FOCUS

UAH Research Magazine // Spring 2018

STAR POWER

Deborah Barnhart's focus is on inspiring tomorrow's leaders

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APPLY WITHIN

The OTC helps UAH inventors protect their intellectual property

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THE UNIVERSITY OF ALABAMA IN HUNTSVILLE

KEY CONTACTS

VICE PRESIDENT FOR RESEARCH AND ECONOMIC DEVELOPMENT
Dr. Ray Vaughn
(256) 824-6100
Ray.Vaughn@uah.edu

ASSOCIATE VICE PRESIDENT FOR RESEARCH AND ECONOMIC DEVELOPMENT
Dr. Thomas Koshut
(256) 824-6100
Tom.Koshut@uah.edu

ASSOCIATE VICE PRESIDENT FOR CONTRACTS AND GRANTS
Dr. Robert Lindquist
(256) 824-2882
Robert.Lindquist@uah.edu

OFFICE OF RESEARCH SECURITY
Denise Spiller
Security Administrator
(256) 824-6444
Denise.Spiller@uah.edu

OFFICE OF SPONSORED PROGRAMS
Gloria Greene
Director
(256) 824.2657
Gloria.Greene@uah.edu

CONTRACTS AND GRANTS ACCOUNTING
Valarie King
Director
(256) 824-2231
Valarie.King@uah.edu

OFFICE OF TECHNOLOGY COMMERCIALIZATION
Kannan Grant
Director
(256) 824-6621
Kannan.Grant@uah.edu

OFFICE OF ENVIRONMENTAL HEALTH AND SAFETY
Bryce Morgan
Director
(256) 824-6053
Bryce.Morgan@uah.edu

OFFICE FOR PROPOSAL DEVELOPMENT
Dr. Virginia (Suzy) Young
Director
(256) 824-3448
Suzy.Young@uah.edu

CENTER FOR APPLIED OPTICS
Dr. Pat Reardon
Director
(256) 824-2530
Patrick.Reardon@uah.edu

CENTER FOR CYBERSECURITY RESEARCH AND EDUCATION
Dr. Tommy Morris
Director
(256) 824-6576
Tommy.Morris@uah.edu

CENTER FOR SPACE PLASMA AND AERONOMIC RESEARCH
Dr. Gary Zank
Director
(256) 961-7401
Gary.Zank@uah.edu

EARTH SYSTEM SCIENCE CENTER
Dr. John Christy
Director
(256) 961-7763
John.Christy@nsstc.uah.edu

INFORMATION TECHNOLOGY AND SYSTEMS CENTER
Dr. Sara Graves
Director
(256) 824-6064
Sara.Graves@uah.edu

PROPULSION RESEARCH CENTER
Dr. Robert Frederick
Director
(256) 824-7200
Robert.Frederick@uah.edu

RESEARCH INSTITUTE
Dr. Steven Messervy
Director
(256) 824-6881
Steven.Messervy@uah.edu

ROTORCRAFT SYSTEMS ENGINEERING AND SIMULATION CENTER
Dave Arterburn
Director
(256) 824-6846
arterbd@uah.edu

SYSTEMS MANAGEMENT AND PRODUCTION CENTER
Dr. Gary Maddux
Director
(256) 824-2679
Gary.Maddux@us.army.mil

D.S. DAVIDSON INVENTION TO INNOVATION CENTER
Rigved Joshi
Director
(256) 824-6058
rigved.joshi@uah.edu

Dr. Ray Vaughn
VP for Research and Economic Development

Progress and Pride at UAH...

Welcome to this edition of FOCUS, UAH's research magazine. I would invite you to look over the various articles we have included in this issue as each of them represents progress at UAH and tremendous pride in our students, faculty, and staff. Each time I choose topics to report on, I have difficulty narrowing down the many I wish to share to the few we have space for. This time I wanted to include a couple of articles on our work in advanced manufacturing; a true success story in our cybersecurity program in reporting vulnerabilities to the government; an update on our business incubator/accelerator; a truly successful year that our Office of Technology Commercialization (OTC) experienced; a ballistics-testing facility that we operate; and a profile of one of our many successful graduates – Dr. Deborah Barnhart, CEO and executive director of the U.S. Space & Rocket Center (USSRC).

We are proud to call Dr. Barnhart one of our graduates – she has certainly made an international impact in her leadership role at the USSRC. People worldwide know of Huntsville because of Space Camp. Not being one to rest on her laurels, Dr. Barnhart continues to grow the offerings at the USSRC and most recently received a promise of $10 million in state funding to support a Cyber Camp. UAH partners with her in teaching Cyber Camp programs, and we look forward to expanding that relationship as the program grows. We are most certainly appreciative of all that Dr. Barnhart does for this community and our university.

For this issue, we choose to tell you about a wonderful and talented assistant professor in UAH's Department of Electrical and Computer Engineering – Dr. Maria Pour. Maria is the winner of a National Science Foundation (NSF) CAREER Award, one of the NSF's most prestigious. The award provides five years of funding to support her research in the area of phased array antennas. Applications for her work include remote sensing, advanced radar, next-generation mobile communications, and wireless communications for military, space, and satellites. She seems a perfect fit for this community.

Commercialization and protection of intellectual property is always an important function at a research university, and UAH is no exception. Our OTC is charged with this responsibility. During this past fiscal year, they filed 42 invention disclosures and 27 patent applications, and 6 patents were issued to UAH inventors. Please take a moment to learn more about the OTC by reading the article we have included in this issue.

Many are unaware that UAH operates the Aerophysics Research Center on Redstone Arsenal that conducts hypervelocity and high-energy testing for our customers. This 67,000-square-foot facility houses a rare commodity – a two-stage light-gas gun capable of meeting Department of Defense high-energy impact-study requirements. UAH has operated this facility since 1991, and it continues to serve a variety of customers today.

We also report on a new group of cybersecurity scholarship students that have a service obligation to the government upon graduation. UAH is the fourth-largest NSF Scholarship for Service program in the nation and the largest in Alabama. In addition to training the next generation of cyber engineers, our research staff is also making a national impact through the discovery and reporting of serious vulnerabilities in industrial control systems. One such success story is included in this issue.

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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THE UNIVERSITY OF ALABAMA IN HUNTSVILLE

A Tier 1 national 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

- **5TH** Federally financed Aeronautical/ Astronautical engineering research
- **13TH** Federally financed Atmospheric Sciences research expenditures
- **10TH** Federally financed Computer Sciences research expenditures
- **13TH** NASA R&D expenditures
- **20TH** Federally financed Astronomy research expenditures
- **18TH** Federally financed Business & Management research expenditures
- **25TH** Department of Defense R&D expenditures

SOURCE: National Science Foundation

RESEARCH

$463 million
Five-year contract and grant research total

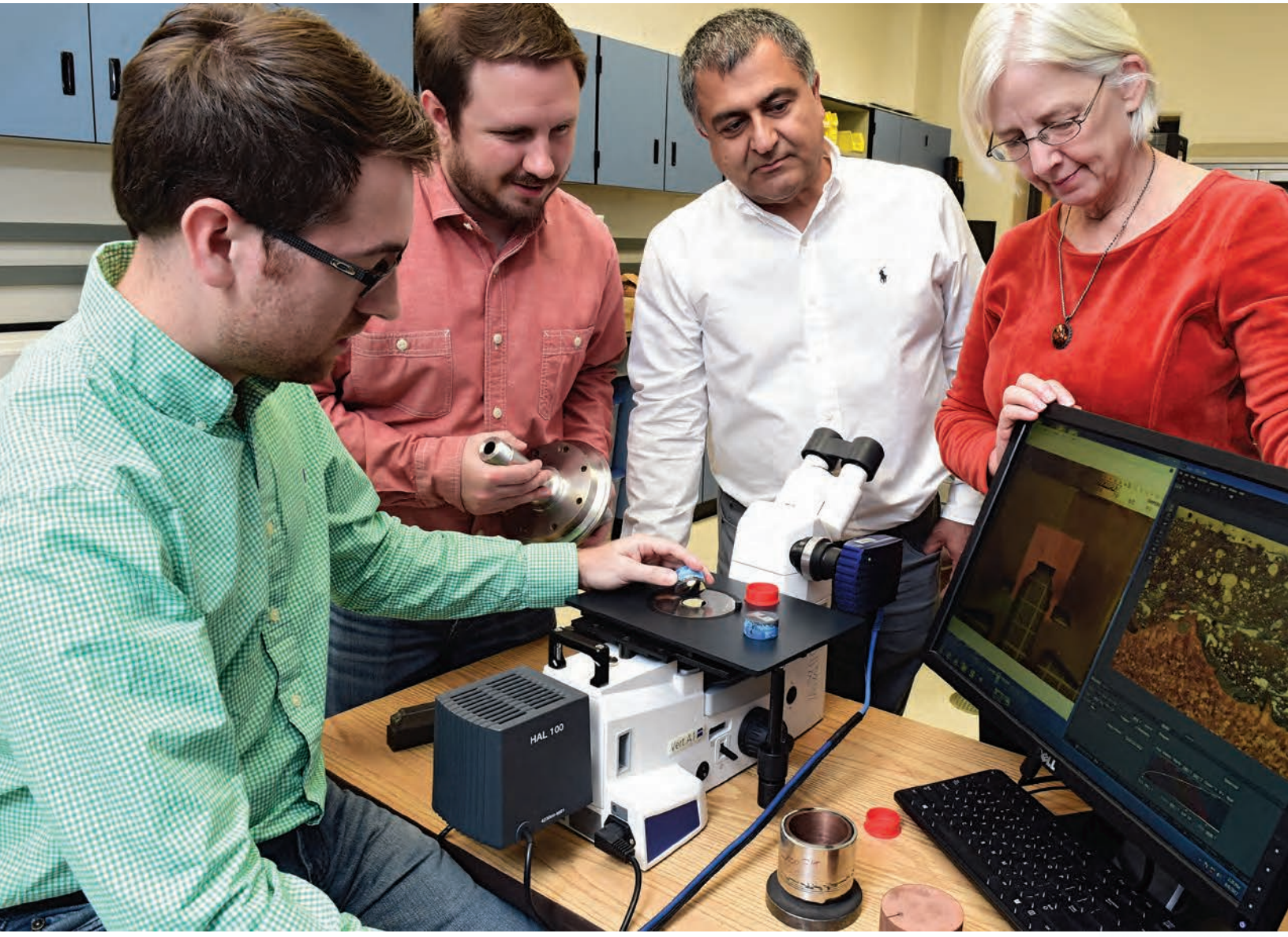
$5 million
Five-year license and royalty revenue total

$96.9 million
Fiscal 2016 research expenditure total

ISSUED PATENT TOTAL – 75

UAH STUDENTS INTEGRAL

to successful hot-fire test of new NASA igniter



▲ **Majid Babai** (center), advanced manufacturing chief at NASA's Marshall Space Flight Center in Huntsville, Alabama, along with **Dr. Judy Schneider**, mechanical and aerospace engineering professor at UAH, and graduate students **Chris Hill** and **Ryan Anderson** examine a cross section of the prototype rocket engine igniter created by an innovative bi-metallic 3-D printing advanced manufacturing process under a microscope. *(Credit: NASA/MSFC/Emmett Given)*

When engineers at NASA's Marshall Space Flight Center (MSFC) wanted to test the strength and reliability of their newest, additively manufactured rocket engine igniter, they turned to Dr. Judy Schneider for help. A professor of mechanical and aerospace engineering at The University of Alabama in Huntsville (UAH), Dr. Schneider and her students study the correlation of environmental effects on the mechanical performance of structural materials, and in particular, those produced by advanced manufacturing processes.

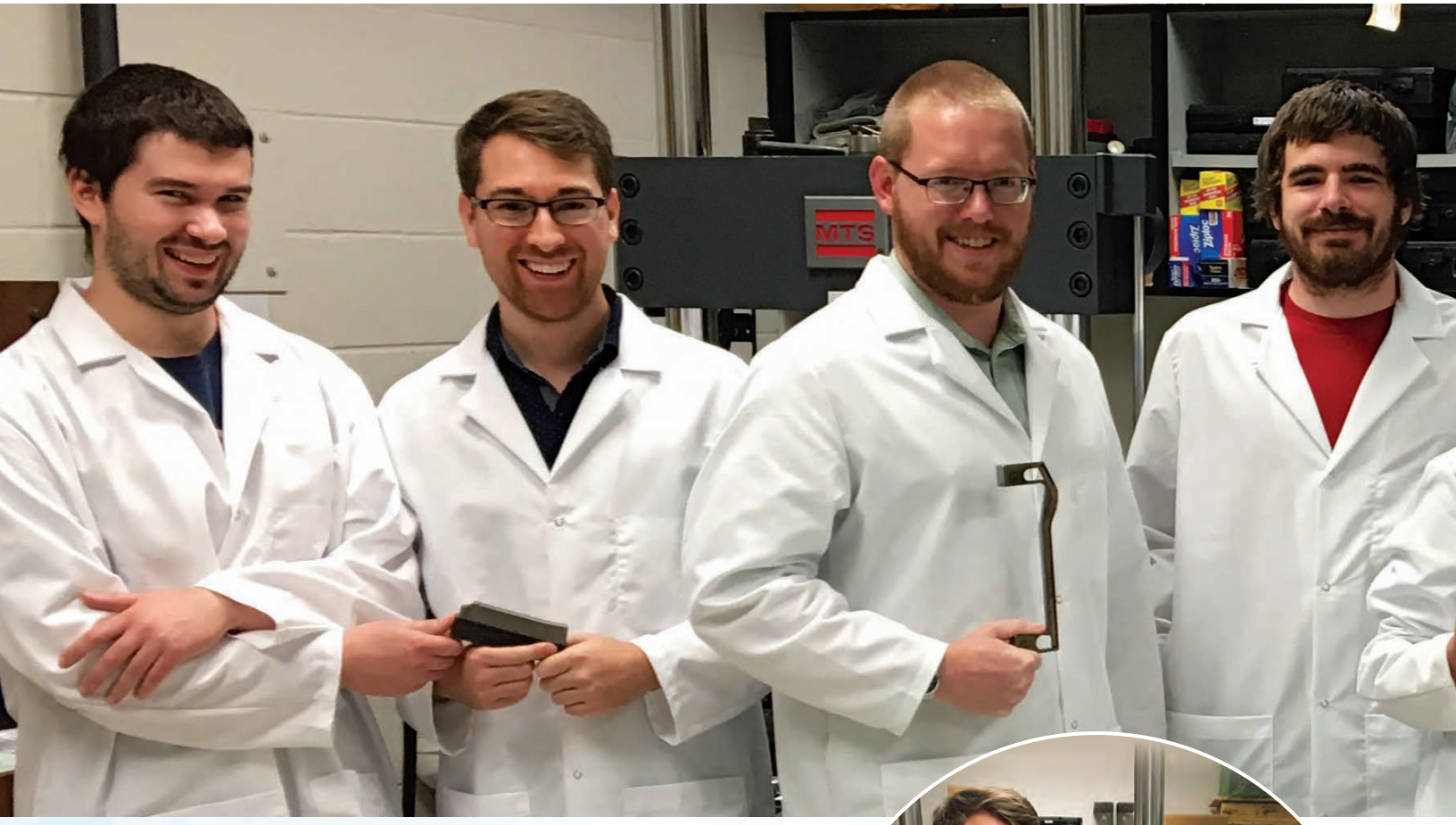
"The companies and government agencies that we work with have the ability to print parts using cutting-edge manufacturing processes, but they don't necessarily know the properties of the parts they're making – they're just taking their best shot," says Dr. Schneider, who is a fellow of ASM International. "What we do is test their samples by looking at the mechanical properties and the microstructures, and then we analyze the results and report back so that the company or agency can modify their printing process accordingly."

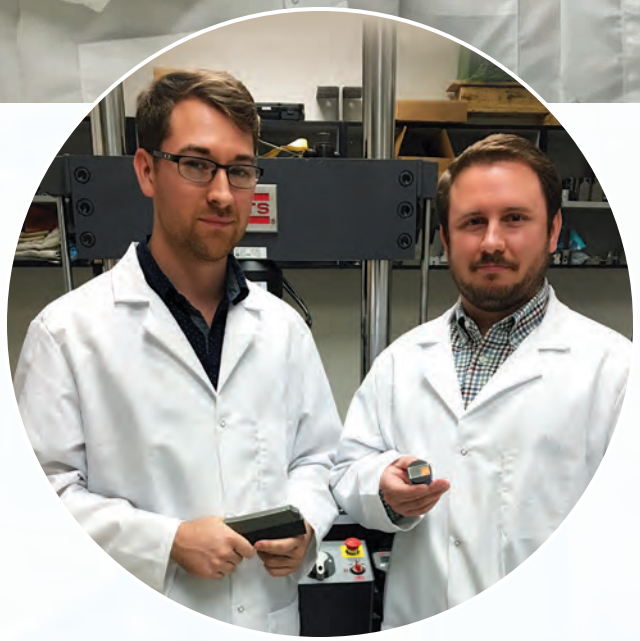
In this case, the additive manufacture of the igniter prototype used by NASA MSFC was produced by DMG-Mori, a global machining manufacturer. Using a process known as automated blown-powder laser deposition, they were able to save both time and money by printing a single bi-metallic part rather than manufacturing and brazing together multiple parts. But before the NASA MSFC engineers could hot-fire test it, they had to find out from Dr. Schneider and her team if the resulting structure could withstand the rigors of the environment.

"MSFC has invested heavily in this additive manufacturing process, but they were worried about the resulting mechanical properties," she says. "So we reached out to DMG-Mori, and they suggested we send someone to help make samples of the Inconel and copper used in the igniter for us to test." That someone ended up being master's mechanical engineering student Chris Hill, who spent a spring semester at DMG-Mori's Hoffman Estates, IL, facility, where test specimens were produced to verify the parameters for fabrication of the igniter.

"First we had to figure out how to make the Inconel test coupons using the blown-powder laser deposition process, and then we had to get it to bond to the copper," says Hill, who also earned his undergraduate degree in the field from UAH. "That was the most challenging, because we had nothing to go off. We couldn't ask other companies what they were doing because of the proprietary nature, so we really had to think outside the box."

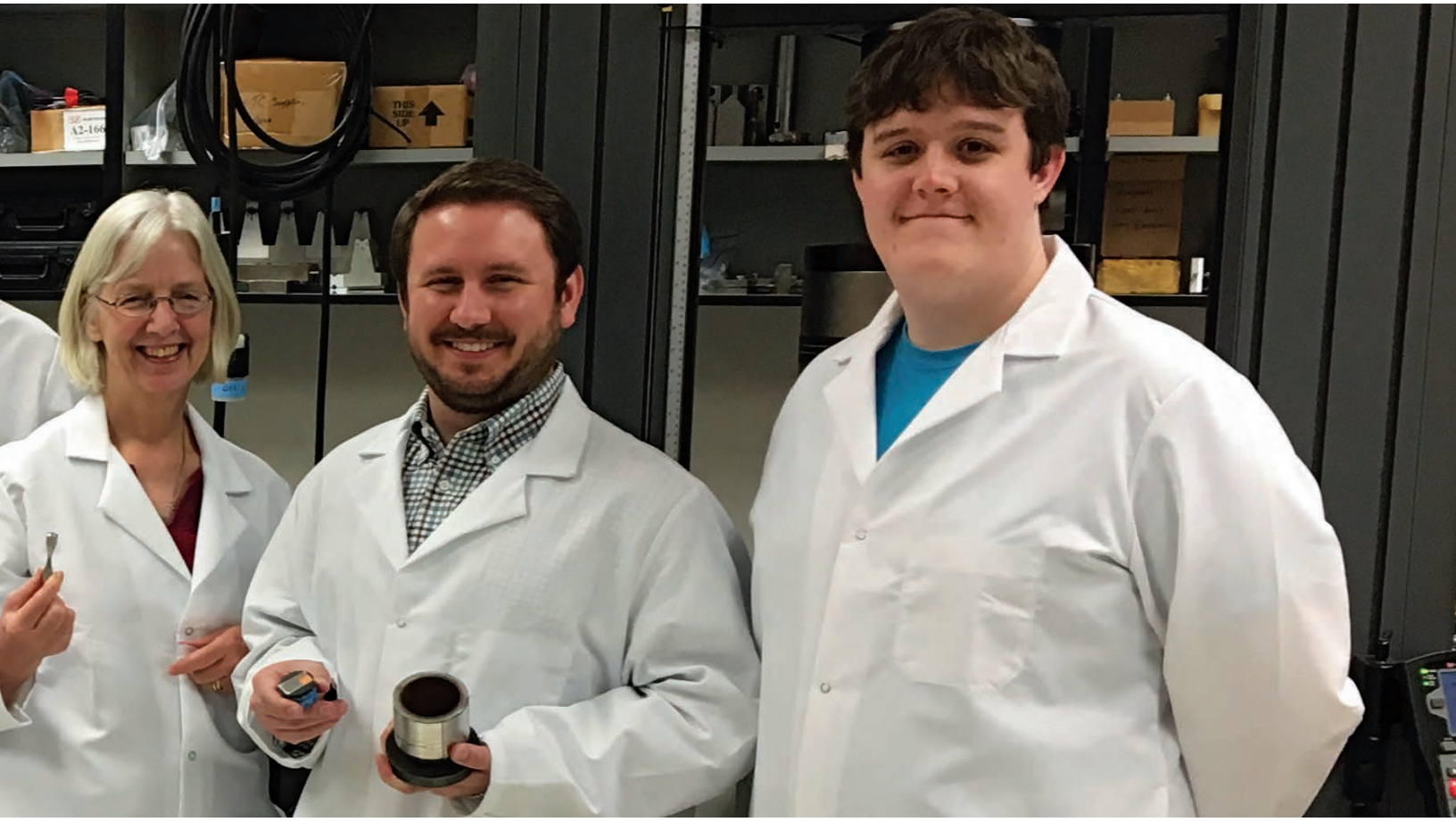
By the time he returned that May, he had successfully prepared 42 test coupons – 27 for tensile testing and 15 for fatigue testing. Hill worked with fellow master's student Ryan Anderson to conduct a variety of tests on the samples to analyze the microstructure and mechanical properties. "We did tensile, fatigue, and hardness testing, as well as void analysis," says Hill.





- **Ben Lund**, **Chris Hill**, **Tom Stockman**, **Zack Myers**, **Dr. Judy Schneider**, **Ryan Anderson**, and **Phillip Morrison** (l-r) study the correlation of environmental effects on the mechanical performance of structural materials.

- UAH mechanical engineering graduate students **Chris Hill** and **Ryan Anderson** played a key role in confirming the strength and reliability of MSFC's newest rocket engine igniter.



"Then we analyzed the results from the mechanical tests we ran." The properties of the base materials are now the focus of Hill's master's thesis.

With the baseline properties in hand, it was time for Anderson to evaluate the bi-metallic bond – a process that involves mounting a piece of the test coupon within a phenolic and polishing it until the grain structure is visible under an optical microscope. "It's difficult to prepare these samples when you have a hard material like Inconel and a soft one like copper because you have to spend a lot of time polishing it," says Dr. Schneider. "You also have to be very detail oriented, and document and take pictures of everything so that you have the answer to any questions about the process." Fortunately, she adds with a smile, "Ryan is a whiz at this!"

Anderson, whose master's thesis is focused on how different processes affect the resulting interface in bi-metallic builds, says he was mainly focused on the bond between the Inconel and copper and evaluating it. "I have been looking at the microstructure to see how the bond is created using different additive manufacturing processes, like wire feed and blown powder," he explains.

What Hill and Anderson found was that the igniter fabricated using the blown-powder process was metallurgically sound, thanks to the interfusing of the two metals involved. That assurance subsequently allowed NASA MSFC to schedule and successfully subject the igniter to hot-fire testing in July 2017. "It was nice to see it come to fruition like that, because when you work in a laboratory you don't always have that opportunity," says Dr. Schneider. For Hill, being able to follow the process from test coupon to a finished product was "the cherry on top," he says.

But while the project itself is over, the students are continuing to reap the rewards of such a valuable experience. Hill has since been asked to join MSFC's team as an intern, and both he and Anderson are working with Dr. Schneider, NASA MSFC, and DMG-Mori on a paper for publication in a peer-reviewed journal. The results of this project were also presented at the recent 68th International Astronautical Congress meeting in Adelaide, Australia, in September 2017, and in the spring, Ryan will present at the Minerals, Metals, & Materials Society's 2018 annual meeting in Phoenix, AZ.

"These students now have an in-depth knowledge of advanced manufacturing processes and how to design for each particular process," says Dr. Schneider. "It's fun for us because we're learning all the little tricks, and the students earn their graduate degrees in a very relevant field!" ■

Dr. Maria Pour

CAREER awardee balances research on phased array antennas with helping others forge a career in the field

The National Science Foundation (NSF) Early Career Development Program (CAREER) is designed to support early-career faculty who have "the potential to serve as academic role models in research and education and to lead advances in the mission of their department or organization." As such, recipients of the award are encouraged to support the NSF's mission of fostering the integration of research and education, and helping to "recruit, train, and prepare a diverse STEM workforce to advance the frontiers of science and participate in the U.S. technology-based economy."

That's a mandate Dr. Maria Pour, an assistant professor in UAH's Department of Electrical and Computer Engineering, takes seriously. In the year or so since she was selected to receive a five-year CAREER award for $500,000 in support of her research on phased array antennas, she has dedicated herself to growing UAH's graduate program in electrical engineering. "Currently I have four Ph.D. students and four M.Sc. students in the program," says Dr. Pour, who joined the UAH faculty in the fall of 2015 after earning a Ph.D. in electrical engineering from the University of Manitoba in Canada. "I also have two undergraduate research assistants. My mission is to encourage undergraduate students to pursue graduate degrees and build their future careers in the area of antennas and applied electromagnetics."

"My mission is to encourage undergraduate students to pursue graduate degrees and build their future careers in the area of antennas and applied electromagnetics."

To attract new students to the program, she's sought to increase its visibility among members of the university's undergraduate and graduate community and beyond. Earlier this spring, she hosted a seminar on antennas and radars that featured seven speakers, including two locally employed professionals. "I'm trying to encourage undergraduate students to join our graduate school, especially women and underrepresented students, so I want to do one seminar per semester," she says. "As part of this, I want to present a short course on antennas: real-world applications and future career opportunities."

Recruiting is only half the equation, however; the other half is retention. To that end, Dr. Pour has invested both time and money in making the university's research facilities and resources more robust. "We completed an operational undergraduate antenna lab for training and education, which is equipped with a four-port vector network analyzer up to 20 GHz," she says. "And we are about to finish up a new spherical near-field antenna test range. It's an anechoic chamber covered with microwave absorbers, and it has a frequency range from 0.65 GHz up to 18 GHz, so it's perfect for testing antennas."

As for the research requirements of her CAREER award, which are considered co-equal to those of education and outreach, Dr. Pour has made similarly impressive progress. She and her group have been active in disseminating the results of their efforts through scholarly publications to develop new techniques to address the current challenges of phased array antennas. "We are working on reducing the grating lobes and making them reconfigurable without using mechanical means, so that they can be used for wide scanning applications," she says. "This would bring a greater degree of freedom over the course of operations and an improvement in terms of the cost of the overall antenna unit." Currently, they are developing prototypes to make sure the techniques they've proposed will work well in practice.

Dr. Pour has also managed to secure additional funding from a variety of sources, enabling her to expand her research in new directions and to provide her students with even more opportunities for real-world, hands-on experience. In 2017, she received a Ralph E. Powe Junior Faculty Enhancement Award from the Oak Ridge Associated Universities, as well as the Outstanding Junior Faculty Award and the Outstanding Research Award from UAH's College of Engineering; in 2016, she received the Southeastern Center for Electrical Engineering Education Award for her work on developing adaptive aperture reflector antennas and a New Faculty Research Award from UAH's Office of the Vice President for Research and Economic Development for her work on multi-function virtual antennas.

As appreciated as this financial support is, it's not what drives Dr. Pour to meet – and often exceed – the goals set by the institutions that have honored her with some of their most prestigious awards. Rather, it's her passion for her chosen profession and her aspiration to impart that passion to others. "I've always loved mathematics, and the best field is applied electromagnetics," she says. "I would like to transfer the knowledge to future generations." ■

A REPUTATION FOR INSPIRATION

As CEO, **Dr. Deborah E. Barnhart's** focus is on ensuring that the USSRC continues to inspire tomorrow's leaders well into the future

As the CEO and executive director of the U.S. Space & Rocket Center (USSRC), the state's largest tourist attraction and the nation's largest repository of space artifacts, Dr. Deborah E. Barnhart has to keep an eye on both the past and the future while staying firmly rooted in the present. "We have a mission of preserving those things that come in the wake of discovery, of helping people understand the history of our nation and the accomplishments that technology has brought us," she says. "But we've also been putting a lot of time and effort into strengthening our educational foundation, and doing the workforce development necessary to help people continue to make those discoveries. We want to open the door to young children so they know that they can follow this path."

A key component of that workforce development is the USSRC's space, aviation, and robotics programs. Of the three, the best known is Space Camp, which has amassed more than 750,000 alumni since opening its doors in 1982. "We started with programs for elementary school students, then added middle and high school programs, and now we have a teacher camp," she says. Thanks to a longstanding partnership with UAH, participants in the latter two are also able to earn credit. "UAH has been a critical partner from the very beginning of Space Camp," says Dr. Barnhart, who is herself an alumna of the university. "Having a university partner willing to accredit our programs, which serve as an informal support to formal education, gives us credibility and authenticity."

Two other recent partnerships have proved just as fruitful. The first, U.S. Cyber Camp, was launched last summer by the USSRC, UAH, and Cyber Huntsville to address a predicted workforce shortage of

Since opening its doors in 1982, Space Camp has hosted more than 750,000 students from around the world. *(Credit: USSRC)*

> My friends, they were dancing here in the streets of Huntsville when our first satellite orbited the Earth. They were dancing again when the first Americans landed on the Moon. I'd like to ask you, don't hang up your dancing slippers."
>
> – Wernher von Braun

skilled labor in the field of cybersecurity. The inaugural weeklong sessions, which were hosted by the USSRC, featured cyber-related activities, demonstrations of cyberattacks, and simulations of defensive cybersecurity strategies. "This time we started with high school students, since the topic is complex and the program elements that UAH had developed were more appropriate for that age level," says Dr. Barnhart. "But we hope to move backward to younger and younger ages in the future."

The second, American Girl® 2018 Girl of the Year Luciana Vega™, was the result of a collaboration between the USSRC, NASA, and American Girl. As a Space Camp trainee with "a head for science and her heart set on exploring Mars," Luciana's story invites girls to engage in informal STEM opportunities, whether it's exploring her Mars habitat or taking part in her first space mission. "We formulate who we are as children in our play, and it makes our vision of who we are in the future," says Dr. Barnhart. "For them to see a Latina child who has a STEM future, it changes their lives." And much like Space Camp, she continues, Luciana has the power to "raise the expectations and aspirations of young children."

Given Dr. Barnhart's advocacy for and work on behalf of the STEM fields, the fact that she majored in English as an undergraduate at UAH may seem paradoxical. But she is quick to dispel that notion. "I wanted to study the things I was interested in, and English taught me not to be fearful of learning and reading to get the background information on something in order to make a decision," she says. As a result, throughout her service as a Captain in the Navy and later in her career as an executive in the private sector, she found herself "far better able to communicate" than many of her peers – something that holds true to this day. "Being an English major has never served me wrong in any area of endeavor," she says. "Whether

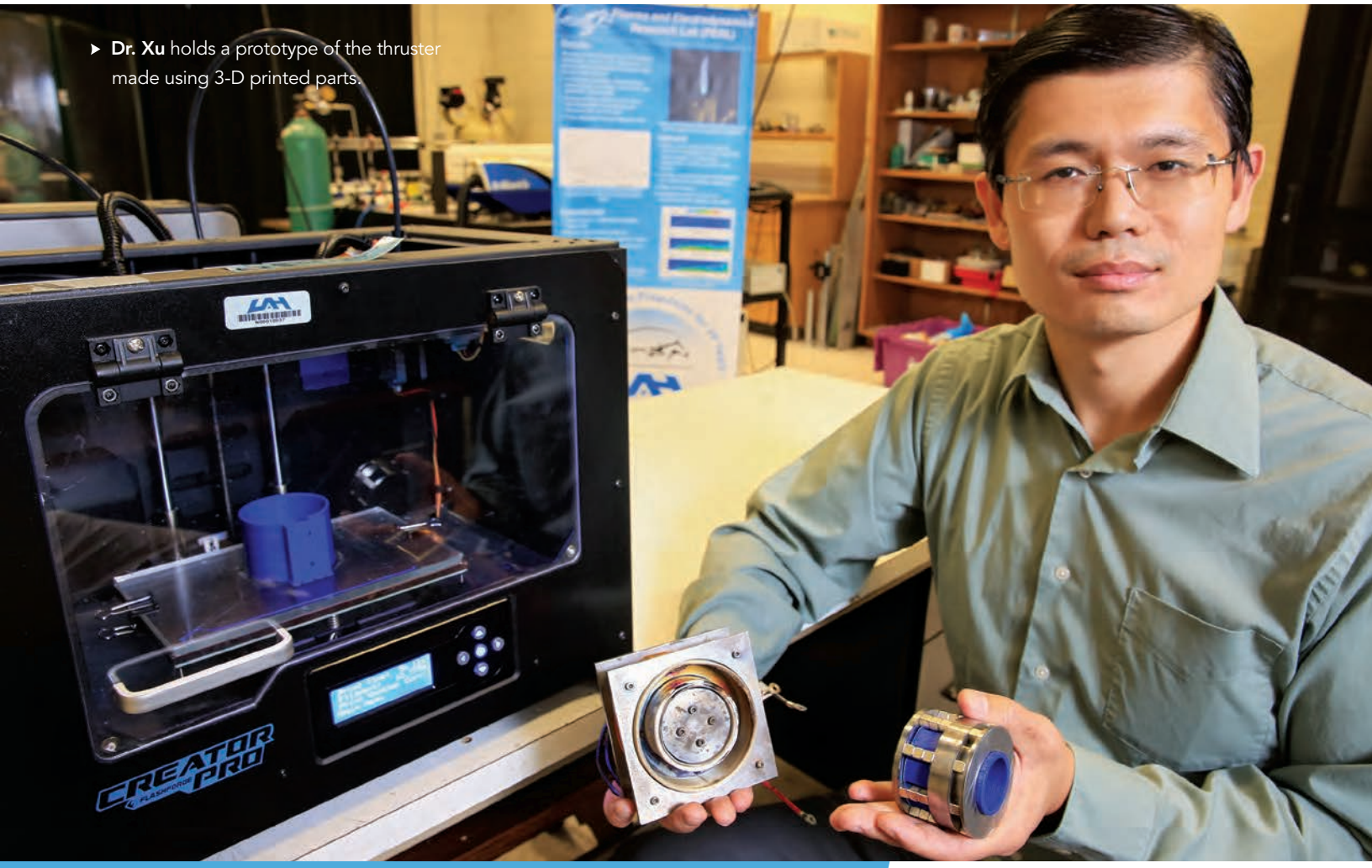
it's public speaking or writing a white paper or applying for a grant, I can't name a day that goes by that my English degree isn't an advantage for me."

Certainly the milestones she has achieved since being named CEO in 2010 are testament to that fact. Not only has Dr. Barnhart expanded the USSRC's educational reach, but she's also restored the state's iconic attraction to financial soundness. "We're now one of only one-half of one percent of museums in the whole country that are self-sustaining from operational income," she says.

And the future looks just as bright. The USSRC is set to serve as the hub for the city's celebration of the 50th anniversary of Apollo 11's lunar landing next year, complete with daily reenactments, a summer festival, and a potentially world-record-setting rocket launch. "We're so excited," says Dr. Barnhart, who was appointed community leader for the celebration by Huntsville's mayor, Tommy Battle. "We're also working with the city to re-enact Dr. von Braun being carried around the square, when he told us not to hang up our dancing slippers."

Fortunately, she has no intention of doing so herself – at least not anytime soon. "Every day of my life, no matter where I am, someone comes up to me and talks to me about Space Camp and what a difference it made," she says. "Who gets that kind of reward? When you're working with a mission that has such importance, I just can't conceive of not doing this." ■

▸ American Girl doll Luciana Vega is a Space Camp trainee with "a head for science and her heart set on exploring Mars." *(Credit: USSRC)*



▸ **Dr. Xu** holds a prototype of the thruster made using 3-D printed parts.

UAH ENGINEERING STUDENT uses 3-D printing to successfully build and test Hall-effect thruster

Ethan Hopping has always been passionate about space. "I remember visiting the U.S. Space & Rocket Center in elementary school," he says, "and being inspired by the story of the Apollo program and Huntsville's role in it."

That inspiration initially led him to earn his undergraduate degree in aerospace engineering at UAH in 2015, and to return to UAH to pursue his master's degree in aerospace systems engineering after a summer internship with NASA's Marshall Space Flight Center. Now Hopping is set to graduate after completing an ambitious Hall-effect thruster research project under the guidance of Dr. Gabe Xu, an assistant professor in the Department of Mechanical and Aerospace Engineering.

Like chemical rockets that push payloads into orbit, Hall-effect thrusters – named for American physicist Edwin Hall – are used for the same purpose but with much higher efficiency and lower force. That's because, while the former store the energy necessary for producing thrust in the propellant's chemical bonds, Hall-effect thrusters use plasma and electric fields to accelerate the atoms to very high speeds of multiple kilometers per second.

Depending on the mission, electric propulsion systems like Hall-effect thrusters can reduce the mass of propellant required by a factor of 10 or more as compared with chemical rockets. Consequently, they have the ability to reach deep-space destinations that are currently inaccessible to their chemical counterparts.

"I humorously like to say that ion engines and Hall-effect thrusters are the Prius of the in-space propulsion world," says Hopping, "because they rely on high fuel efficiency to bring about significant cost reduction and range improvements, but at the expense of high thrust."

▸ UAH master's student Ethan Hopping, who now works at Blue Origin, and UAH professor Dr. Gabe Xu partnered to design and test a Hall-effect thruster with a 3-D printed channel and propellant distributor.

The project emerged from Dr. Xu's interest in the effect of different geometric parameters on the performance of miniature Hall-effect thrusters. There was one problem, however; to test these different effects would require multiple thruster prototypes, each with varying dimensions, and that would quickly get expensive. "The high cost of manufacturing not only limits research opportunities, but also limits the use of Hall-effect thrusters in small satellites because the propulsion systems are too expensive in comparison with the rest of the satellite," explains Hopping.

The solution turned out to be the low cost and fast turnaround of 3-D printing. Hopping, who already had experience with 3-D printing, was tasked with designing and building a fully functioning miniature Hall-effect thruster from scratch. His product, the UAH-78AM, is the first Hall-effect thruster to be built at UAH.

"We scaled our design from a larger Hall-effect thruster that had publicly available design and performance data," explains Dr. Xu. Hopping then worked on the magnetic field design, a feat that included learning three different modeling programs. Ten months later, Hopping and Dr. Xu tested the first version of the thruster in the small vacuum chamber at UAH's Johnson Research Center and it worked.

After some design modifications, Hopping took the thruster to NASA's Glenn Research Center in Cleveland, Ohio, to collect performance measurements. Those ultimately proved that the UAH-78AM, though composed of 3-D printed parts, worked just as well as traditional thrusters of the same size and power level, but at a fraction of the cost and production time.

"This was an amazing opportunity," Hopping recalls, "to be surrounded by electric propulsion system experts and work in a research environment that has a long history of developing and testing Hall-effect thrusters. I learned a lot!"

Hopping and Dr. Xu presented a paper on their project this past October at the International Electric Propulsion Conference in Atlanta, Ga. And while Hopping is now looking forward to next month's graduation, he's already putting to use what he learned at UAH as a propulsion development engineer at Blue Origin in Kent, WA.

"My time at UAH equipped me with the knowledge and experience I need to support Blue Origin's mission as an aerospace engineer," he says. "I didn't know exactly what I wanted to do professionally when I started school, but I was sure that I wanted to support an industry that challenges us to be better, both as individuals and as a species, and spaceflight certainly does that!" ■

TEN NSF CYBERCORPS SCHOLARSHIPS awarded in program's fourth year at UAH

THIS YEAR'S UAH RECIPIENTS INCLUDE:

- Christian Schenck
- Jordan Flowers
- Polychroniades "Telly" Panteleimon
- Irene Cervantes
- Jonathan Slack
- Erika Davis
- Nicholas Benson
- Logan Johnson

Ten students were awarded full cybersecurity scholarships by UAH; eight are from UAH, and two are from partner universities. UAH is in the fourth year of a five-year, $4.2 million grant from CyberCorps® Scholarships for Service (SFS), a program administered and funded by the National Science Foundation (NSF) in cooperation with the U.S. Office of Personnel Management (OPM).

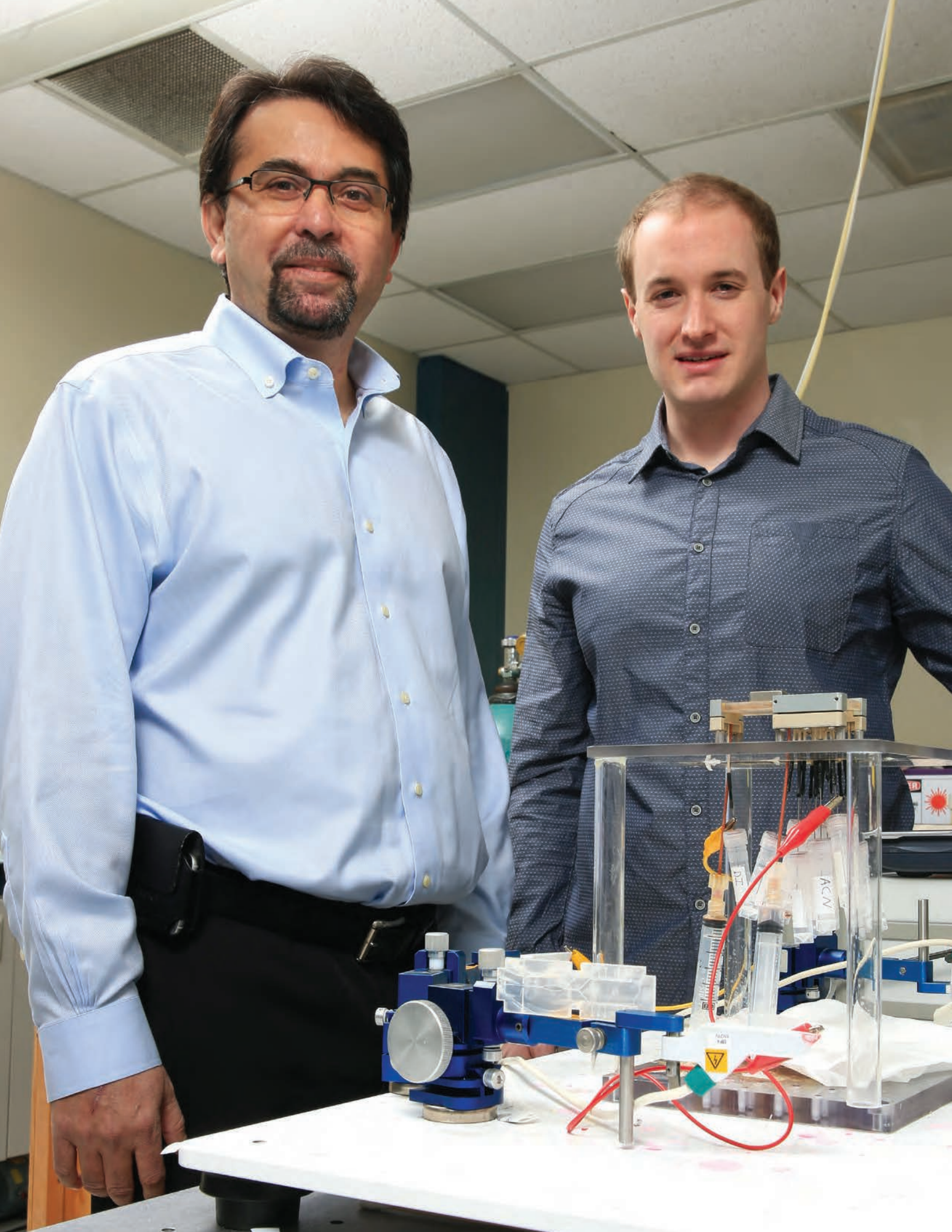
The scholarship comprises full tuition and fees, an annual stipend of $22,500 for undergraduates and $34,000 for graduate students, up to $2,000 per year reimbursement for books, up to $4,000 per year in reimbursement for professional development and travel expenses, and up to $3,000 per year in reimbursement for health insurance. In return, recipients are required to participate in a paid internship during summer semesters and must fulfill a service obligation to the U.S. government upon graduation from UAH.

"UAH has a large number of students across four majors pursuing computing degrees, making it easy to find a cohort of top-notch students for SFS," says Dr. Tommy Morris, an associate professor of electrical and computer engineering and director of UAH's Center for Cybersecurity Research and Education. "This year we have scholarship recipients from the fields of computer engineering, computer science, and information systems, as well as from UAH's interdisciplinary master's program in cybersecurity."

Amber Paris at Calhoun Community College and Chase Golden at Northeast Alabama Community College were also awarded SFS scholarships, in accordance with UAH's expansion of the program last year to include Snead State Community College, Northeast Alabama Community College, and Calhoun Community College. Recipients at partner community colleges are required to complete their degree at UAH and major in computer engineering, computer science, or information systems.

"The CyberCorps® Scholarships for Service program is fantastic, not just for the students, but also for UAH and Huntsville," says Dr. Morris. "Our graduates are meeting the growing demand for greatly needed cybersecurity talent at Redstone Arsenal and beyond." ■

Over 20 students are currently enjoying the benefits of UAH's participation in the NSF's CyberCorps Scholarships for Service program, which includes full tuition and fees, an annual stipend, and more.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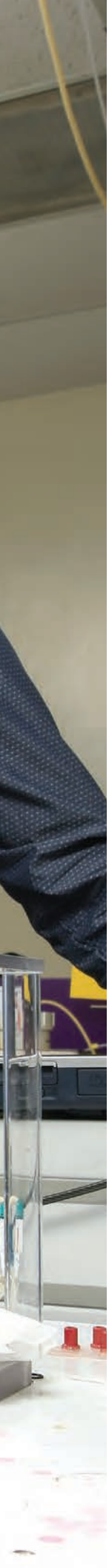


The Office of TECHNOLOGY COMMERCIALIZATION

Promoting and Translating Innovations at UAH

Kannan Grant's door in the UAH Office of Technology Commercialization (OTC) is always open. "We proactively promote and support a culture of learning and innovation at UAH by creating and capitalizing on commercial opportunities that benefit our constituents," says Grant, who has served as the OTC's director since late 2007, "and I think we provide a service that is becoming more important to research-intensive academic institutions such as UAH."

The office, which acts as a liaison between university innovators and industry investors, saw a banner year in 2017. Grant credits much of that success to the time and effort the OTC has devoted to educating its constituents – the UAH faculty members, researchers, and graduate students who generate intellectual property – on how best to protect and commercialize their innovations. "We encourage people to contact us as soon as they think they've got something that's copyrightable or patentable," says Grant. Their proactive approach has translated into a steady increase in invention disclosures over the years, from just 18 in fiscal year 2008 to 42 in fiscal year 2017.

With more disclosures came more patent applications and more patents issued. In 2007, the office filed three patent applications; in 2017 that number had increased to 27, with seven patents issued. "This progress motivates our constituents," says Grant. "One of the first questions a potential investor will ask them is regarding the status of intellectual property protection," he explains. "When they can respond that they have a patent application and it's licensed through the university, the investor has much more confidence moving forward."

For innovations that are in their infant stages, the OTC-managed Charger Innovation Fund (CIF) is available to assist pilot projects by providing financial support for the development of a proof of concept or prototype. "Typically, this is the most difficult money to get," says Grant, who describes a "valley of death," an area where traditional research funds end before investor dollars have been secured. "The CIF bridges that gap."

Proposals for CIF funds are evaluated by an advisory council consisting of UAH faculty, research staff, and members of the local business community. "We have outsiders with investment experience coming in and providing feedback to our constituents on how best to communicate the commercial aspects of a product in layman's terms," says Grant, adding that, for his more scientifically-minded clients, "that's a very valuable experience." In the few years it's operated, the CIF has generated a lot of positive response in the UAH community. "It's a great way for the university to show support for its researchers," says Grant.

Its approachability and overall client-centered focus has paid off for the OTC. Not only is the UAH community seeking its services more often, but increasingly businesses have independently approached the office as well. As it continues to build and strengthen its ties in the region, the OTC's growth shows no sign of slowing down. "We've had a tremendous amount of support from the university and we've accomplished a lot in 10 years," Grant says. "We hope to continue this trend." ■

◀ OTC director **Kannan Grant** and **Dr. Randy Gaillard** are pictured with a mini-oligonucleotide synthesizer that was co-developed by Dr. Gaillard while a graduate student at UAH. Whereas currently available devices are big, bulky, and difficult to transport, this one is the size of an ink-jet printer and cost-effective. The goal is to synthesize equal quality and quantities of oligos to industrial processes but at a sixtyfold reduction in cost.

OPEN FOR BUSINESS

A proof-of-concept facility welcomes the I²C's first tenant as construction nears completion on the business incubator's main building

Construction is well underway on the brand-new Dorothy S. Davidson Invention to Innovation Center (I²C) on the UAH campus. Supported by funding from local, state, and federal sources, as well as a generous $5 million donation from local business executive Dorothy Davidson, for whom the building is named, the three-story, 45,000-square-foot facility will serve as a regional resource offering leadership and support of entrepreneurial initiatives for emerging tech companies throughout 15 counties in Northern Alabama and Southcentral Tennessee.

The I²C's vertical structure and framing for the first and second floors are complete, and the construction crew is preparing to pour the third-floor slab. In the coming weeks, layout for the interior spaces will begin, including 15,000 square feet dedicated to flexible co-working, event, and community-engagement space, as well as ample incubation/office space on the second and third floors. Common areas, including conference and meeting rooms, classrooms, and a cafeteria will follow.

As the building's structure takes shape, so does the I²C's vision of being a world-class destination for public exploration in entrepreneurship and new venture acceleration. "This is indeed exciting!" says Rigved Joshi, the center's director.

The facility will offer affordable and flexible occupancy arrangements for a variety of tenants. Individuals or companies seeking permanent office space or a temporary work environment will have access to modern, collaborative common areas; Wi-Fi, power, and high-speed fiber connection; use of shared office equipment; and a business address and mailroom facility. Startups, entrepreneurs, or freelancers looking to engage with little or no access to the physical facility can opt to partner with the I²C virtually. Additionally, the building will be available to UAH students, faculty, and visitors. "We want the I²C to be the go-to place for enterprising individuals to ideate, collaborate, and build companies that are scalable and investable," says Joshi.

▲ RadioBro, the I²C's first tenant, was founded by UAH alumni – and twin brothers – **Mark and Eric Becnel**.

◀ **Rigved Joshi**, I²C director.

Its location on the UAH campus also means that members of the I²C community will benefit from being able to tap into the university's research and development facilities as well as its large network of faculty mentors, advisors, and student organizations. Opportunities for engagement through student jobs, internships, consulting, sponsored research, and other strategic collaborations also serve to enrich what Joshi calls the I²C's "entrepreneurial ecosystem."

That kind of vibrant and dynamic working environment is exactly what appealed to RadioBro Corporation, a space and aviation technology startup founded in Huntsville by UAH alumni – and twin brothers – Mark and Eric Becnel. With an eye on next-generation technologies, the team of engineers at RadioBro is focused on developing innovative and cost-effective solutions for avionics, radio-frequency identification automotive tracking systems, and small spacecraft technologies. The company will be one of the I²C's first tenants.

"In working with the I²C, we are hoping to partner with like-minded companies to develop new technologies and approach new markets," says Mark Becnel, RadioBro's president. "And we're excited about the opportunity to partner with UAH research and academic programs to get a head start on the next big technological developments in the industry," adds Eric Becnel, the company's vice president and chief product engineer.

The I²C is slated to open in late 2018 or early 2019, but that hasn't prevented Joshi and his team from moving forward with their mission. In the meantime, they have taken up temporary residence at Executive Plaza, a newly purchased UAH property located on Sparkman Drive opposite the Bevill Center. There they have launched a 4,600-square-foot proof of concept (POC) facility to serve as an interim incubator under the I²C initiative. Their strategy is to begin development on a small number of startups at the POC and then transition those operations to the I²C when the facility goes live. "We are currently open for business in Suite 1040 of Executive Plaza and welcoming entrepreneurs and startups to join the I²C movement," says Joshi.

As of February, RadioBro has collaborated with Redstone Aviation, Invictus Aeorospace Group, and ACE Creative Engagement at the POC, and the Becnels are already seeing the benefits of sharing the facility in the form of increased productivity and turnaround. "We could not be happier to have RadioBro as the first incubatee at the Executive Plaza location," says Joshi. With two or three additional small tech companies already in the pipeline, Joshi hopes the POC will be at full capacity in as little as three months. "We are looking forward to delivering quality support and resources for these promising startups to succeed," he says. ■

AEROPHYSICS RESEARCH CENTER

Impressive is the word that comes to mind when describing the UAH Aerophysics Research Center (ARC), an approximately 67,000-square-foot facility located on Redstone Arsenal where high-speed flight and impact testing are conducted.

Part of UAH's Research Institute, the ARC features three two-stage light-gas gun systems that investigate the interactions of a high-speed vehicle and its environment. These systems have the unique capability of sustaining extremely high velocities at up to 7 kilometers per second, a rate 21 times faster than the speed of sound. Coupled to the gun systems are enclosed test chambers, which permit the imaging of air flowing around high-speed objects as well as what happens when two materials collide at high speed.

According to Mark Zwiener, manager of the ARC's range operations, this research helps inform theoretical and calibrate computational models in order to predict more complex events in a computer system. It also offers a much more cost-efficient alternative to actual testing. "When you do something in the lab, you can gain a lot of knowledge by testing in a controlled environment before you go out and actually conduct a live fire test," says Dr. Steve Messervy, director of the Research Institute.

Just as impressive as the facility itself are some of the ARC's upcoming projects. Over the next three to four years, for example, the Center will help the Bureau of Alcohol, Tobacco, Firearms and Explosives (ATF) build their research on explosive forensics by collecting diagnostics on the sensitivities and performance of homemade type devices. These data can then be used by the ATF to train experts in police departments and homeland security that are charged with investigating explosive activities.

Dr. Messervy says the ARC is also slated to work with the Federal Aviation Administration (FAA) on the Airborne Collision Project, which examines the effects of unmanned aerial vehicles (UAVs) colliding with other aviation assets in an effort to build a larger database of what happens when these issues occur. UAH's Rotorcraft Systems Engineering and Simulation Center, serving as the lead on this project, will perform the physics modeling and computational aspect, while the ARC will handle the experimental side.

Zwiener emphasizes the importance of the relationship between the experimental and the theoretical when conducting research like this. "They all work together," he says. "There are some things that are difficult to measure well experimentally. But if you have some properties you can measure well experimentally, then you can compare them to the computational, and that gives you confidence that your other information that's hard to get experimentally is reasonable."

Zwiener adds that experiments are often simplified because the cost and complexity of doing a high-fidelity experiment are limiting. So instead of impact testing the entire assembly of a UAV at really high speeds, for instance, critical components like the battery or motor are tested individually. "Then the computational folks can compare those results, and when they get the modeling of that pretty good, they can add it into the computer and run thousands and thousands of impact events," says Zwiener. These experiments act like benchmarks for computational models to then generate a probability spread of what kind of damage might be done.

Clients often come to the ARC with a need for a certain type of information and don't have the facility or assets to obtain it. "People have theories – they come up with models, but they have to come up with some data that verify what their predictions are from a statistical standpoint," says Dr. Messervy. Such was the case with a more recent project in which the ARC assisted a small business that was developing a novel method for materials characterization. The ARC worked with the principal investigator at UAH, Dr. Judith Schneider in UAH's Department of Mechanical and Aerospace Engineering, to develop an experimental system to research this technique, which would greatly reduce the cost of collecting high-strain-rate data of metals such as steel.

To that end, Zwiener describes himself and his team as problem solvers, often providing customers with alternative experiments or approaches to get the data they need. "You have to like the challenge," says Zwiener. "You have to be a glutton for punishment, maybe because you're going to fail. You can't be afraid to be wrong."

Adds Dr. Messervy with a laugh, "Why do you think they call it research?" ■

▲ **Tony Doll,** chief machinist, inspects a part on the ARC's computer numerical control milling machine.

▲ **Anthony Wasmanski**, ARC crew chief, at the controls of a 25-ton Gantry Crane, which is required for the assembly and operation of the large light-gas gun system.

▶ **Mark Zwiener**, **Tony Doll**, **Mitchell Fleming**, **Michael Davis**, **Anthony Wasmanski** at the high-pressure section of the large light-gas gun.

IMPACT MITIGATION

UAH Ph.D. student discovers – and reports – vulnerability in commercially available PLC, leading to firmware update

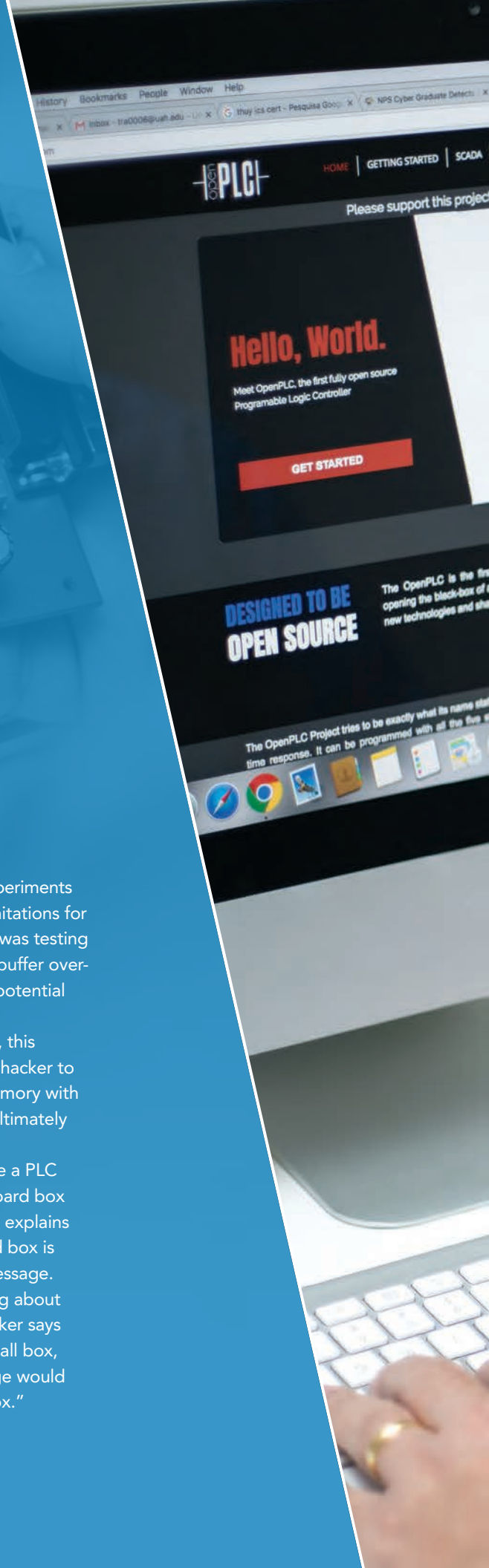
Thanks to UAH cybersecurity student Thiago Alves, a buffer overflow vulnerability was reported to the Industrial Control Systems Cyber Emergency Response Team (ICS-CERT) that allowed Rockwell Automation to release a patch to better protect its Allen-Bradley MicroLogix 1400 programmable logic controller (PLC) from cyberattack.

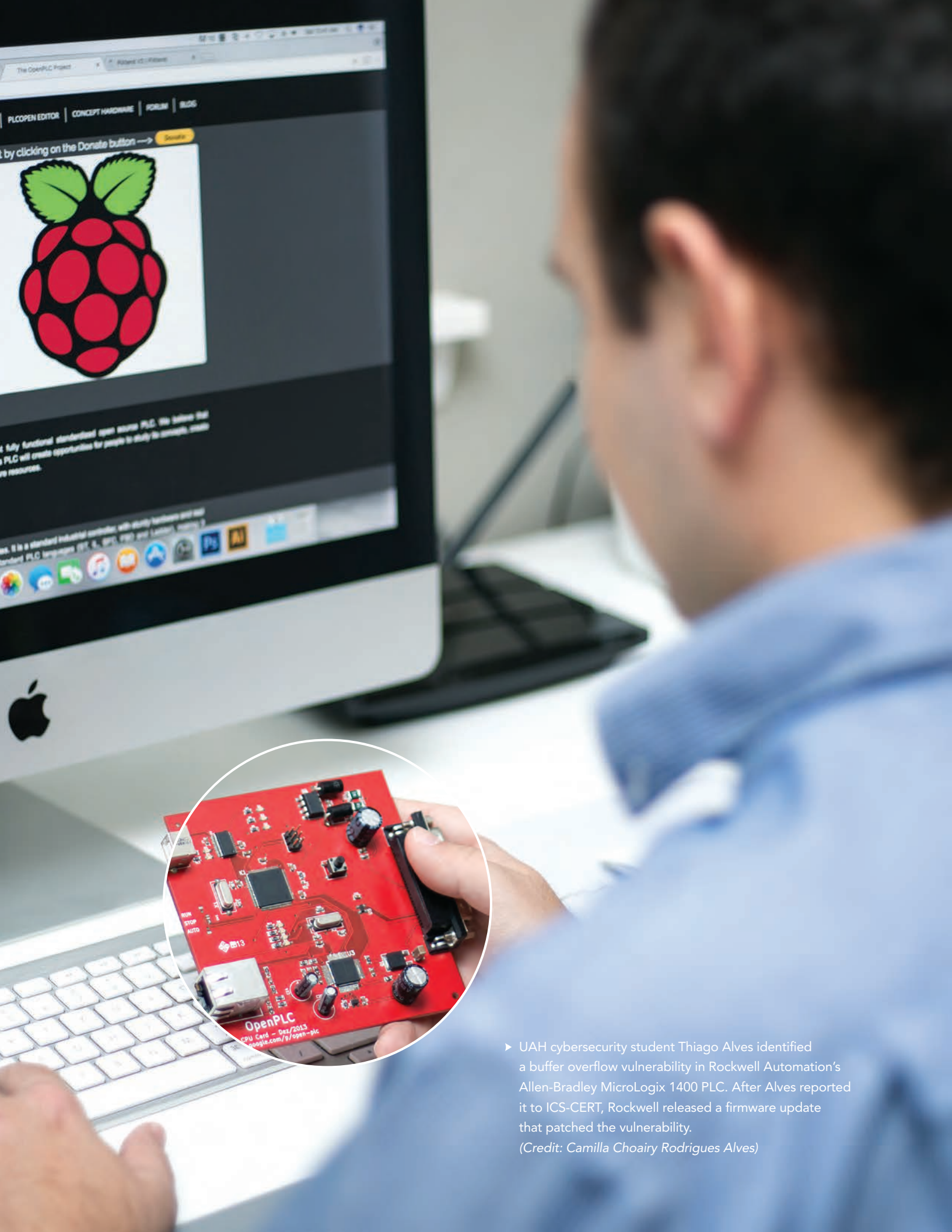
Alves, a graduate research assistant for UAH's Center for Cybersecurity Research and Education (CCRE), discovered the flaw while working on a paper comparing the behavior and functionality of OpenPLC with other PLCs. OpenPLC, the only PLC in the world to give users access to its source code, was created by Alves when he was an electrical engineering undergraduate at the Pontifical Catholic University of Minas Gerais in Brazil.

"To make the comparison with OpenPLC, I got the most popular brands of PLCs, including Siemens, Allen-Bradley, Modicon, and Omron, and I set up some lab experiments to find the characteristics and limitations for each of them," he says. "While I was testing the Allen-Bradley one, I found a buffer overflow vulnerability, which has the potential for serious damage."

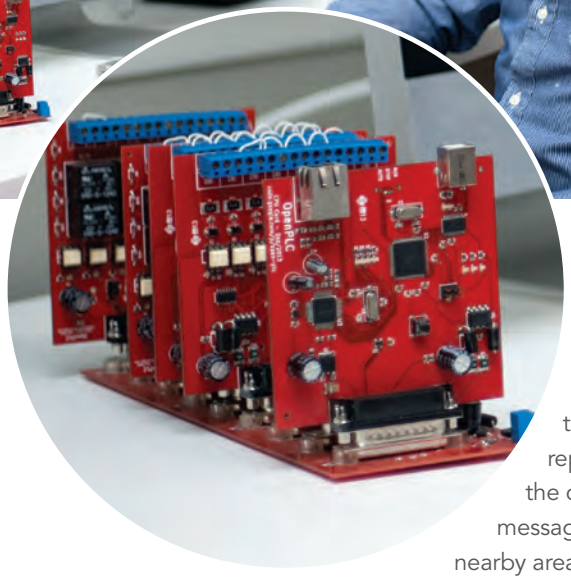
Also known as a buffer overrun, this particular vulnerability enables a hacker to overflow a piece of the PLC's memory with more content than it can store, ultimately resulting in a total system crash.

"Imagine that for every message a PLC receives, it gets an empty cardboard box to put the message contents in," explains Alves. "The size of the cardboard box is determined by the size of the message. An attack, however, relies on lying about the size of the message. The hacker says their message will fit in a very small box, while the contents of the message would actually require an extra-large box."





▸ UAH cybersecurity student Thiago Alves identified a buffer overflow vulnerability in Rockwell Automation's Allen-Bradley MicroLogix 1400 PLC. After Alves reported it to ICS-CERT, Rockwell released a firmware update that patched the vulnerability.
(Credit: Camilla Choairy Rodrigues Alves)



Thiago Alves is the creator of OpenPLC, the only PLC in the world to give users access to its source code. *(Credit: Camilla Choairy Rodrigues Alves)*

As a result, when the PLC receives the hacker's message, the contents overlap the area reserved for it. "That causes the nearby areas to be replaced with portions of the contents of the hacker's message," he says. "And if the nearby areas are storing vital information for the system to function and that information gets replaced, it crashes the system and stalls the PLC completely until it gets rebooted."

The effects would be even more damaging if a hacker decided to fill the message with a virus or malware, which could then be injected into critical parts of the system. "If they managed to do that, they could have the device execute the malware before crashing," he says. "That could cause even more harm, including permanent infection of the device, infection of nearby PLCs, alteration in functionality – you name it."

To alert Rockwell to the flaw, Alves contacted ICS-CERT, which operates within the National Cybersecurity and Integration Center, a division of the Department of Homeland Security's Office of Cybersecurity and Communications; its purpose is to facilitate communication between control system vendors and those who identify vulnerabilities in their products. "I explained the tests I made and gave them the specific message that crashed the PLC," says Alves. "Then they contacted Rockwell and intermediated our conversation." Shorty thereafter, Rockwell released a firmware update that patched the vulnerability.

Since discovering and reporting the flaw, Alves has completed his paper comparing OpenPLC to commercially available PLCs and submitted it for publication. He is also the co-author of a previous article, "Virtualization of Industrial Control System Testbeds for Cybersecurity," published in the proceedings of the 2016 Industrial Control System Security Workshop, which examined the fidelity of a virtual supervisory control and data acquisition testbed to a physical testbed so that the effects of cyberattacks on both systems could be studied. ■

The ICS-CERT operates within the National Cybersecurity and Integration Center, a division of the Department of Homeland Security's Office of Cybersecurity and Communications.

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The selection confirms that the Department's undergraduate and graduate programs in Earth system science meet the standards set by NGA, and that students receive the knowledge and skills needed to become active members of the geospatial sciences field.

Part of the U.S. Department of Defense, the NGA provides geospatial information and support for military and intelligence projects around the world. It also assists in humanitarian and disaster relief efforts in the U.S. and abroad, an area closely aligned with work done by UAH students and faculty affiliated with NASA's SERVIR and DEVELOP programs.