Reardon says. "A lot of places can process data. Our interest is to try to create better data."

The results of their work can improve lives, and sometimes save them. The CAO-affiliated Nano and Micro Devices Center (NMDC) has a 7,000-square-foot clean room facility where, among other projects, researchers from across the campus are developing plasmonic sensors that can be used in devices to detect biological or chemical agents and contaminants. Plasmonic sensors rely on how the electric component of light interacts with free electrons in a metal to create new effects, or metamaterials.

Dr. Yongbin Lin is putting plasmonic structures on the end of an optical fiber to develop a small, supersensitive device that can provide for the early detection of cancer or other diseases at a patient's bedside, or at a remote location in a developing country. The prototype is using 100-nanometer gold dots at the end of a micrometer-sized optical fiber. "It's angels on the head of a pin," Dr. Reardon says.

The CAO also has agreements with six companies for use of the clean room facilities in commercial development research. "I think those relationships are good for everybody, especially when we can involve students who are going to be the prospective employees for these companies," Dr. Reardon says.

Much of the center's recent research and project growth involves the Dept. of Defense, and he is seeing increasing growth with NASA. This CAO research covers applied and fundamental investigations, and can be seen in imaging and remote sensing systems, and in labs. An overall increase in government-related projects has helped the center acquire new equipment and at least two new positions, which Dr. Reardon expects will lead to new graduate student research assistantships.

The center also has rare manufacturing capabilities that include a free-form polishing machine. These allow for in-house production of things like off-axis parabolic mirrors and other optics of higher quality but in less time and expense than 10 or 15 years ago.

They are also devising innovative metrology tools to ensure optical parts meet required specifications, he says. A senior design team in the optical engineering program (OPE) has turned a cell phone camera into a device that can perform optical metrology of mirrors, and now a graduate student is advancing the research.

"My goal is to make a smart phone as good if not better than what is now a quarter-million-dollar instrument that you have to house in a lab to measure these surfaces," Dr. Reardon says.

The CAO has 14 staff and faculty members, including the NMDC, along with six affiliated faculty and approximately 20 graduate students working in master's and doctoral programs. UAH's OPE program was the first accredited undergraduate engineering optics program in the country recognized by the Accreditation Board for Engineering and Technology Inc.

Dr. Reardon says he is seeing growing interest in optical engineering from high school students considering universities, and hearing from more graduates interested in continuing or coming back for master's degrees. The center supports the optical science and engineering program at UAH, which offers an interdisciplinary doctorate supported by the electrical engineering and physics departments.

There are not many optics programs in the country, and UAH's benefits from its proximity to NASA, the Army and federal agencies on Redstone Arsenal in Huntsville, he says. It also benefits from the high-profile role optical technology plays in modern culture and devices.

"Optics in general is an amazing, enabling technology," Dr. Reardon says. "Working in optics means you get to work in biological sensing, or in rocketry to measure the flow of propellants with optical systems. Every industry is using optics – the Internet is based on optic devices and fiber optic lines, and your cell phone has a camera and a liquid crystal display. We're even working with companies that are developing intra-ocular lenses to correct for cataracts.

"There have been so many advances in our ability to produce things, to design, to analyze, to extract information to create completely new things," he says. "It's amazing." ■

▲ Associate Director of the Center for Applied Optics **Dr. Patrick Reardon** with master machinist **Chris Underwood** and the diamond turning lathe.

"We are often the bridge between researchers and the data that they want to obtain or measure. We develop the deployable optics that will get them the data they want to see. A lot of places can process data. Our interest is to try to create better data."

– Dr. Patrick Reardon

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