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"Scientific research is like a saving: if postponed until needed, it is too late to start"

-Wernher von Braun

Welcome to the spring 2019 edition of *FOCUS: The UAH Research Magazine*. UAH is celebrating its 50th anniversary as an autonomous university. This year also marks the 50th anniversary of the Apollo 11 moon landing, a phenomenal engineering and scientific accomplishment in which Huntsville played a central role. UAH Research was initiated eight years prior, in 1961, with the primary mission to provide basic research services in problem areas encountered at the Marshall Space Flight Center and the Army Ordnance Missile Command.

As many of you know, Dr. Wernher von Braun's vision and leadership in the missile and space programs were instrumental in making Huntsville a science and engineering mecca of the United States. For this reason, I have chosen a quote from Dr. von Braun as the title to my introduction. The quote still remains true and represents a core belief within UAH researchers. As you peruse this edition, it will be obvious that UAH is committed to developing "a saving" by means of knowledge building, discovery and workforce development. Tomorrow's challenges will be no less demanding than in the past.

The cover story on hypersonics is an illustrative example of a pressing need for expertise and capabilities to address an imminent threat. Dr. Steve Messervy, the director of the Research Institute, describes how past research efforts have positioned UAH well to collaborate on research involving the effects of projectiles and aircraft flying at hypersonic speeds. The university's Aerophysics Research Center operates three, two-stage light gas gun systems that can investigate the interaction of hypersonic projectiles. The test facilities, combined with faculty and research expertise, provide formidable capability to address hypersonics.

Two additional stories demonstrate UAH's commitment to increasing capabilities in critical technologies. Africa Flores, a research scientist in the Earth System Science Center (ESSC), has received a grant to advance the use of artificial intelligence to help understand and protect the planet. Jerry Hendrix has recently joined the Rotorcraft Systems Engineering and Simulation Center as its Director of Unmanned Aerial Systems (UAS) Programs. Jerry brings a wealth of knowledge from the Texas A&M FAA UAS Test Site.

This edition also highlights recent accomplishments of two of UAH's best researchers, Dr. John Christy and Dr. Sara Graves. Dr. Christy, Alabama state climatologist and director of the ESSC, has recently been appointed to the U.S. Environmental Protection Agency Science Advisory Board. This appointment is quite an honor and recognizes Dr. Christy's research accomplishments and expertise in climate research. Sara Graves, director of the Information Technology and Systems Center and a professor of computer science, has been awarded a $2 million, three-year Intelligence Community Center of Academic Excellence award. The effort will focus on critical technologies for the intelligence communities.

The student focus section features the research of Melissa Guerrero, who received her bachelor and master's degrees in English at UAH. The article describes how Guerrero used video games to tell very old stories.

Finally, two articles provide a peek into some exciting new research. First, UAH scientists are getting a first look at data coming from the Parker Solar Probe (PSP). The PSP team, which includes UAH, has been recognized with the 2018 American Astronautical Society Neil Armstrong Space Flight Achievement Award. Second, the new Chemical and Materials Engineering Chair, Dr. Anuradha Subramanian, is investigating ultrasound therapy to regrow post-operative cartilage for stronger knee joints. The National Institutes of Health funds this work.

We are proud of the accomplishments of our faculty, staff, students and alumni. We are excited about the future and welcome collaborative partnerships. Please contact the Office of Research and Economic Development to be provided more information on the efforts featured in this magazine or any other research project at UAH. ■

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▸ Cover photo: Dr. Steve Messervy, director of UAH's Research Institute, with a light gas gun system at UAH's Aerophysics Research Center, which operates from the Aerophysics Research Facility on Redstone Arsenal.

THE UNIVERSITY OF ALABAMA IN HUNTSVILLE

A **"RESEARCH INTENSIVE"** 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
- **9TH** Federally financed Economics research
- **10TH** Federally financed Computer Sciences research expenditures
- **11TH** NASA R&D expenditures
- **12TH** Federally financed Atmospheric Sciences research expenditures
- **21ST** Federally financed Astronomy research expenditures
- **28TH** 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

$94.4 million
Fiscal 2017 research expenditure total

ISSUED PATENT TOTAL – 75

'A REAL THREAT'

UAH READY TO HELP NATION CATCH UP IN HYPERSONIC RESEARCH

When Russian President Vladimir Putin announced in December that his country's "invulnerable" Avangard hypersonic nuclear missiles were ready to deploy, that focused the United States Dept. of Defense on hypersonic development and testing.

That research will have a large impact on the future U.S. national security picture, and could also bring commercial benefits. Unlike the predictable parabolic flight of conventional or Intercontinental Ballistic Missiles (ICBMs), hypersonic missiles fly at speeds greatly exceeding the speed of sound and can change flight trajectory to avoid detection or interception countermeasures.

"The Chinese and Russians are ahead of us in hypersonic R&D and testing," says Dr. Steve Messervy, director of The University of Alabama in Huntsville Research Institute. "Just in the open literature, everybody knows they're ahead of us."

The Dept. of Defense has assigned Under Secretary of Defense for Research and Engineering Mike Griffin, a former UAH eminent scholar and tenured professor of mechanical and aerospace engineering, to put some thrust behind U.S. hypersonic research.

Under Dr. Griffin's leadership, Dr. Messervy says funds have been allocated to the U.S. Air Force, U.S. Army, U.S. Navy and the Defense Advanced Research Projects Agency (DARPA) in the hypersonic field. Likewise, aerospace and defense companies are seeking answers.

UAH is well equipped to partner with commercial clients and the Dept. of Defense in hypersonic projectile testing and data acquisition to research what affects projectiles and aircraft flying at hypersonic speeds, Dr. Messervy says.

The university's Aerophysics Research Center (ARC), operating from the Aerophysics Research Facility located on Redstone Arsenal, provides the government and commercial clients with a ready means of hypersonic scaled testing with its three, two-stage light gas gun systems that investigate the interactions of high-speed vehicles and their environments.

"The Chinese and Russians are ahead of us in hypersonic R&D and testing," -Dr. Steve Messervy

"I do a lot of work with the Army Space and Missile Defense Command (SMDC)," Dr. Messervy says. "A lot of people are working on the technical issues of hypersonic flight, which generates high temperature and control issues at that speed."

It's a ballistics race right now, since the Russians have a boost glide hypersonic missile. The Chinese have built experimental versions.

"The idea is to make a missile change its

parabolic flight pattern," Dr. Messervy says. That can be done through aerodynamic design, control software, or both.

Areas of U.S. research interest include the thermodynamics of the bow wave created in front of a projectile at Mach 5 or higher speeds and the physics of the plasma field created by that wave. Both influence and affect projectile design, the materials used and the methods of flight control, Dr. Messervy says.

"The area that UAH works in most is helping establish some of the testing that will be required," he says. The high costs of full-scale tests demand that prototypes first be researched by computer simulation and then in scaled testing, he says. Scaled testing is UAH's forte.

One-eighth scale testing is where the so-called "big guns" at UAH's ARC provide critical data that UAH scales up to represent a full-size flight. Sometimes ARC clients provide the projectiles, but typically, test projectiles are made to client specifications in the ARC machine shop.

UAH's light gas guns simulate environments in which a projectile would actually fly, so it is possible to test it at various simulated altitudes at critical points along its flight path.

"We can invoke whatever environment we need to in the light gas gun," Dr. Messervy says. "For example, we can make it look like flight at 70,000 feet, based on the air molecules contained inside the gun." Software captures every aspect of the test flight and impact, generating needed data as the cameras record.

The ARC fills an essential function that cannot be supplanted in the testing chain, Dr. Messervy says.

"You can build all kinds of computer models, but how do you validate a computer model? You do some large-scale testing – but before you do that you do some scaled testing. The costs are just too prohibitive to do it any other way."

UAH is also involved in a federal initiative to construct a center to perform hardware in the loop (HIL) simulation testing on the SMDC campus at Redstone. HIL testing is a dynamic systems technique that allows development and testing of real-time, complex systems in operation.

The facility is currently in the proposal phases, and Dr. Messervy expects some initial facility funding will be available this year. Commercial defense firms will be partners in its development.

"UAH would like to help the government build this facility," Dr. Messervy says. "What we are interested in, based on our testing, is that the hardware in the loop facility as it is built will be a long-term investment."

When Dr. Messervy needs a physicist, he turns to Dr. Jason Cassibry, associate professor of mechanical and aerospace engineering, whose work is motivated by the lead our adversaries have.

"We have a real scare here, a real threat," Dr. Cassibry says. "Hypersonic missiles present a threat that no modern defense can stop, and we need to come up with solutions to that threat."

A researcher for UAH's Propulsion Research Center (PRC), Dr. Cassibry says the center is pursuing opportunities in hypersonic research in collaboration with those underway at the ARC.

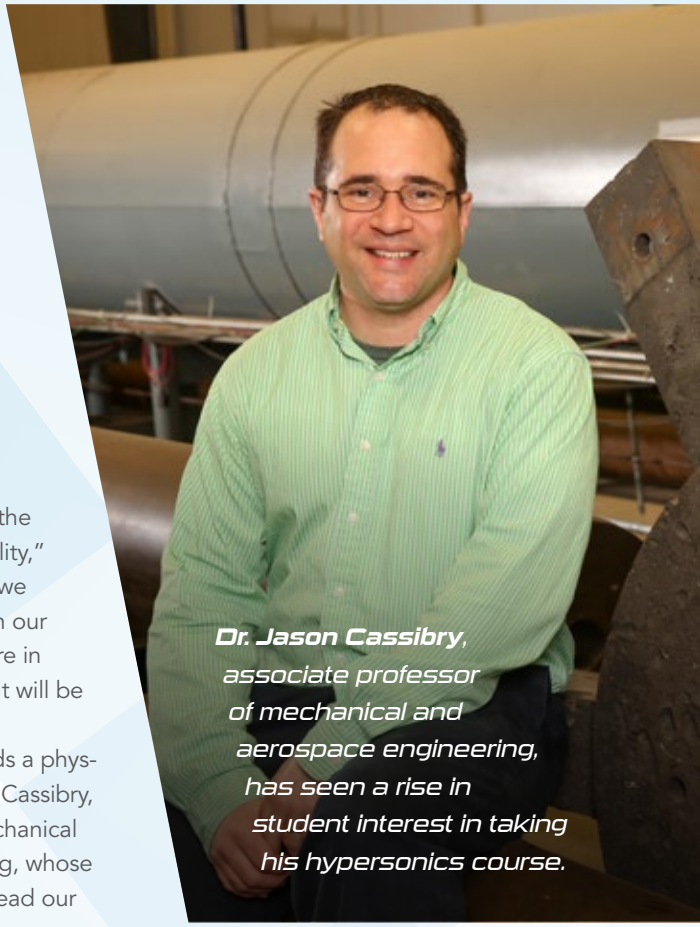
"We're very enthusiastic about the opportunities that are coming up," he says, "and even though this is defense work at this stage, it will trickle down to commercial applications, which will benefit society if we can solve these challenges."

As an educator, Dr. Cassibry teaches a hypersonics course every two years to build capabilities in students to pursue the work.

"We have seen a noticeable increase in enrollment this past fall," he says. "The interest has built because of the rapid increase in funding in hypersonics."

As a researcher, Dr. Cassibry works in numerical modeling in simulations.

"I'm interested in better integration of



***Dr. Jason Cassibry**, associate professor of mechanical and aerospace engineering, has seen a rise in student interest in taking his hypersonics course.*

simulations with experiments in order to better understand the physics of hypersonic vehicle systems," he says.

Closing the information-gathering gaps between simulations and physical testing will better inform researchers as they progress to full-scale tests.

"You just don't know what might happen in a real-world test because of the myriad of complexities involved," Dr. Cassibry says. "Increased collaboration between experiment and simulation groups will help buy down the technical risks of flight tests."

Bringing simulation and reality closer together opens new insights.

"In an experiment, you might have some really great flight data in the form of imaging, for example, or you might have some data about the temperature inside the shock wave or boundary layer, but you can't get detailed information along the surface, so simulations that validate the available diagnostic information can help fill in the gaps."

If the data sets agree, he says, then a more complete picture of the forces and flow fields around the test body emerges.

"I've been working with a graduate student and collaboratively with companies and with the ARC and PRC in going after funding," Dr. Cassibry says. "We are working on some test cases now to try to position ourselves for opportunities as they come along."

His work could dovetail with the proposed HIL facility at Redstone Arsenal. Filling the gaps between simulation and physical testing "allows you to get a lot closer to a flight test without having to commit to the funds and risks associated with a flight test," he says. It could speed development times.

UAH's TranSonic/SuperSonic/WindTunnel (or TS/SS/WT) is another PRC venture, and principal investigator Dr. Phillip Ligrani is working in collaboration with other researchers on a proposal to the National Science Foundation (NSF) that would see the $2 million facility doing hypersonic research.

"We're developing ideas for a proposal for the NSF, and also continuing to talk with people who are with NASA and the U.S. Air Force and others who are involved in hypersonic research," says Dr. Ligrani, a professor of mechanical and aerospace engineering and the university's eminent scholar in propulsion.

The basic research proposal "will involve using the wind tunnel and also using predictions" to investigate control of heat transfer and thermal transport control through shock wave control in supersonic and hypersonic boundary layers.

The compressors and four 16-ton, 14-foot-long air storage tanks are capable now of achieving Mach 4 hypersonic speeds, he says, but the current tunnel piping and test section are rated Mach 2.7.

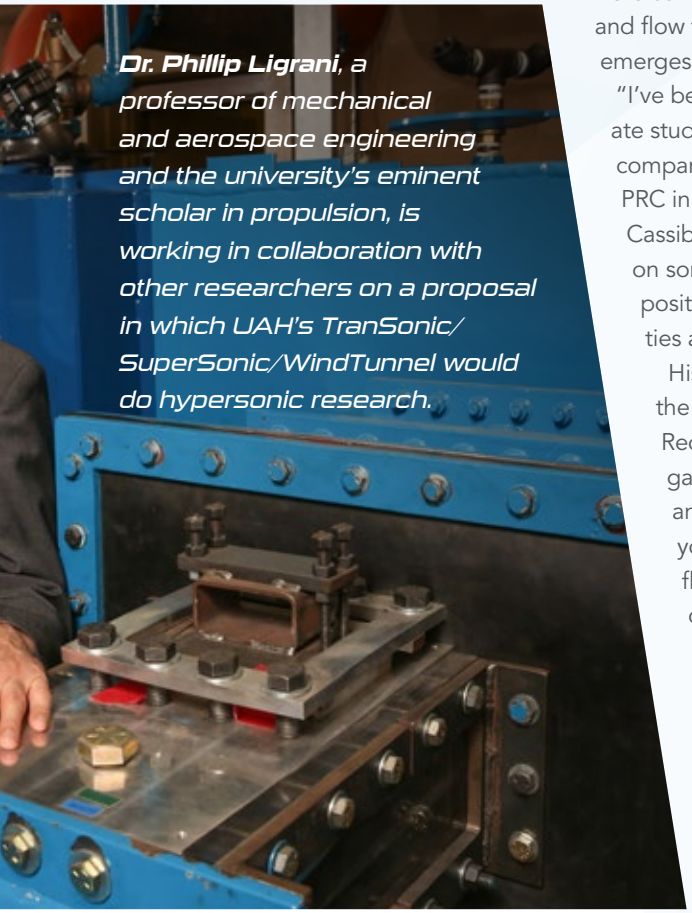
"We have the infrastructure to easily achieve Mach numbers up to 4," Dr. Ligrani says. "Producing flows at higher Mach numbers is a challenge, because, at hypersonic speeds up to Mach 6, the pressures can be higher compared to a Mach 2.7 supersonic flow by a factor as large as 68."

The UAH proposal involves research on hypersonic wave drag, an intense aerodynamic heating and drag created by vastly increased flow friction.

"It's because the velocities are so high," Dr. Ligrani says. "Velocity variations and velocity gradients are also very high, so there's a lot of velocity change in a very short distance. That generates very high friction and very high drag."

Understanding hypersonic aerodynamic heating processes caused by drag could lead to better leading edge shapes and materials to deal with the heat and pressure. UAH is already involved in aerodynamic testing of engine intake shock wave phenomena at supersonic speeds.

"There is very much interest right now in scramjets at hypersonic speeds, and the associated propulsion systems," Dr. Ligrani says. "There's also much interest in aero-engine intakes and how they perform at supersonic and hypersonic speeds." ■



***Dr. Phillip Ligrani**, a professor of mechanical and aerospace engineering and the university's eminent scholar in propulsion, is working in collaboration with other researchers on a proposal in which UAH's TranSonic/SuperSonic/WindTunnel would do hypersonic research.*

ESSC RESEARCH SCIENTIST RECEIVES AI FOR EARTH INNOVATION GRANT

A research scientist at UAH's Earth System Science Center (ESSC) is one of 11 change-makers selected to receive Microsoft and National Geographic AI for Earth Innovation grants to apply artificial intelligence (AI) to help understand and protect the planet.

Africa Flores, who is originally from Guatemala, will use her AI for Earth Innovation Grant to focus on developing a prototype of a harmful algal bloom (HAB) early warning system to inform Guatemalan authorities about upcoming HAB events in Lake Atitlan, a landmark of Guatemala's biodiversity and culture.

"The research team at UAH and I will use these funds to work on using artificial intelligence to test a number of environmental and weather variables for their skill to forecast harmful algal blooms in Lake Atitlan," says Flores, whose proposal was one of those selected from over 200 applications.

Flores has been at UAH since 2011, beginning as a graduate research assistant in ESSC's master's program. "I work with the SERVIR program, a NASA and USAID partnership that fosters the use of Earth observations and geospatial technologies to address environmental challenges in Africa, Asia and Latin America," she says.

"Africa has been working in remote sensing of water quality for many years, and wrote her graduate thesis at UAH on the subject," says Dr. Robert Griffin, associate professor in atmospheric science, who works with Flores. "For Africa, being Guatemalan herself, this funded research carries additional meaning, allowing her to reach back and have impact in communities in the country where she grew up."

The AI for Earth Innovation Grant program will provide award recipients with financial support, access to Microsoft Azure and AI tools, inclusion in the National Geographic Explorer community and affiliation with National Geographic Labs, an initiative launched by National Geographic to accelerate transformative change and exponential solutions to the world's biggest challenges by harnessing data, technology and innovation.

The grants will support the creation and deployment of open-source trained models and algorithms so they are available to other environmental researchers and innovators, and thereby have the potential to provide exponential global impact. The AI for Earth Innovation Grant program builds upon Microsoft's AI for Earth program, which counts as grantees nearly 200 individuals and organizations on all seven continents, and the National Geographic Society's 130-year history of grant-making, supporting more than 13,000 grant projects along the way.

"I'm extremely happy and honored to be working with top-notch scientists in this proposal, all from UAH," Flores says. "I feel extremely privileged to be a part of a research center like the ESSC at UAH. This university, my former advisors and professional colleagues have provided me with lifelong lessons and growth opportunities. I love to be able to do scientific research and to have the support of a whole system designed to foster novel and applied scientific research." ■

DR. JOHN CHRISTY NEW MEMBER OF EPA SCIENCE ADVISORY BOARD

Alabama's state climatologist and the director of the Earth System Science Center (ESSC) at UAH has been appointed to the U.S. Environmental Protection Agency (EPA) Science Advisory Board (SAB).

Dr. John Christy was appointed to the three-year position by Trump administration EPA Acting Administrator Andrew Wheeler. He joined seven other experts who were appointed to serve on the 44-member SAB, which has four committees involved with agricultural science, chemical risk, drinking water and radiation. Twenty-six new members were also appointed or nominated to serve on its committees.

"The Science Advisory Board advises the EPA on the big questions about environmental protection that need scientific inquiry and how we can judge what evidence is there to establish science-based regulations to protect people and the overall environment as best as possible," says Dr. Christy, who had applied to be considered for the position. "My expertise was considered due to my climate research, so I will be speaking to that issue, but the board works on many more issues than just climate."

The EPA says nominees willing to serve have been vetted for potential conflicts of interest and each has committed to remaining financially independent from EPA grants during their tenures.

"In a fair, open, and transparent fashion, EPA reviewed hundreds of qualified applicants nominated for this committee," says Wheeler. "Members who will be appointed or reappointed include experts from a wide variety of scientific disciplines who reflect the geographic diversity needed to represent all 10 EPA regions." ■

Expert has **BIG PLANS** as director of UAH Unmanned Aerial Systems Programs

Jerry Hendrix has joined the Rotorcraft Systems Engineering and Simulation Center (RSESC) at The University of Alabama in Huntsville as its director of Unmanned Aerial Systems (UAS) Programs responsible for UAS research.

"Jerry's leadership and achievements as the former executive director and chief engineer of the Texas A&M FAA UAS Test Site and his past experience supporting Dept. of Defense and NASA programs will benefit our students as they prepare for careers in this emerging field and grow our existing UAS research and collaborations," says Dave Arterburn, RSESC director.

"Jerry is a researcher and practitioner, having used UAS to support first responders in a number of emergency response scenarios, including Hurricane Harvey recovery operations in Houston," Arterburn says. "He brings much-needed real world experience to our students and staff as they develop new technology to support customers at both the local and national level."

Hendrix will be leading the UAH Alliance for System Safety of UAS through Research Excellence (ASSURE) team for the Federal Aviation Administration (FAA) UAS Center of Excellence. He comes to UAH after serving at Texas A&M as executive director for the Texas designated FAA UAS Test Site and the Board of Regents-approved Lone Star UAS Center of Excellence and Innovation.

▲ Jerry Hendrix is the RSESC's new director of Unmanned Aerial Systems (UAS) Programs.

"First and foremost, I am an innovative leader and a high energy coach. I guarantee those will be brought to UAH," Hendrix says. "We will build on the past success at UAH to date, and at the Texas A&M University System, and further that here."

Going forward, Hendrix says UAH plans:

- To continue FAA ASSURE research supporting the FAA and Mississippi State University;
- Operationalization and testing of UAS in the National Airspace System (NAS), which includes UAS testing from developmental test to operational test;
- Advanced research in systems integration, autonomy, counter UAS systems, modular open systems architectures and reusable components;
- Disaster response using UAS while working with the local community and the Federal Emergency Management Agency (FEMA).

"We will focus on branding and a culture of technical excellence. Those things matter and allow us to gain respect," Hendrix says. "We have to build on our recognized brand of nationally ranked strong technical excellence and establish a strong respected culture that attracts opportunity/business and research."

UAH will leverage the strong backing from the university, professors, students, alumni and the Huntsville community to assemble the infrastructure and tools needed for success, Hendrix says.

"Our vision is that companies and the government alike will line up for UAH to conduct UAS research on their behalf," he says. "For UAH, I am really excited about exploring more on how we can offer our research to the local community."

UAH's customer base will include governmental and commercial entities, Hendrix says.

"The plan is to enter into strategic partnerships and focus on research and test support for emerging UAS designs, and testing UAS in specific business cases. We hope to establish a world renowned research center in autonomous UAS systems and counter UAS technologies supporting our customers."

Hendrix, who has experience ranging from the International Space station to the F22 aircraft to Apache helicopters, says working with this technology and its potential national impact is extremely rewarding.

"I look forward to working with Alabama GEO-HSV and the local UAS Working Group," he says.

Hendrix is also excited about the future for Urban Air Mobility and package delivery. "In November, NASA announced their Urban Air Mobility Challenge. Soon we will see autonomous people movers, like an air taxi for local communities. Cities are positioning themselves to be a test city! Why not Huntsville?"

Package delivery and inspections supporting utilities, airports, transportation, railroads, etc., are another fast-growing area for UAS use, and also one in which Hendrix is experienced.

"I plan to work to bring similar collaborations to UAH and the Huntsville community, including the Port of Huntsville and beyond."

ASSURE and UAH continue to lead the way in opening UAS operations over people and UAS detection and avoidance, he says.

"Interestingly, working in the UAS arena is an all-encompassing aviation field," Hendrix says. "The world complexion is changing with the advent of things like Urban Air Mobility, military and civil package delivery, advanced teaming, autonomous mission operations and even nefarious UAS operations. This is so exciting, and I look forward to expanding UAH as a national leader." ■

VIDEO GAMES OFFER A NEW WAY TO TELL VERY OLD STORIES, STUDENT'S RESEARCH SHOWS

Given its reputation as "part Comic-Con and part academic conference," Pioneer Con proved the perfect venue for Melissa Guerrero to share her research comparing medieval Robin Hood texts to the popular Japanese role-playing video game Persona 5. "It's like a 'nerd' conference, so it's less formal than your typical academic conference," says a laughing Guerrero, who graduated from UAH with her master's degree in English this spring. "It fits within my realm of interest."

Held at Jefferson State Community College and sponsored by the college's chapter of Sigma Kappa Delta English Honor Society, Pioneer Con is an annual daylong event that gives "students, faculty, and members of the community a chance to release their inner geek." This year's program featured a keynote address from novelist and poet Phoebe North, author of "Starglass" and "Starbreak," as well as student- and faculty-led sessions, face painting, cosplay and two Dungeons & Dragons mini-campaigns.

Guerrero, who also earned her bachelor's degree in English from UAH, has long been a fan of video games. "I grew up with them," she says. "So when I saw the opportunity to combine what I'm studying in literature with video games, I jumped at it." Though she had already been a recreational player of Persona 5, she decided to make it the focus of her capstone research project for a variety of reasons. "The characters are relatable, the game play is fun, and story lines are really unique and incredible," she explains.

Set in modern-day Tokyo, the game centers on a falsely accused student named "Joker" who uses his newly discovered super powers to fight evil as part of a band of vigilantes known as the Phantom Thieves of Hearts. "All the characters are teenagers and have been harmed in some way by a figure of authority," says Guerrero. "Ultimately what you're trying to do is stand against these oppressive authority figures and reform society."

It wasn't until Guerrero took Dr. Joseph Taylor's medieval literature seminar, however, that the parallels between Persona's theme and that of medieval Robin Hood texts began to reveal themselves. "The game's critique of law and justice reflects Robin Hood's critique," she says. "So even though the game is set in a post-medieval society, it still has those same ideas of justice and law and reformation that were around in the 14th and 15th centuries."

It also means that the characters in the game are, by default, on the wrong side of the law. But like Robin Hood, says Guerrero, they're seen not as villains but as heroes acting on behalf of the common man. "They're someone society roots for, because they will always fight for those who are oppressed," she says. "So we look up to them in that sense – if they can fight against oppression, then we can too."

That "challenge to legal authority and that authority's distortion into tyranny," explains Dr. Taylor, is what gives the outlaw narrative its enduring appeal. "Medievalism is vibrant in popular culture today, as evidenced by the success of television series such as 'Game of Thrones' and 'Vikings', to take but two examples," he says. "In her work, Melissa illustrates the resonance of not only the outlaw narrative but also medieval legal theory and forms of resistance in the modern world. Her project specifically analyzes how 15th century ballads like 'Robin Hood and Guy of Gisborne' and 'A Gest of Robin Hood' inform and influence Persona 5's narrative and game-play scenarios."

But more than just wanting to show the similarities between two media separated by millennia, Guerrero is hoping her research will stimulate a discussion about the role that video games can play in education. "A lot of people think video games are immature and childish, but they're a new form of storytelling in this modern era and a means to make people better," she says. "Narratives can change a person, and that person who is changed can change the world." ■

UAH SCIENTISTS GETTING FIRST LOOK AT PARKER SOLAR PROBE DATA

Now in orbit, the Parker Solar Probe (PSP) is streaming a large amount of data from the Solar Wind Electrons Alphas and Protons (SWEAP) instrument suite to NASA and then to The University of Alabama in Huntsville (UAH), where the SWEAP team is analyzing it.

As the spacecraft does its work, the entire PSP team including UAH has received the 2018 American Astronautical Society (AAS) Neil Armstrong Space Flight Achievement Award for its work.

"The award is a great acknowledgement of all the hard work that went into making this mission and SWEAP a success, and hopefully it's a sign of more recognition to come," says Dr. Gary Zank, director of UAH's Center for Space Plasma and Aeronomic Research (CSPAR) and the Aerojet Rocketdyne chair of the university's Department of Space Science.

Part of PSP's SWEAP array is a Faraday cup designed, created and tested by a partnership between UAH, Marshall Space Flight Center (MSFC) and the Harvard Smithsonian Astrophysical Observatory (SAO) to sample solar wind while directly exposed and traveling closer to the sun than spacecraft have ever been.

SWEAP includes two Solar Probe Analyzer instruments known as SPAN-A and SPAN-B. With a wider area of coverage, the SPAN devices collect particles and sort them through a series of deflectors and voltages based on their mass and charge. SPAN-A measures electrons and ions. SPAN-B is dedicated to electrons only.

"Two of my researchers, Dr. Lingling Zhao and Dr. Laxman Adhikari, spent a week at Harvard-Smithsonian learning about the data and how to process it, together with UAH graduate student Yu Chen," says Dr. Zank.

LONG-TERM PROJECT

Data analysis is expected to take years, as the PSP mission has a projected life of seven years and could be extended.

"The SWEAP team takes the Level 1 data from NASA and begins to clean it up, taking into account offsets and other instrumental effects," Dr. Zank says. "This initial data is essentially a set of voltage readings."

The voltages are converted to data products corresponding to the appropriate moments that describe plasma variables such as number density, plasma velocity and temperature.

"Much of these activities are automated, and we're at the discovery stage in exploring the data products, trying to understand especially how the solar wind this close to the sun differs from the more familiar solar wind that we have studied closer to the Earth," Dr. Zank says.

Initially accessible to PSP team members, processed data stored in a data center later is available to researchers broadly. Launched Aug. 12, 2018, PSP completed its first solar orbit on Jan. 19, 161 days after it left Florida's Cape Canaveral Air Force Station.

The Parker Solar Probe will make about 24 orbits of the sun in seven years, and is streaming data to UAH scientists now. *(NASA)*

Dr. Gary Zank

TANTALIZING EXCITEMENT

PSP provided UAH scientists with their first tantalizing excitement when – while closest to the sun – it crossed a narrow region called the heliospheric current sheet where opposite magnetic fields arise and vanish.

"It appeared to observe a region with unusually large and chaotic or turbulent fluctuations in the plasma variables," Dr. Zank says. "This is quite unusual compared to our experience closer to the Earth."

Dr. Adhikari is the researcher working with Dr. Zank to use PSP data to study the evolution of turbulence in the solar atmosphere, and the turbulence between the sun and the Earth.

"We will use the data of solar wind speed, density, temperature and magnetic field from the PSP to calculate several turbulence quantities and compare them with our theoretical results," Dr. Adhikari says. "We will explore how the turbulence energy, density, speed and temperature evolve in the heliosphere between the sun and the Earth. Our aim in this project is to understand the origin of the fast solar wind and the heating of the solar corona to millions of degrees Kelvin."

Coronal heating and the acceleration of the solar wind are two of the most persistent problems in space plasma physics and solar physics, he says.

"The PSP makes about 24 orbits of the sun in seven years," Dr. Adhikari says. "In each orbit, the PSP runs closer to the sun, eventually reaching the closest distance of about 9.8 solar radii. Therefore, the PSP data of every orbit is very important for understanding the turbulence near the sun, and I am excited to explore turbulence near the sun using the PSP data."

MAGNETIC FLUX ROPES

UAH scientists are also studying whether tiny magnetic island-like structures called magnetic flux ropes are present in the region, as well as observing the characteristics of the magnetized turbulence there.

"Basically, I'm working with Dr. Zank to explore the particle acceleration associated with small-scale magnetic flux ropes utilizing the PSP data," says Dr. Zhao, another collaborating researcher. "This project would identify and characterize small-scale flux ropes, particularly in the vicinity of the heliospheric current sheet."

That research explores the properties of the small-scale flux ropes at the perihelion, or the place where PSP is closest in orbit to the sun. It also looks into the association between small-scale flux ropes and energetic particle acceleration.

"We would like to see the unusual energetic particle flux enhancement associated with solar wind magnetic flux-rope dynamics," says Dr. Zhao.

"In our prior work, we have developed a stochastic transport theory for charged particles propagating in a turbulent region filled with numerous interacting small-scale magnetic flux ropes. And our theory has successfully predicted the observed unusual energetic particle flux enhancement and spectra evolution at 1 au and 5 au," she says. "We want to further test our theory to see if it applies to the region near the solar corona."

Graduate student Chen traveled to SAO in Cambridge, Mass., to learn more about PSP because she's part of a group working with Dr. Qiang Hu, an associate professor of Space Science, on spacecraft observation of small-scale magnetic flux rope.

"The origin of these small structures is still debatable, and the sun is one of the possible sources," Chen says. "The PSP is designed to observe the inner corona of the sun and it will approach more closely to the sun than any other spacecraft or probe, so we hope that the PSP could provide observational data which would help us to determine the origin or evolution of these structures."

These inquiries provide a pathway to a future potentially ripe with new discoveries.

"Stay tuned!" Dr. Zank says. "This is going to be extremely interesting." ■

Dr. Lingling Zhao

Dr. Laxman Adhikari

Yu Chen

STRONGER

KNEE JOINT REPAIRS COULD RESULT FROM CME CHAIR'S RESEARCH

Research underway at The University of Alabama in Huntsville could provide stronger repairs for injured knees.

A low-cost, effective method that uses low intensity pulsed ultrasound therapy to regrow post-operative cartilage in articular joints like the knee or shoulder could result from experiments by Dr. Anuradha Subramanian, the chair of the UAH Department of Chemical and Materials Engineering (CME).

In a nation with more than 6 million articular joint injuries a year, mostly to the knee, that would be welcome news and could help avoid some knee replacement surgeries. And if it works in a rabbit's knee, that'll be the first 'hop' to getting it to work in yours.

"The main focus of my research is to help the doctor to achieve the best possible clinical outcome," says Dr. Subramanian, who recently joined UAH as CME chair. Her efforts are funded by a two-year National Institutes of Health (NIH) grant.

Because it is a protein-rich matrix with very few cells and it has no blood vessels, the cartilage that serves as a cushion between bones in a joint such as the knee cannot regrow itself.

"Cartilage has no capacity for cell repair," Dr. Subramanian says. "So how can we replace what is lost?"

Current surgical techniques don't optimize the bond between existing cartilage and new cartilage that has been grown from stem cell rich marrow blood in nearby bones, or grafted from another area, or grown outside the body and transplanted.

The stem cell technique, which uses microfractures created in the adjoining bone by drilling into it to produce stem cell rich blood, is less than optimal because not all of the resulting mesenchymal cells convert to the chondrocyte cells needed to regrow cartilage. Some instead become fibroblasts and create much less sturdy collagen.

▲ Dr. Anuradha Subramanian is researching the use of low intensity pulsed ultrasound therapy to regrow cartilage in articular joints.

(Michael Mercier / UAH)

In both the stem cell and the grafting techniques, a weaker boundary layer lacking integration develops between the new and existing cartilage, potentially weakening the repair and inviting re-injury.

Plus, post-operative cartilage is trying to repair itself in a less than ideal environment.

"Let's say I have a cartilage injury and I go to the doctor, and he opens my knee," says Dr. Subramanian. "You are asking that cartilage to make a repair in a pro-inflammatory environment, and pro-inflammatory environments are known for killing the cartilage, not helping it."

Scientists have long observed in the laboratory that cartilage responds positively to physical pressure. Physical pressure is currently used therapeutically to help healing in post-operative joints.

Likewise, in the lab scientists discovered that physical pressure created at the cellular level by low intensity pulsed ultrasound in the 1.5 MHz range has a beneficial effect on cartilage regrowth, says Dr. Subramanian.

"But," she says, "they found that low intensity pulsed ultrasound at 1.5 MHz did not work in vivo" - in other words, in the body.

Dr. Subramanian hypothesizes that perhaps the ultrasound did not reach the intended target, or perhaps it reached the target but not at the correct frequency or amplitude to be therapeutic.

While at the University of Nebraska at Lincoln, Dr. Subramanian began to look at low frequency pulsed ultrasound therapy "from the ground up" by experimenting with cartilage harvested from slaughterhouse cattle knees.

In vitro, she discovered that 5 MHz is a more effective frequency for the technique and that ultrasound-grown cartilage did not create the weakened transitional divide between it and existing cartilage that is seen in other techniques.

"When you apply the ultrasound, this divide won't exist," she says.

Under the NIH grant, she is studying the composition and density of the various cell layers that surround the knee in rabbits and the effect ultrasound has on different cell layers, using very highly detailed Magnetic Resonance Imaging (MRI) scans of the joint.

"This is where it is very helpful that I am an engineer. The first thing you have to understand is how the ultrasound will propagate in the joint," Dr. Subramanian says. "We will reconstruct the properties of the knee on the computer. Then using a transducer, we will model the propagation of the ultrasound on the computer."

That research should show how ultrasound propagates in various tissues, how various cells respond to the ultrasound and how the different cells respond to various resonant frequencies.

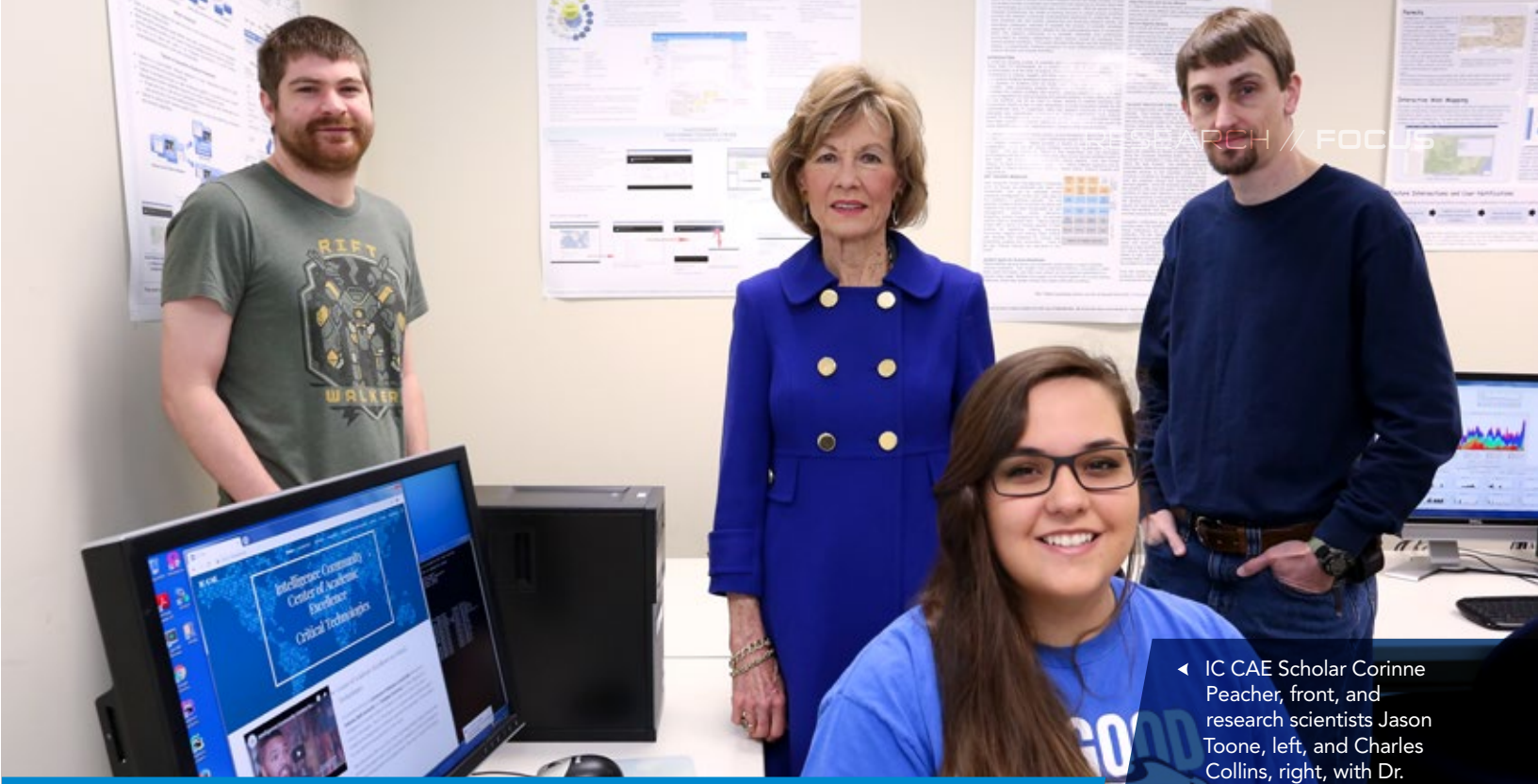
The rabbit knee will be MRI scanned and 3-D computer modeled, and the effects of ultrasound on the different tissues and structures will be added to create software that will show a clinician the best route by which to target cartilage in need of regrowth help, and at what intensity.

"Then we will take a rabbit and create a defect, and apply the ultrasound for three months, and then look at the effect" versus a control animal, she says. If that's successful, the next step is testing in sheep, and then in humans.

Could the day come when a surgeon takes an MRI of a knee, and the computer software tells the doctor how much and where to apply low intensity pulsed ultrasound for optimal post-operative cartilage regrowth and healing?

"Right now, we are in the computer modeling stage, and the NIH grant will fund us through the early animal experiments," says Dr. Subramanian. "Everything the surgeon is facing right now – everything we need for repair – we have shown in vitro. But in vitro is one thing, in vivo is another. Will it work in vivo? That is what I am after." ■

> *"The main focus of my research is to help the doctor to achieve the best possible clinical outcome."*
> *- Dr. Subramanian*



IC CAE Scholar Corinne Peacher, front, and research scientists Jason Toone, left, and Charles Collins, right, with Dr. Sara Graves, center, in the IC CAE laboratory. *(Michael Mercier / UAH)*

UAH, partners designated an **Intelligence Community Center of Academic Excellence**

The University of Alabama in Huntsville, with partners Alabama A&M University (AAMU) and Tuskegee University (TU), has been awarded a $2 million, three-year Intelligence Community Center of Academic Excellence (IC CAE) grant by the United States Dept. of Defense to expand capabilities in critical technologies and to prepare students for careers in the intelligence community.

Key areas of study in the program are artificial intelligence, machine learning, data visualization, computational statistics/algorithm design and computer science analytic writing and briefing.

UAH's Information Technology and Systems Center (ITSC) will administer the grant, says Dr. Sara Graves, director of the ITSC and professor of computer science.

"The intelligence community needs to utilize technologies such as artificial intelligence and machine learning to analyze, mine and visualize the vast amounts of data being collected in a timely fashion," says Dr. Graves.

"Both ITSC and the UAH Department of Computer Science have a long record of excellence in research in the critical technologies demanded by the intelligence community," she says. "Our students are trained through coursework and research experience and are in high demand. They often complete internships, and have part-time jobs with local agencies or industry before they graduate."

A diverse cadre of IC CAE Scholars will learn the skills and have the experience to become eligible and competitive for internships and careers across the defense agencies. Students who are IC CAE Scholars will participate in workshops and colloquia, interact with distinguished speakers, and travel to conferences as they complete the course requirements. Students will work with faculty and research staff conducting critical technologies research.

Many of the courses students will take as part of the program are already available. Some topics are being offered as special topics courses. Seminars and workshops will provide additional training. IC CAE Scholars will be awarded IC CAE Certificates. UAH's Department of Computer Science is submitting applications for approval of a Data Science certificate and concentration programs.

The consortium will develop an IC CAE Critical Technology Studies Program that provides the opportunity to earn credentials in critical technologies at both the undergraduate and graduate levels.

"The program will be evaluated based on the number of students placed in jobs with the intelligence community," Dr. Graves says. "The specialized training, internship opportunities and interactions with the intelligence community are expected to yield enhanced job placement opportunities within the intelligence community for students."

The Dept. of Defense grant provides funding to develop curriculum and enhance faculty expertise in critical technologies at all participating universities, Dr. Graves says.

"The IC CAE program benefits UAH by providing training for faculty in emerging areas of computer science; new opportunities for UAH students to acquire skills in high demand critical technologies; and opportunities for increased research collaboration with the intelligence community." ■

▲ Hector Sanchez-Moran, left, a master's student in chemical and materials engineering, and Armin Ahmadi, a doctoral student in chemical and materials engineering, in Dr. Kyung-Ho Roh's lab.

FIVE UAH RESEARCH PROGRAMS ARE **TOP 25 IN U.S.**, SAYS NATIONAL SCIENCE FOUNDATION

Aeronautical and astronautical engineering tops a group of five federally financed research programs in which The University of Alabama in Huntsville is ranked in the Top 25 nationally, according to the latest National Science Foundation (NSF) survey.

The NSF ranked UAH aeronautical and astronautical engineering fifth in the nation, followed by economics at No. 9 and computer and information sciences in 10th place. UAH's Atmospheric Sciences program ranks 12th in the new report, and astronomy is ranked 21st.

"We are very pleased with the latest research expenditure rankings received from NSF," says Dr. Robert Lindquist, vice president for research and economic development. "UAH has a long history of science and engineering research and working with our federal government partners."

The university is also in the company of other top research universities nationally at two federal agencies. UAH ranks 11th in NASA-sponsored research and 28th among Dept. of Defense-sponsored research.

The National Oceanic and Atmospheric Administration (NOAA), the Dept. of Energy, and the National Institutes of Health (NIH) also are partnered with UAH in research endeavors.

The anchor tenant in Cummings Research Park – the nation's second-largest research park – UAH is one of America's premier doctoral-granting, research-intensive universities.

With robust capabilities in astrophysics, cybersecurity, data analytics, logistics and supply chain management, optical systems and engineering, reliability and failure analysis, rotorcraft and unmanned systems, severe weather, space propulsion, and more, UAH prepares students for demanding positions in engineering, the sciences, business, nursing, education, and the arts, humanities, and social sciences. ■

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UAH'S DEPARTMENT OF ATMOSPHERIC SCIENCE **NAMED**

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The National Geospatial-Intelligence Agency (NGA) and the U.S. Geological Survey named UAH's Department of Atmospheric Science a Center of Academic Excellence (CAE) in geospatial sciences.

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.