FOCUS

The UAH Research Magazine
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STAND AND BE COUNTED

Carbon program helps developing countries help themselves to tackle global greenhouse gas challenges

page 4

ENERGY'S HOLY GRAIL

Researchers are seeing starlight at the end of the tunnel: plasma fusion, virtually limitless and clean

page 8

STRONGER EVERY DAY

A new day dawns for pain sufferers – exploring a therapy to grow new cartilage for aching joints

page 10

THE UNIVERSITY OF ALABAMA IN HUNTSVILLE

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Whether protecting the environment, revolutionizing astronomy or seeking to improve our health, UAH research has far-reaching impacts

As a research university, one of our primary goals is making real-world impacts a focus of our work. Our cover story on carbon accounting is a great example. This project provides NASA satellite data to developing nations from Central America to Vietnam to measure global greenhouse emissions and biomass, helping these countries meet their climate and land-use goals without having to launch satellites of their own.

Similarly, UAH mechanical and aerospace engineering scientists are crafting plasma jet guns to support Los Alamos National Laboratory experiments in a sprint to one of the holy grails of fusion physics: virtually limitless energy that produces zero hazardous waste.

A professor of chemical and materials engineering hopes her project will make life more pain-free for millions of people. Cartilage serves as a cushion between bones, but has no blood vessels to regrow itself. This low-cost method seeks to use ultrasound to produce quality post-operative cartilage in knees.

Looking to space, a professor in the Department of Space Science has demonstrated – for the first time – how energetic neutral atoms can be used to safely probe particle acceleration in solar flares and coronal mass ejections that could disrupt power grids, satellites and communications networks.

UAH broke ground on a new 80,000-square-foot engineering building this spring to provide world-class research and collaborative teaching resources to our largest college and meet STEM workforce needs. In addition, innovators from two colleges, six departments and four centers were honored for patents won. In the past five years, our new technology disclosures have doubled, while patents filed increased by 45% and patents issued jumped 150%.

To enhance safety, an assistant professor in the Department of Mechanical and Aerospace Engineering is investigating 'thermal runaway' to learn why lithium-ion batteries can suddenly fail, causing fires or even explosions. And an assistant professor in the Department of Civil and Environmental Engineering won a fellowship to research predicting and preparing for hurricanes that threaten Gulf of Mexico ecosystems.

UAH also hosted a workshop in the exciting new field of astrostatistics, a discipline that combines statistics with astronomy, promising to revolutionize the way we explore the cosmos, an event that attracted renowned astrostatisticians from all over the world.

A Ph.D. candidate was featured in National Geographic for research on thundersnow that shows this phenomenon produces large, less frequent lightning flashes, a key to wintertime safety. And a graduate student designed a small-scale rotating detonation engine to help boost future NASA missions by burning fuel through a supersonic detonation wave to enhance the range, speed and affordability of these devices over traditional rockets.

The ninth annual Research Horizons Poster Session gave undergraduates a chance to shine, as 34 topics were presented by student researchers, including projects that emulate the re-entry of a planetary probe, illuminate interbacterial competition and improve diesel assembly lines.

One of UAH's greatest strengths is its partnerships. To find out more about these, or any other research project, please contact the UAH Office of Research and Economic Development. ■

POINTS OF PRIDE

THE UNIVERSITY OF ALABAMA IN HUNTSVILLE

A **CARNEGIE R1 TOP-TIER RESEARCH UNIVERSITY** that serves as the anchor tenant of the second-largest research park in the United States, UAH is considered one of the nation's premier research universities.

FEDERALLY FUNDED EXPENDITURES

IN ALABAMA

1ST

IN ALABAMA

- Environmental Sciences, including Atmospheric Sciences
- Computer Sciences
- Physical Sciences

2ND

IN ALABAMA

- R&D expenditures

NATIONALLY

6TH Aerospace/Aeronautical/Astronautical R&D expenditures

9TH Computer and Information Sciences R&D expenditures

10TH Atmospheric Science and Meteorology R&D expenditures

11TH NASA-funded R&D expenditures

12TH Astronomy and Astrophysics R&D expenditures

17TH Department of Defense-funded R&D expenditures

18TH Industrial and Manufacturing Engineering R&D expenditures

SOURCE: National Science Foundation FY21 Data

RESEARCH

$555 million
Five-year contract and grant research total

$169.5 million
Fiscal 2022 R&D expenditure total

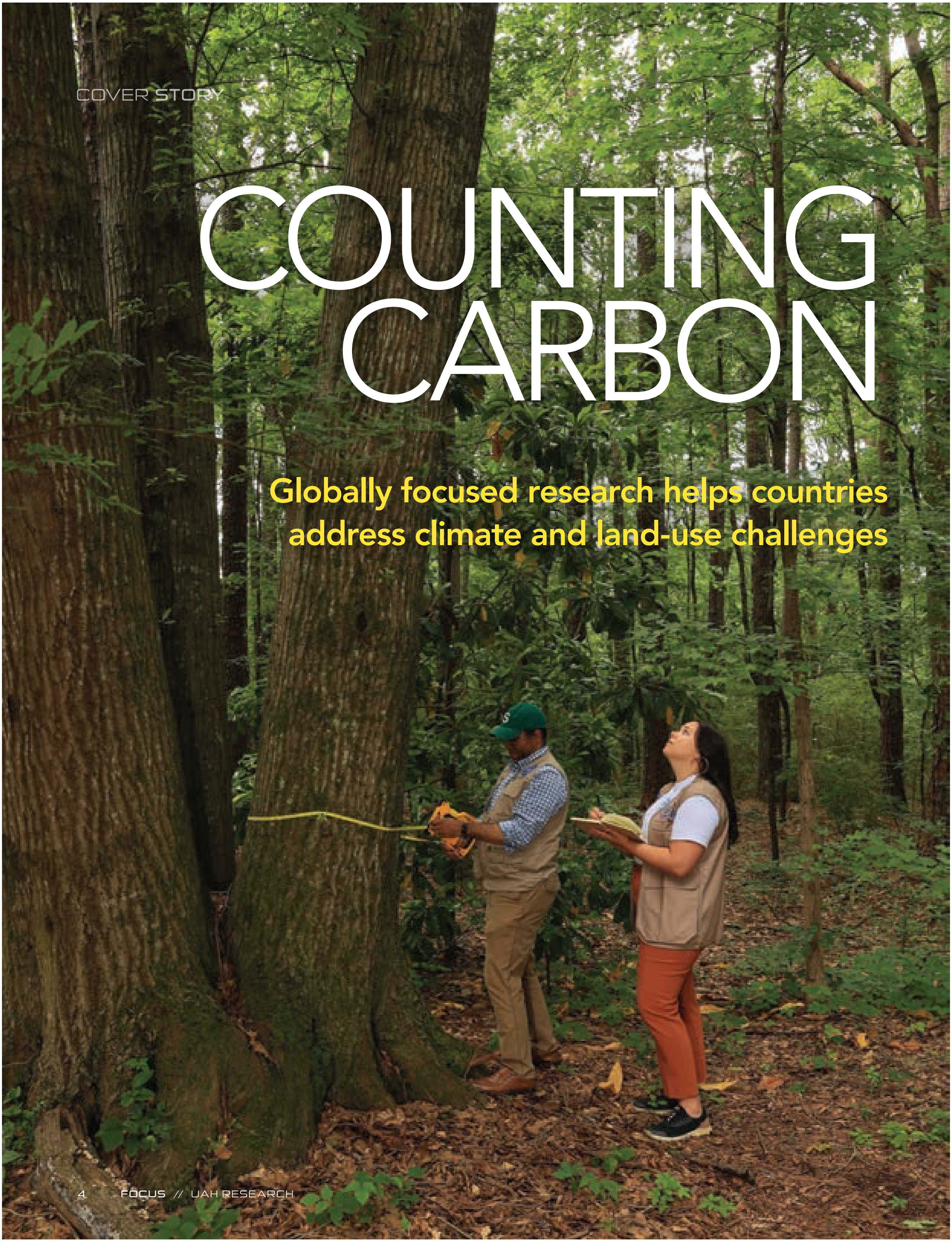
$5.1 million
Ten-year license and royalty revenue total

157
Issued patent total

Cover: UAH researchers Dr. Emil Cherrington and Christine Evans study Mesoamerica satellite data as part of the S-CAP carbon accounting project under the Lab for Applied Science within the Earth System Science Center.

COUNTING CARBON

Globally focused research helps countries address climate and land-use challenges



There's an old saying when it comes to positively impacting the environment: "Think globally, act locally." Researchers in the Lab for Applied Science within the Earth System Science Center have found a way to do both at the same time, bringing cutting-edge technologies to meet the climate and land-use needs of developing nations around the world.

Dr. Emil Cherrington, a research scientist at UAH, leads a carbon accounting project called SERVIR-CArbon Pilot, or S-CAP, that measures greenhouse emissions and biomass to account for carbon shifts in different regions, and investigates the carbon released due to land cover change, such as deforestation. S-CAP is being led by UAH researchers who support the Science Coordination Office for the SERVIR program.

"Internationally, SERVIR supports much of what NASA is doing with land cover, helping to engage key regional centers which collaborate with NASA and USAID," says Dr. Cherrington.

SERVIR is an initiative that strengthens the capacity of nations across the globe to address critical challenges in food security, water resources, weather and climate, land use and disasters using satellite data. Derived from the Spanish word meaning 'to serve,' the program was launched in 2005, jointly co-founded by NASA and the United States Agency for International Development (USAID).

From its initial establishment in Mesoamerica, SERVIR has since grown into a global network of regional hubs that work with NASA satellite data to co-develop solutions in hub countries in South America, West Africa, Eastern and Southern Africa, the Hindu Kush Himalaya and Southeast Asia regions.

"We have almost 30 UAH research staff supporting this program," says Dr. Robert Griffin, associate professor in the Department of Atmospheric and Earth Science, co-director for the Lab for Applied Science, and the principal investigator for UAH's SERVIR team. "NASA spends billions of dollars to put these satellites into space, and the main thrust of the program is to make sure they have an impact. It's very much a collaborative effort, university and hub scientists along with NASA civil servants working together to come up with solutions. Our group occupies a unique niche with NASA, especially working with its Applied Sciences Program – thinking about what our science can impact."

"Think globally, act locally"

S-CAP is a more recent addition that resides under the SERVIR umbrella and makes use of its established network. "S-CAP responds to key areas outlined in the strategic plan for the NASA Earth Science Division's Applied Sciences Program," explains Dr. Cherrington. "In early 2020, we came up with the concept of plugging in the mapping of biomass and carbon dioxide emissions into the land cover change monitoring work that SERVIR was already doing, and we started implementing this applied research in 2021."

A native of Belize in Central America, the scientist knows first-hand the importance of environmental management, having worked on research ranging from land cover monitoring in West Africa to using NASA satellite data to assess risks to Belize's coral reefs. S-CAP is the next step to maximizing both scientific and natural resources by comparing data from many sources to paint the most accurate picture possible for large-scale analysis of land cover needs.

"The idea is to build on the different SERVIR land cover services that are already in development and to translate land cover change data into estimates of carbon stock and carbon dioxide emissions estimations, and we're implementing this in pilot countries in more of SERVIR's focus regions," says Dr. Cherrington.

'Carbon stock' represents the absolute quantity of carbon held in a habitat at any specified time.

"From a scientific perspective, it's about getting a much better handle on how much biomass we have globally, how much carbon our ecosystem is holding and releasing," Dr. Cherrington says. "There are a number of countries trying to improve the methods of how they are looking at the impact of carbon. A big part is looking at other people's data and comparing them. We found that with SERVIR and the regional centers in Asia, Africa and the Americas, the data fits in and shows how much biomass we really have."

The UAH team is collaborating with researchers from SERVIR's NASA-funded Applied Sciences Team and also with scientists affiliated with NASA's Carbon Monitoring System to strengthen SERVIR greenhouse gas (GHG) monitoring capacities and develop training materials for GHG estimation for use in the target regions. For S-CAP, that includes the pilot countries of Bangladesh, Bhutan, Cambodia, Colombia, Costa Rica, Côte d'Ivoire, Ghana, Guatemala, Guyana, Kenya, Nepal, Peru, Thailand, Vietnam and Zambia.

"Our pilot countries already do biannual reporting to a global mechanism called REDD+ which focuses on helping countries reduce deforestation and degradation," says Christine Evans, a research scientist who recently earned her master's degree from UAH in Earth system science. "The big highlight from S-CAP is that there is no one correct way to do this, but it's important to look at the entire range of different data sets to better understand what is happening. We call this an ensemble approach.

"For example," Evans goes on, "if we want to accurately measure how much biomass a tree really contains,

UAH S-CAP Project Scientist Christine Evans (left) investigates mangrove restoration in Guyana with Vanesa Martin-Arias (right), SERVIR - Amazonia Regional Science Coordination Lead.

Courtesy Christine Evans

we would have to cut it down, dry it in a special oven, and then weigh it. But with remote sensing, there are multiple ways of estimating forest biomass without having to cut down trees. Using the imagery of what's there now, we can fairly easily tell how much forest a country has. The more complicated part is estimating how much biomass has been lost and converted into carbon dioxide emissions over the years. Using the ensemble approach gives us a much better estimate of that. Synthesizing all these different areas gives a better idea of their current emissions and their country's overall carbon 'budget.'"

Africa Flores-Anderson, S-CAP team member and UAH research scientist within the Lab for Applied Science, expands on how S-CAP fits into and adds value to SERVIR's global Land Cover portfolio: "S-CAP is leveraging the SERVIR Global Land Cover Change Inter-comparison project and estimating carbon emissions from the multiple change detection methods used across the SERVIR global network. S-CAP is adding value to SERVIR land cover mapping efforts."

Flores-Anderson recalls the early days of SERVIR and how far the program has come. "It started in Central America with capacity building and rapid-response activities. But we have since expanded to Africa and Asia. We have a more holistic program now, with stronger focus on climate mitigation and resilience."

A particularly valuable aspect of the SERVIR initiative is that it is multi-disciplinary. "Everyone brings their unique perspective to the team, whether it's communications, anthropology, Earth science, etc.," says Dr. Griffin.

One of the most important aspects of S-CAP is converting the information gained from multiple land cover change maps and global datasets into actionable knowledge for countries.

"We have people right now on multiple continents," Dr. Griffin explains. "The ultimate goal is to have an impact in each of the different regions. For S-CAP, there is a series of training activities at the country level where we are able to communicate the impact of our analysis on the ground."

Researchers like Evans take this data to the field, working to train local researchers to support the overall S-CAP goals for their region. She has already given workshops in Guatemala, Guyana and Colombia, and plans future forays to other hub nations. "Our hope is to help them enhance their carbon accounting capabilities, so that every time they generate new land cover, they will get new measurements of GHG emissions," Evans says.

"Christine has been serving as a project scientist who is doing the heavy lifting for this part of the effort," Dr. Cherrington says. "The work she has done to transfer that knowledge to these different regions is important. This enables them to leverage NASA's data, so that these countries don't have to launch their own satellites."

Determining the focus of these resources involves an understanding of which countries already have the demand and the capacity, Dr. Cherrington points out. "SERVIR is covering over 50 countries, and S-CAP is focusing on 15, chosen in concert with our hub organizations. Certain countries are further along for the demand for the data sets there. It's all about how can we help these countries do a better job in terms of managing their carbon dioxide emissions."

At over eighteen years, SERVIR is the second longest-running collaborative program supported jointly by USAID and NASA. USAID's projects usually run five years at a maximum, Flores-Anderson notes. "We built trust and have to make sure our contributions are actually addressing specific needs local stakeholders have. It's a long, iterative process."

To support that process, it's vital to integrate regional data-gathering into the overall picture to make the program truly effective.

"We have people on the ground who have in situ data, so part of what I'm doing is validating what we are doing based on the local knowledge," Evans adds. "SERVIR hub organizations have shared thousands of data points, and leveraging this data from these regional centers is giving us a better idea about what works. Global data sets are pretty accurate, but regionally can really differ, so that can help guide them on what data sets to look at."

"We have a term for our philosophy: 'co-development,'" Dr. Cherrington says. "We are developing things with them. What is your need? What do you have already? It is all built with them, and that makes things go much more smoothly." ■

BREAKING AWAY

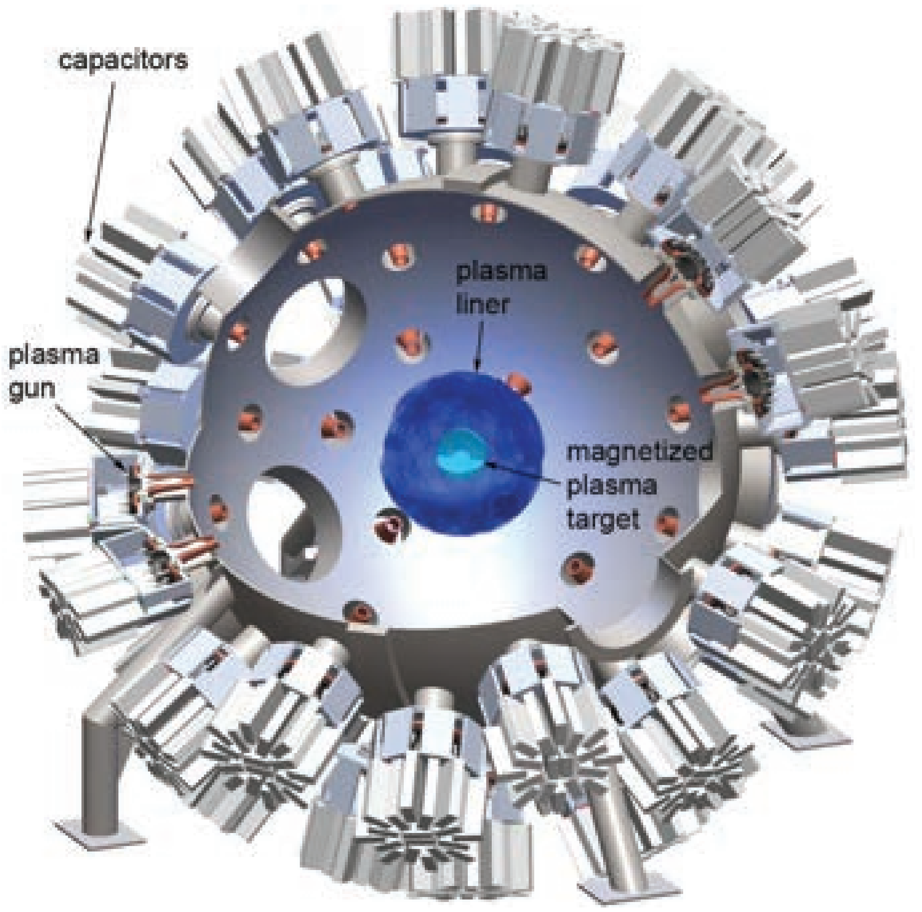
UAH researchers charge toward "holy grail" clean energy project

Nuclear fusion has been a goal of scientists around the world since the 1950s. Unlike solar and wind power, fusion energy is virtually limitless, and – unlike electricity generated by fission reactors, coal, oil or natural gas – fusion requires no fossil fuels and leaves zero hazardous waste behind.

Two mechanical and aerospace engineering researchers, Dr. Gabe Xu and Dr. Jason Cassibry, have placed UAH right in the thick of this conversation. The pair won awards totaling $750,000 from the Department of Energy Established Program to Stimulate Competitive Research to partner with the Los Alamos National Laboratory (LANL) to help make strides toward this dream goal. The project marks the first experimental collaboration between UAH and the LANL, bringing cutting-edge fusion and high energy density plasma research to the university.

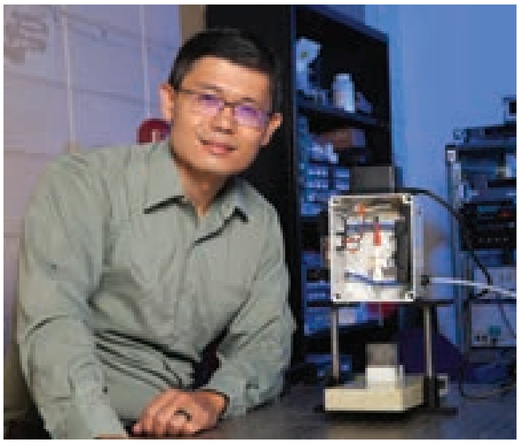
"Plasma fusion is one of the holy grails in our field of plasma physics and important for the world," Dr. Xu says.

Plasma is mostly associated with stars, which generate energy when protons of hydrogen atoms in their cores violently slam together to fuse and form helium atoms. Producing accurate simulations



▲ The fusion reaction is created using a shrinking plasma shell, called the liner, to compress a high-density magnetized plasma target in the center of a spherical vacuum chamber. The plasma liner is generated by dozens of high-velocity plasma jets produced from plasma guns mounted around the chamber.

Courtesy LANL



Dr. Gabe Xu (left), associate professor of mechanical and aerospace engineering and Dr. Jason Cassibry (right), professor of mechanical and aerospace engineering affiliated with the UAH Propulsion Research Center.

of plasma fusion in the laboratory is crucial to guiding experiments that could ultimately lead to the development of a viable fusion reactor. 'Breakeven fusion' describes the moment when plasmas in a fusion device release at least as much energy as is required to heat them, which could someday provide abundant clean energy.

The UAH researchers are studying magnetized high-energy-density plasma interactions to support a concept called plasma-jet magneto-inertial fusion, or PJMIF, one of the key components to achieving breakeven fusion. Magneto-inertial fusion, or MIF, is a class of fusion devices that use magnetic fields to confine a warm, low-density plasma, which it compresses to fusion conditions.

"The PJMIF concept creates a fusion reaction by using a shrinking plasma shell, called the liner, to compress a high-density magnetized plasma target in the center of a spherical vacuum chamber," explains Dr. Xu.

"The focus of our project is to look at the next step in the PJMIF approach, namely the interaction of the plasma liner with the magnetized target plasma. For fusion to occur, the liner has to compression the target and convert its kinetic energy into thermal energy and heat the plasma to fusion conditions. Our small-scale test will be one step towards understanding the plasma interactions and energy conversion process that can inform the larger scale efforts of PJMIF."

The plasma liner is generated by dozens of high-velocity plasma jets produced from coaxial plasma guns mounted around the chamber, Dr. Xu notes. "As the plasma jets move towards the target in the center, they merge into the shell/liner."

While the Los Alamos National Laboratory is focused on studying this merging behavior and formation of the liner, UAH's role in the partnership seeks to examine the interaction between the magnetized plasma target and a high-velocity plasma jet. One of the primary objectives of Dr. Xu and his lab is to develop the staged plasma guns required to produce the plasma jets, which will in turn lead to large-scale plasma gun development at LANL.

"Imagine taking a slice of the PJMIF sphere; that's what we're looking at," Dr. Xu says. "To get high compression, you want high-velocity kinetic energy in the jets. We recently successfully fired a single-stage coaxial plasma gun in the lab. That was the first step in the project, and arguably the most important."

Just how integral is the concept to achieving clean energy?

"Understanding how the two plasmas interact and how to convert the kinetic energy of the jet to thermal energy that can heat and compress the target will help PJMIF and other related concepts towards breakeven," the researcher says. "It's hard to predict the best way to achieve breakeven fusion. Progress on inertial and magnetic concepts suggests a working fusion pilot plant is achievable in about 15 to 20 years. The National Ignition Facility achieved ignition for the first time last year. That's not breakeven, but it's a step towards it."

Thinking about the path to that boundless future brings a smile. "Next, we'll start designing secondary acceleration stages and learn how to couple them physically and electrically," Dr. Xu says. "It will not be easy, as the coaxial configuration makes electrical connections challenging, but we're excited to try. The science we learn from our project will inform future pulsed-fusion concepts and designs that can finally give us clean energy." ■

LEAPS AND BOUNDS

Advancing toward the day when ultrasonic therapy makes stronger knees

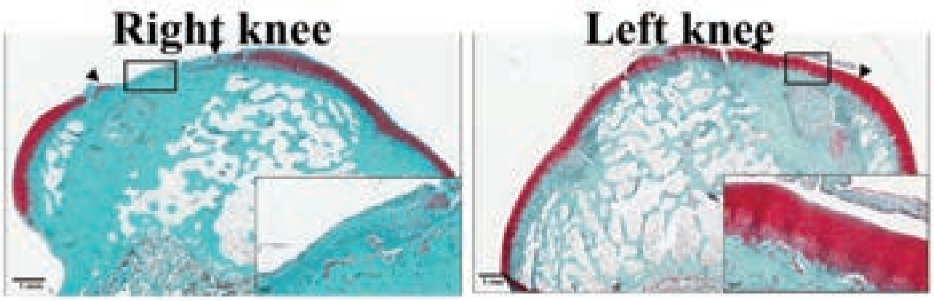
Dr. Anu Subramanian has explored the effects of ultrasound on cartilage regrowth in NIH-funded in-vitro and bovine cadaver knee research since before she joined UAH in 2018.

Low-intensity ultrasound therapies may one day rebuild stronger knees following injury or surgery, thanks to research by Dr. Anu Subramanian, a professor of chemical and materials engineering. She is exploring the effects of ultrasound on cartilage regrowth through National Institutes of Health (NIH) funding totaling $1.9 million over the course of her career.

Dr. Subramanian's investigations have progressed over the years from the test-tube phase through cadaver cow knee work, rabbit testing and now to equine knee investigations in collaboration with Colorado State University (CSU).

Cartilage that serves as a cushion between knee bones is a protein-rich matrix containing very few cells. It has no blood vessels, so it cannot regrow itself. Orthopedic surgeons try to compensate for that reality with a technique that drills into the adjoining bone to create microfractures to produce blood rich in stem cells.

Some of the resulting mesenchymal cells convert to another type, called chondrocyte cells, that are needed to regrow collagen. However, some instead become fibroblasts and create a much less sturdy form of collagen which produces a weaker bond with



This panel shows a stained section of a representative right and left rabbit knee joint, respectively. The solid arrows show the boundaries of the defect. Left rabbit knee joints were treated with cLIUS and the right knee joints served as the control. A robust red color between the arrows in the left joint indicates tissue regeneration.

Courtesy Anu Subramanian

the potential for future failure following injury or surgical intervention.

To address this problem, Dr. Subramanian has been researching a low-cost method that uses continuous low-intensity ultrasound (cLIUS) therapy to regrow quality post-operative cartilage in joints like the knee or shoulder. Under the current four-year, $494,000 continuing R01-NIH grant that's part of her total award, ultrasound will be used following equine surgeries at CSU.

The advance aims to bring the day closer when an injured knee will undergo Magnetic Resonance Imagery, then a computer will tell the surgeon where and how best to apply post-operative ultrasound to encourage cartilage regrowth with characteristics very close to the original material.

"We have demonstrated the proof-of-concept in a rabbit model, and currently we are working to translate the findings to a larger animal model, the equine model, which has joint characteristics close to that of a human," Dr. Subramanian explains.

Dr. Sarma Rani, a UAH associate professor of mechanical and aerospace engineering, is a co-investigator in the current grant, which also supports doctoral students Shahid Khan (biotechnology science), Aryana Singh Bhati (biotechnology), Sattik Basu (mechanical and aerospace engineering) and Owen Trippany (mechanical and aerospace engineering; chemical and materials engineering).

Following approval by the Institutional Animal Care and Use Committee (IACUC) of the American Association for Laboratory Animal Science, research with rabbits was successful in demonstrating that ultrasound promotes integration of newly grown tissue with the surrounding native tissue, Dr. Subramanian notes.

"We surgically created defects in the knee joints of rabbits using a technique called microfracture, where a small defect is created and the cartilage is debrided and tiny holes are drilled into the underlying bone to harness the endogenous supply of mesenchymal stem cells that have healing potential," the researcher says.

"Our results demonstrate that healing of chondral defects treated with microfracture can be accelerated by employing the cLIUS regimen at the beneficial frequency. We have demonstrated in our IACUC-approved study that joints that received ultrasound upon microfracture had improved cartilage repair and better repair scores when compared to control joints that did not receive any ultrasound, but underwent microfracture."

The results also demonstrated that ultrasound can encourage repair in the initial pro-inflammatory joint environment that immediately follows surgery or injury. "Inflammation during the recovery and regeneration phase plays a critical role in modulating the repair outcome," Dr. Subramanian says.

"For example, during the early recovery phase, the joint environment harbors a plethora of cytokines moieties that, if left unchecked, can have a catabolic effect and impede the repair process. So, treatment modalities need to encourage healing and repair, but also mitigate the catabolic effects of the cytokines present. Our work has shown that continuous low-intensity ultrasound, when used at the beneficial regimen, promotes repair and regeneration in an inflammatory environment."

Dr. Subramanian says she's always been intrigued by the benefits to be gained by approaching challenges like these at the intersection where biology, medicine and engineering meet.

"I think my engineering perspective brings quantitative aspects to this research, and I am able to define the underlying challenges using a process modeling approach," she says. "Over the years, I have ventured more and more into cartilage biology and the underlying biochemistry and molecular biology aspects." ■

HOWDY, NEIGHBOR?

RESEARCHERS DISCOVER MONSTER BLACK HOLE ‘PRACTICALLY IN OUR BACKYARD’

A UAH physics professor is the lead author of an Astrophysical Journal research submission that details the discovery of a so-called ‘monster’ black hole that contains about 12 times the mass of the sun. The celestial object is also “closer to the sun than any other known black hole, at a distance of 1,550 light years,” says Dr. Sukanya Chakrabarti. “So, it’s practically in our backyard.”

Dr. Chakrabarti is the Pei-Ling Chan Endowed Chair in the Department of Physics and Astronomy. “It is not yet clear how these noninteracting black holes affect galactic dynamics in the Milky Way,” she says. “If they are numerous, they may well affect the formation of our galaxy and its internal dynamics.”

Black holes are seen as exotic because, although their gravitational force is clearly felt by stars and other objects in their vicinity, no light can escape a black hole, so they can’t be seen in the same way as visible stars.

"In some cases, like for supermassive black holes at the centers of galaxies, they can drive galaxy formation and evolution," Dr. Chakrabarti says.

To find the black hole, the UAH researcher and a national team of scientists analyzed data from nearly 200,000 binary stars released from the European Space Agency's Gaia satellite mission.

"We searched for objects that were reported to have large companion masses, but whose brightness could be attributed to a single visible star," Dr. Chakrabarti says. "Thus, you have a good reason to think that the companion is dark."

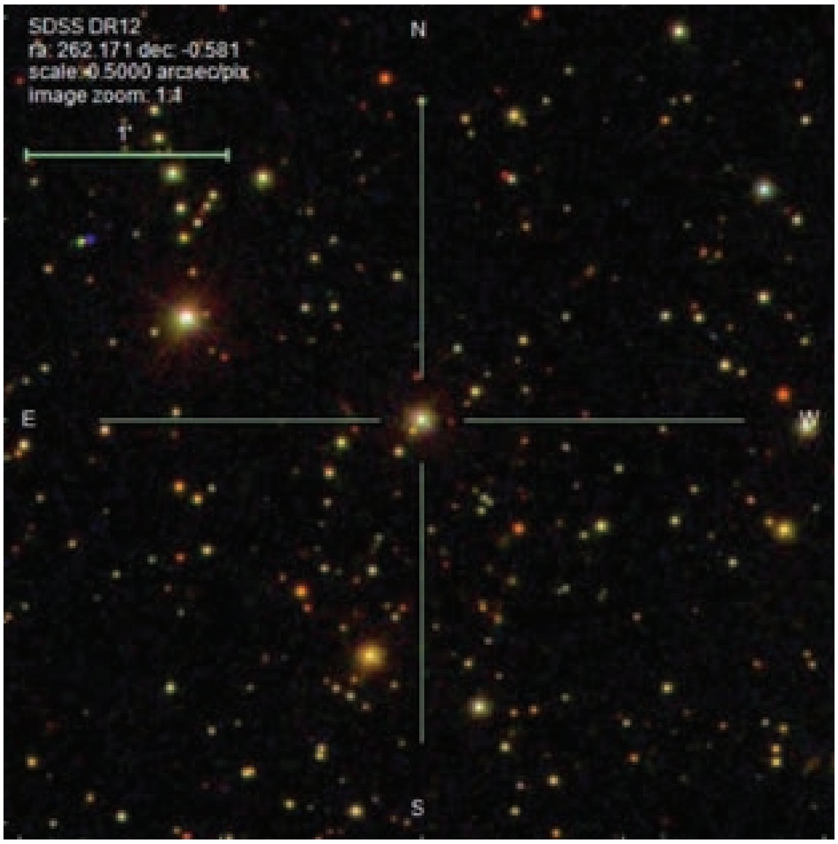
Intriguing sources were followed up with spectrographic measurements from various telescopes, including the Automated Planet Finder in California, Chile's Magellan Telescopes and the W.M. Keck Observatory in Hawaii.

"The pull of the black hole on the visible sun-like star can be determined from these spectroscopic measurements, which give us a line-of-sight velocity due to a Doppler shift," says Dr. Chakrabarti. A Doppler shift is the change in frequency of a wave in relation to an observer, like how the pitch of a siren's sound changes as an emergency vehicle passes.

"By analyzing the line-of-sight velocities of the visible star, we can infer how massive the black hole companion is, as well as the period of rotation, and how eccentric the orbit is," she says. "These spectroscopic measurements independently confirmed the Gaia solution that also indicated that this binary system is composed of a visible star that is orbiting a very massive object."

The black hole has to be inferred from analyzing the motions of the visible star because it is not interacting with the luminous star.

"In this case we're looking at a monster black hole, but it's on a long-period orbit of 185 days, or about half a year," Dr. Chakrabarti says. "It's pretty far from the visible star and not making any advances toward it." ■



▲ The cross-hairs mark the location of the newly discovered monster black hole.

Courtesy Sloan Digital Sky Survey

▲ Dr. Sukanya Chakrabarti, the Pei-Ling Chan Endowed Chair in the Department of Physics and Astronomy, is the paper's lead author.

HAVING A BLAST

Using energetic neutral atoms to probe the origins of violent solar storms

Solar flares and coronal mass ejections (CME) are two of the most energetic processes in the solar system, showering the Earth's magnetic field with billions of tons of highly energetic plasma gas, potentially disrupting power grids, satellites and communications networks. Understanding the underlying acceleration process involved in large solar energetic particle (SEP) events like these has been one of the central problems in heliophysics research.

Dr. Gang Li, a professor in the Department of Space Science, is the first author of a paper in The Astrophysical Journal that demonstrates – for the first time – how energetic neutral atoms (ENAs), could be used as a new means to probe the acceleration process in large SEP events, as well as to differentiate between the two acceleration sites: large loops in solar flares and CME-driven shocks.

"This work is likely to excite the heliophysics community to consider more about the generation and propagation of solar ENA particles," Dr. Li says. "The paper demonstrates for the first time that ENAs can be used to distinguish between CME/Flare SEP acceleration, laying down the necessary theoretical groundwork for possible future measurement of solar ENAs."

The researcher's work is supported by two NASA Living With Stars grants, as well as a National Science Foundation grant.

"Dr Li's work provides a groundbreaking new approach to exploring the physics of particle acceleration in the atmosphere of the Sun remotely," says Dr. Gary Zank, director of UAH's Center for Space Plasma and Aeronomic Research and the Aerojet Rocketdyne chair of the Department of Space Science. "This expands the already substantial effort in the Department of Space Science of using ENAs to explore remote regions of the heliosphere, where we utilize ENAs created in the distant boundaries of the heliosphere and neighboring interstellar medium to explore the plasma physics of those regions."

"The ultimate goal of using ENAs is to obtain various physics parameters at the acceleration sites," Dr. Li adds. "Scientists know that particles can be accelerated at two possible locations: either solar flares or CME-driven shock. However, which site is more efficient in accelerating particles? Which site can accelerate particles to higher energies?"

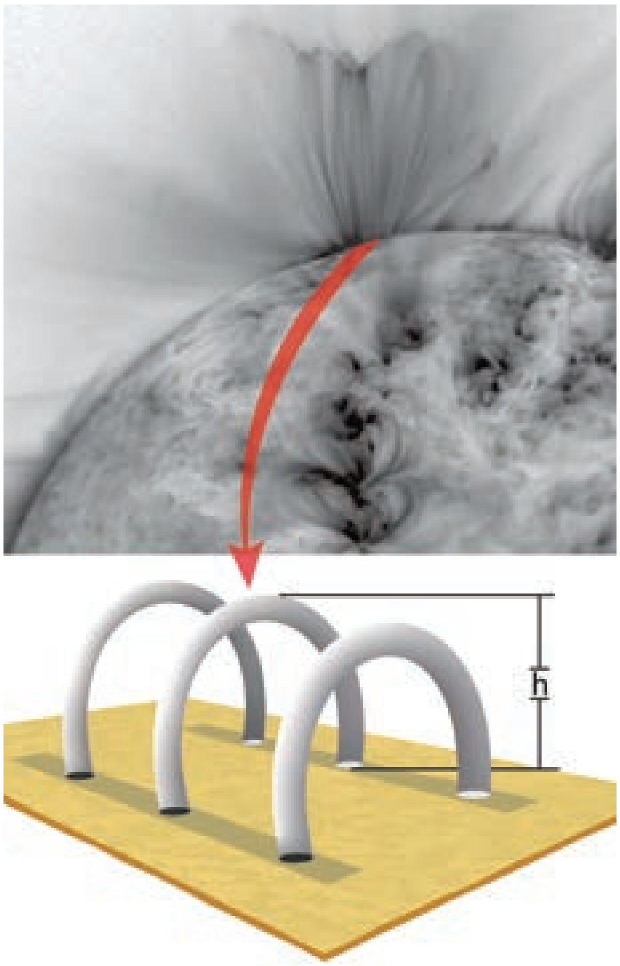
The main barrier to solving these mysteries through experimental observation is the Sun itself, as basic understanding of near-Sun conditions and the physical processes involved in the production of SEP events is hampered by an inability to make direct measurements near the acceleration sites.

ENAs represent a potential method for supplying answers, because they are neutral hydrogen atoms that are not affected by magnetic fields.

"This is very important, because these neutral particles are not affected by the solar wind MHD [magnetohydrodynamic] turbulence as they propagate from the Sun to observers," Dr. Li explains. "In comparison, protons, ions and electrons, because they are charged, their propagation from the Sun to the Earth is distorted by the solar wind magnetic field. ENAs, therefore, carry all the physics information of the acceleration site. So, observing them offers an entirely new opportunity to constrain the underlying particle acceleration process."

Also, the energetic atoms could still be measured by a dedicated ENA detector at a distance of 1 astronomical unit, or about 150 million kilometers from the Sun. The quest to retrieve this data could ultimately lead to a new NASA solar mission to better understand these particles and how large SEP events originate to impact the Earth's magnetosphere.

In fact, a new NASA mission called IMAP (Interstellar Mapping and Acceleration Probe), will have ENA instruments at 1 astronomical unit capable of measuring ENAs created both in the distant reaches of the heliosphere and also originating from the Sun. ■



The illustration depicts postflare loops in solar flares. Large-scale and high-postflare loops are potential production sites of solar energetic neutral atoms or ENAs.

Courtesy Gang Li

Dr. Gang Li, professor in the UAH Department of Space Science.

Breaking new ground

CHARGING INTO THE FUTURE WITH APPROVAL OF RAYMOND B. JONES ENGINEERING BUILDING

UAH held a groundbreaking ceremony for a new 80,000-square-foot engineering facility to be named the Raymond B. Jones Engineering Building, honoring the longtime business and community leader and past chairman of the UAH Foundation. The facility, which received initial approval by The University of Alabama System Board of Trustees, will provide cutting-edge resources to support the largest college at UAH, comprising more than 2,850 students, as well as 90 faculty and staff.

"UAH is known for our talented faculty and students who go on to be some of the brightest leaders in the national security, space exploration, healthcare, arts and business sectors," said UAH President Charles L. Karr at the ceremony. "The Huntsville community is known for our remarkable STEM labor force, and the Jones Engineering Building will enhance our students' experience."

Phase I of the project received Stage II approval from The University of Alabama System Board of Trustees at its April 2023 meeting. Phase I is estimated to cost $62.38M, and the facility will replace the Wernher von Braun Research Hall, constructed in 1964. The new building will be located west of the existing Engineering Building, adjacent to the campus lake along John Wright Drive.

UAH is classified as R1 – "Very high research activity" status – among doctoral-granting universities by the Carnegie Classification of Institutes of Higher Education. Five of UAH's research programs currently rank among the top 20 federally funded programs in the U.S. Fiscal year 2021 marks the tenth year in a row UAH has

▲ Raymond B. Jones, civic leader and past chairman of the UAH Foundation.

Courtesy Raymond B. Jones family

University of Alabama System Board of Trustees, UAH Foundation, representatives of local and state governments, members of the military, members of the family of Raymond B. Jones, community leaders and UAH faculty, staff and students were on The University of Alabama in Huntsville campus April 14, 2023, to break ground for the new Raymond B. Jones Engineering Building.

Conceptual view of the UAH College of Engineering Building. Renderings are conceptual and subject to change. All projects are subject to the approval of The University of Alabama System Board of Trustees.

had five or more research programs ranked in the top 25 nationally for federal research funding.

"Ensuring the growth and success of UAH is one of our top priorities, and the groundbreaking of this transformative building is a testament to that commitment," said UA System Board of Trustees President Pro Tempore W. Stancil Starnes. "The Jones Engineering Building will be integral to UAH's role in supporting the region's workforce, research and educational needs, and we are confident it will favorably impact this community for generations to come. The future is bright for UAH."

Huntsville and North Alabama comprise both the fastest-growing region of the state and a high-tech hub with a continual need for a highly educated STEM labor force. The new Jones Engineering Building will feature modernized, world-class research and collaborative teaching facilities that will ensure the university continues to meet the state's workforce needs.

"This new building will serve as a centerpiece for UAH, enabling us to recruit the very best and brightest students from all 67 counties in our state, from states across the nation and beyond," said College of Engineering Dean Shankar Mahalingam.

All stages of this multi-phased project are subject to approval by the UA System Board of Trustees. ■

Eureka!

UAH recognizes inventors for patent awards during 2022-2023 year

UAH honored the achievements in innovation by inventors from two colleges, six departments and four centers who were awarded patents during the past year during the University Awards for Excellence ceremonies.

"Inventors like these individuals are making increasing contributions to UAH and to the marketplace through their innovations, which are proactively managed by the Office of Technology Commercialization," said Kannan Grant, director of the OTC.

"UAH's increased investment in its people has resulted in a significant increase in patenting activity. In the past five years, new technology disclosures have doubled; the number of patents filed has increased by 45%, and the number of patents issued has increased 150%. These plaques are a testament to the achievements of UAH innovators."

Dr. Robert Lindquist, vice president for research and economic development, presented desk plaques commemorating the patent awards.

11,261,945, "Coupling System for Reducing Fatigue and Dynamic Amplification of Loads in Objects," James Blackmon and Frederick Gant (Engineering)

11,300,502, "Time-Wavelength Optical Sampling Systems and Methods for Determining Composition of a Sample Based on Detected Pulses of Different Durations," Lingze Duan and Lin Yang (Science)

11,353,625, "Systems and Methods for Forecasting Lightning and Severe Storms," John Mecikalski (Science)

11,378,748, "Optical Frequency Discriminators Based on Fiber Bragg Gratings," Lingze Duan and Dipen Barot (Science)

11,383,410, "Methods of Curing Ionic Liquid Epoxy Mixtures," William Kaukler (Rotorcraft Systems Engineering and Simulation Center)

11,346,330, "Hall Effect Thruster with Additively Manufactured Components," Gabe Xu and Ethan Hopping (Engineering)

11,483,967, "Method of Conversion to Automated Lawn Mower," Farbod Fahimi, Gavyn Grove, Matthew L'Antigua, Joseph Martin, Rahul Rameshbabu, Tyler Oliger (Engineering)

11,559,457, "Rotational Swing Systems and Methods for Providing Vestibular Stimulation," Deana Jo Aumalis (Early Learning Center), Scott Banwell, Stephanie Krueger, Haley Brunick, Christina Carmen, Christopher Kelley, Michael Langley (Engineering)

11,554,244, "Systems and Methods for Multi-Modal and Non-Invasive Stimulation of the Nervous System," Emil Jovanov (Engineering) ■

Circuit Breaker

Researcher wins $600K NSF CAREER Award to research dangerous battery failures

Research focused on why and how lithium-ion batteries may suddenly fail energetically, causing smoke, fire or even an explosion, a phenomenon called thermal runaway, has earned a UAH researcher a National Science Foundation (NSF) CAREER Award totaling $598,181.

Dr. Guangsheng Zhang, an assistant professor in the Department of Mechanical and Aerospace Engineering, is the principle investigator on the five-year award slated to run through April 2028. NSF CAREER Awards are made to emphasize the importance of early development of academic careers, and embody the commitment to encourage faculty and academic institutions to value and support the integration of research and education.

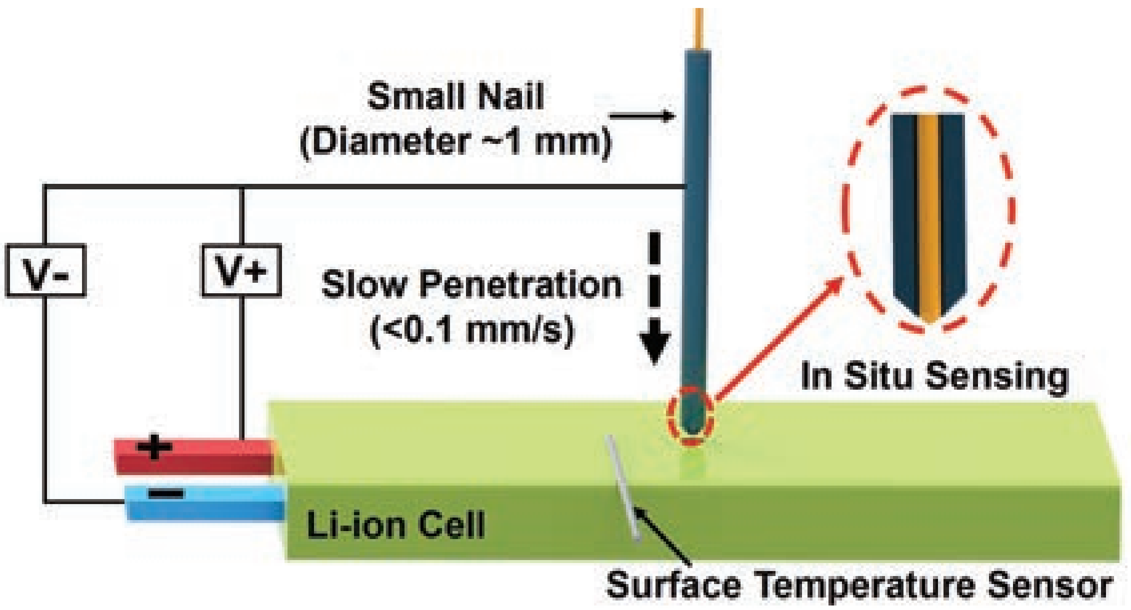
"I feel very fortunate and honored to receive this award," Dr. Zhang says. "I was intrigued by this problem about 10 years ago when I was just starting research on lithium-ion batteries. I was shocked by news that lithium-ion batteries in some advanced electric vehicles and airplanes suddenly caught fire without warning. Such tragedies occurred again and again over the years, influencing various industries from toys and smart electronics to utility-scale energy storage. It suggested that a fundamental understanding of the problem is needed."

A thermal runaway in a battery is a situation where one exothermal process, meaning a condition or incident accompanied by a release of heat, triggers other processes, ultimately resulting in an uncontrollable increase in temperature.

"What makes this most concerning is that, in some cases, the batteries suddenly caught fire when the devices or vehicles were not in use," the researcher says. "Investigations have attributed many of those fires to lithium-ion battery thermal runaway caused by internal short circuit (ISC)."

Dr. Zhang built on his Ph.D. and postdoctoral research on in situ diagnosis of fuel cells and batteries to develop diagnostic methods with his students to trigger and characterize ISC of lithium-ion batteries.

"Unfortunately, there are still many unknowns," he notes. "What is the threshold of ISC causing thermal runaway? How exactly does ISC form and slowly evolve to the threshold of thermal runaway, in some cases after years of normal



operation? How can ISC be prevented from reaching the threshold of thermal runaway? These questions become increasingly intriguing and urgent as the deployment of Li-ion batteries rapidly increases in various applications."

Finding answers is the goal of the current project. "First, we plan to identify and determine the threshold of thermal runaway caused by ISC through in situ measurement of critical parameters, such as ISC current, temperature and heat generation," Dr. Zhang says. "Second, we aim to understand the formation and evolution of ISC through imaging and electrochemical characterization. Third, we plan to understand the effects of some novel strategies on ISC behaviors."

The researcher believes insight gained from this research will advance the understanding of lithium-ion battery ISC and thermal runaway, inspiring engineers in battery and battery-powered industries to come up with novel solutions.

In addition, the project will facilitate educational and outreach activities, "such as the organization of a series of seminars on energy storage, creating an energy storage club, developing a new course on batteries, mentoring undergraduate student research and establishing hands-on workshops for high school students," Dr. Zhang notes. "Also showcasing energy storage research at local STEM events. These activities aim to attract and train the next generation workforce to prepare them for the challenges and opportunities in emerging battery-enabled industries, such as the electric vehicle industry and renewable energy storage industry." ■

▲ Some thermal runaway incidents are caused by internal short circuit (ISC) of individual Li-ion cells. The schematic depicts a variation of a nail penetration test widely used to trigger ISCs for safety evaluation since the early commercialization of Li-ion cells. Using a smaller nail and slower penetration of the cell than conventional testing, as well as in situ sensing, provides a more extensive understanding of ISC and thermal runaway behaviors.

Courtesy Guangsheng Zhang

CONSERVE AND PROTECT

Researcher honored with fellowship for work helping coastal ecosystems

Dr. Abdullahi Salman, an assistant professor in the Department of Civil and Environmental Engineering, will spend the next two years advancing scientific knowledge to predict and prepare for ecosystem challenges in the Gulf of Mexico and its coastal zones as the region navigates a changing climate and energy transition.

The researcher was named to the 2022 cohort of Early-Career Research Fellows in the Environmental Protection and Stewardship track by the Gulf Research Program (GRP) of the National Academies of Sciences, Engineering and Medicine. The fellowship includes a $76,000 award.

"Conducting research that will help protect the ecosystems in the Gulf of Mexico has been one of my goals since I joined UAH," Dr. Salman says. "The GRP fellowship will go a long way in helping me to advance the research and contribute to preserve and protect our precious ecosystems."

Extreme winds from hurricanes can damage these fragile environments through the influx of organic material. Hurricane-induced storm surges can also lead to scouring of estuarine habitats, which is sea-floor erosion caused by strong tidal currents that results in the removal of inshore sediments and formation of deep holes and channels, as well as inundating terrestrial and freshwater habitats with saltwater.

"Coastal ecosystems – including estuaries, barrier islands and coastal rivers – face increasing risk from hurricanes and climate change-related stressors," Dr. Salman says.

Similarly, the researcher notes that extreme precipitation due to the violent storms can also cause scouring in riverine ecosystems, with impacts projected to worsen due to climate change.

"Two questions will drive the research. How do we predict changes to ecosystems due to increasing hurricane activities because of climate change? And how do we make decisions on protecting the ecosystems, considering the deep uncertainty involved in modeling climate change-related hurricane hazard changes?" ■

"Conducting research that will help protect the ecosystems in the Gulf of Mexico has been one of my goals since I joined UAH."

PROBABLE CAUSE

USING STATISTICS TO REVOLUTIONIZE BIG DATA ASTRONOMY

The digital age has been a tremendous boon to the fields of both statistics and astronomy. However, according to Dr. Max Bonamente, a professor of physics and astronomy at UAH, most astronomers are not sufficiently trained to realize the substantial benefits to be gained by putting these disciplines together. He and his colleagues are working to change all that through pioneering research in the burgeoning field of astrostatistics.

Dr. Bonamente published a paper in the Monthly Notices of the Royal Astronomical Society, one of the world's leading research journals in astronomy and astrophysics, that showcases an innovative new twist in probability distributions that promises to revolutionize the ways cosmological data can be interpreted.

"Traditionally, astronomers have been poor statisticians – we like to 'make up the statistics as we go,'" the researcher explains. "My latest paper is a new method to account for systematic errors. It describes a new probability distribution method I developed that hadn't been thought of before. It's nerdy stuff but has real-life implications in terms of making conclusions from observations. Many astronomers don't have the necessary math background to do statistics carefully. It's hard, because statistics is hard math at its core. Few people want to take the extra time to do it. Of course, not everyone feels that way."

This is evidenced by the success of a workshop recently hosted by UAH, organized by Dr. Bonamente along with his colleague, Dr. Lingling Zhao, an assistant professor of space science. Called iid2022: Statistical Methods for Event Data and subtitled Illuminating the Dynamic Universe, the event was funded by the National Science Foundation and attracted some of the most renowned researchers from the astrostatistics community.

The gathering was designed to train young scientists in proper statistical methods for the analysis and interpretation of data and included hands-on collaborative analysis of sample problems employing advanced software. The gathering also provided a forum for astronomers and researchers in related fields to exchange recent advances in the analysis of event data.

A native of Italy, Dr. Bonamente moved to the U.S. in 1997 and is a UAH alumnus, earning both an M.S. and Ph.D. in physics at UAH, where he has developed the use of a statistical method called Markov chain Monte Carlo (MCMC) for analysis of cosmological events. MCMCs comprise a class of special algorithms used in probability distributions, a mathematical function that gives the probabilities of the occurrence of different possible outcomes for an experiment.

"These methods have made it possible to analyze data faster and with greater accuracy," the researcher notes. "Nowadays, machine learning is everywhere in astronomy. We used MCMCs to measure the Hubble constant, for example, which was a big deal at the time." The Hubble constant is one of the most important numbers in cosmology because it tells us how fast the universe is expanding.

Astrostatistics represents the future of Big Data management and analysis in astronomy, as the latest technologies are producing staggering amounts of data of truly mindboggling complexity. The challenge to analyze this data is only growing exponentially as new data-gathering mechanisms evolve in radio, microwave, infrared, X-ray, gamma ray, interferometer and optical instruments that will require new statistical algorithms and techniques to make sense of it all.

"Most astronomers or physicists don't know much of probability theory, let alone statistics," Dr. Bonamente points out. "A scientist's job ought to be that of being careful, and not to give in to the desire to find a great new result when it's not there. So, marrying math and astronomy is the natural direction for me." ■

◂ This is an artist's concept of a galaxy with a brilliant quasar at its center.

Courtesy NASA, ESA and J. Olmsted (STScI)

STUDENT // FOCUS

BRINGING THE THUNDER

Ph.D. candidate featured by National Geographic for thundersnow research

Sebastian Harkema, a doctoral candidate in the Department of Atmospheric and Earth Science, found his research in thundersnow highlighted by National Geographic, the publication heralding the student as a leader in his field.

For decades, scientists believed electrification within snowstorms was caused by collisions between ice crystals and a substance called graupel, or snow pellets, in the presence of supercooled liquid water. The student's investigations in graduate school, funded by the Future Investigators in NASA Earth and Space Science and Technology program, found that graupel may not play as large a role in the electrification of wintertime stratiform events, such as nor'easters, as previously thought.

Harkema also observed that when thundersnow occurs, the lightning associated with the wintertime event produces large, less frequent flashes.

"This is key to promoting lightning safety during thundersnow events. Large, less frequent flashes, along with snow dampening the sound of thunder, could pose a risk to society outdoors, who are unaware that thundersnow is occurring during a snowstorm," Harkema notes.

Harkema has written and co-authored a number of publications and presented his findings on the meteorological phenomenon at several conferences, winning various accolades in recognition of his work. Most recently, he presented his research on the Inhibition of Large-Scale Electrification Within Wintertime Stratiform Regions at the 2023 American Meteorological Society Conference, receiving high praise from colleagues within his field.

The doctoral candidate was originally interested in UAH's Department of Atmospheric and Earth Sciences due to its strong focus in satellite and remote sensing. Shortly after applying to UAH, he was contacted for an opportunity to work on a winter weather project through UAH Earth System Science Center's cooperative agreement with NASA's Short-term Prediction and Transition Center for his graduate studies.

Wanting to take advantage of other research opportunities for students in winter weather, the student was encouraged to apply to NASA's 2020 Investigations of Microphysics and Precipitation for Atlantic Coast Threatening Snowstorms field campaign where he was given his first opportunity to study electrification with winter storms using aircraft observations.

"It's quite an honor to be featured by National Geographic," Harkema says. "Their yellow rectangle border is iconic. When you see it, you know you're going to be reading about the latest advances in scientific research." ■

NASA hot fire demo of full-scale rotating detonation engine hardware manufactured from small-scale design.

Courtesy NASA

QUICKENING PULSES

GRADUATE STUDENT DESIGNS ROTATING DETONATION ENGINE AIMED TO BOOST LUNAR AND MARS MISSIONS

Michaela Hemming, a doctoral candidate in the Department of Mechanical and Aerospace Engineering, is using a NASA Space Technology Graduate Research Opportunities (NSTGRO) fellowship to make advances in propulsion under the guidance of NASA engineers.

Hemming has designed a small-scale rotating detonation engine (RDE) manufactured by NASA as part of a joint research effort. The innovative engine burns fuel rapidly through a supersonic detonation wave – essentially a series of controlled explosions – that enable the device to deliver high performance in a relatively small volume. This innovative technology promises to enhance the range, speed and affordability of these engines when compared to traditional rockets, ramjets or gas-turbines.

"This is a four-year fellowship that includes a Visiting Technology Experience where I assist with research at NASA Marshall that aligns with my research," Hemming says. "RDEs have demonstrated more power output and comparable performances to traditional deflagration liquid rocket engines, with lower fuel consumption and substantially lower complexity and size," Hemming explains. "These devices are being considered especially for human landers and interplanetary travel to the Moon and Mars."

Hemming is an aerospace systems engineering doctoral candidate performing her dissertation work with advisor Dr. Gabe Xu, associate professor of mechanical and aerospace engineering at UAH, who helped design the project. The UAH engine development team includes Dr. John Bennewitz, an assistant professor of mechanical and aerospace engineering, as well as graduate researchers Garrett Cobb and Ruthie Hill, and undergraduate researcher Jared Sauer. Hemming's NASA advisor is Tom Teasley, a liquid propulsion systems development and test engineer at Marshall Space Flight Center (MSFC).

One of the specific goals of the grant has been to develop a modular subscale research test article to investigate detonation cycle rocket engine performances.

UAH team supporting rotating detonation engine project, (left-right), Dr. Gabe Xu, Patrick Rugel, Khadija Jalloul, Ruthie Hill, Michaela Hemming, Jared Sauer, Garrett Cobb and Paige Berg.

"The Combustion Devices Group at NASA MSFC are building a large-scale version of the engine I designed for UAH to understand the scalability of these engines," Hemming says. "I am hoping to assist with that work late this summer term."

The subscale engine was designed to be produced through additive manufacturing, or metal 3D printing, which uses a heat source – most commonly a laser – to fuse atomized powder particles together one layer at a time until the particular part is completed.

"Collaborating with NASA has been an incredible learning experience!" the doctoral candidate says. "Everything that we test and design at UAH has a direct impact on the research and decision-making of testing going on at MSFC. It has been very useful for us to have an immediate contact at NASA to ask questions, but what we work on at UAH informs their work just as much as their work informs ours. It is a true collaboration that complements both research institutions' strengths."

Hemming's project will help inform the design of NASA's first full-scale 10,000 pound-force rotating detonation rocket engine funded by NASA's Space Technology Mission Directorate. NASA investment in these novel technologies and student engineers paves the way for a strong and sustainable space economy and helps to shape their future career paths.

"I hope to work on the research community's toughest propulsion problems in space travel," Hemming says. "I chose to come to UAH and the Propulsion Research Center for my graduate degrees because of this university's reputation in experimental propulsion research. Not only would I get a quality education and research experience, but I would also be doing so under the advisement of professors who cared about my future as much as I did." ■

UAH undergraduates thrive in 9th annual

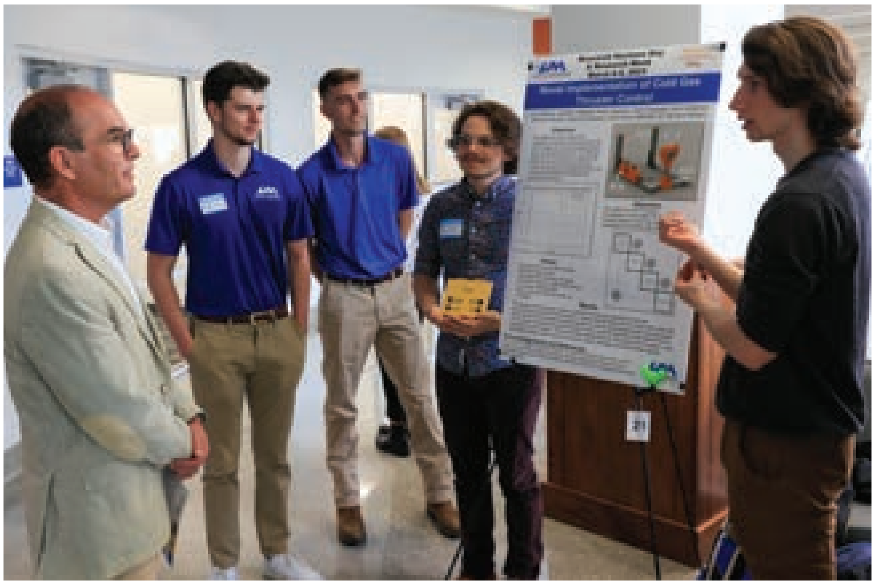
RESEARCH HORIZONS POSTER SESSION

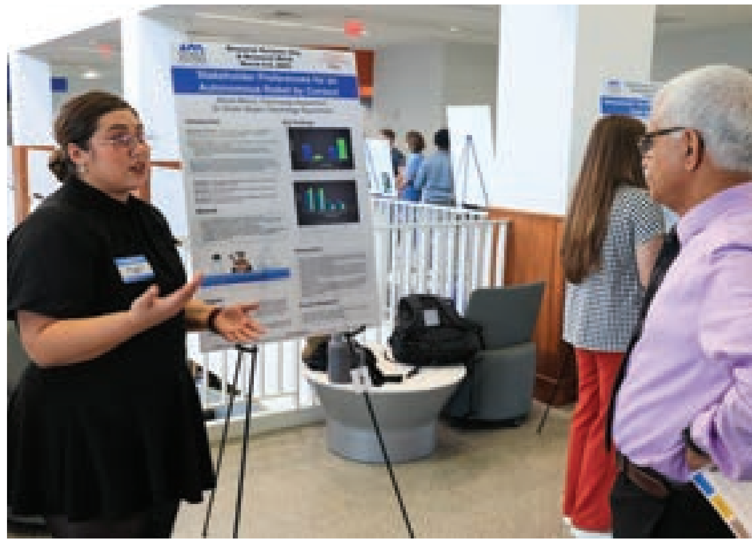
Each year, the poster session highlights the wide variety of research activities underway at UAH, as well as giving students a chance to practice their presentation skills and gain constructive feedback from faculty, staff and fellow students.

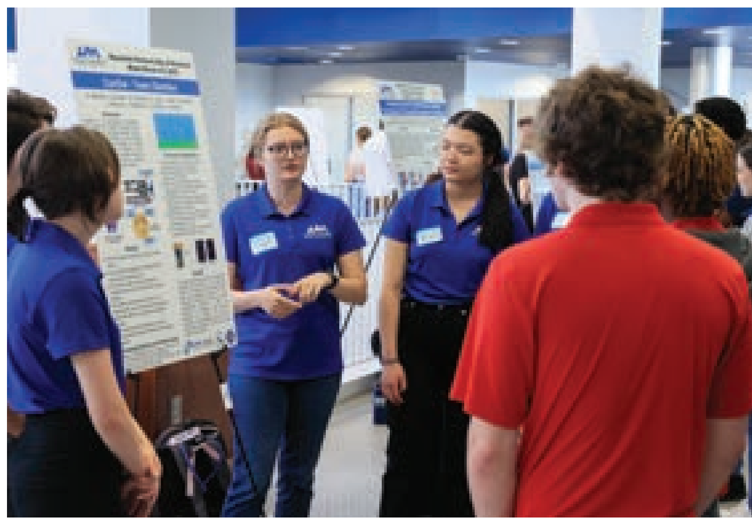
A total of 34 projects were presented by the students who conducted the work, exploring everything from topics like CanSat payloads that emulate the re-entry of a planetary probe, to interbacterial competition amongst lactobacilli or balancing an assembly line in a diesel manufacturing plant.

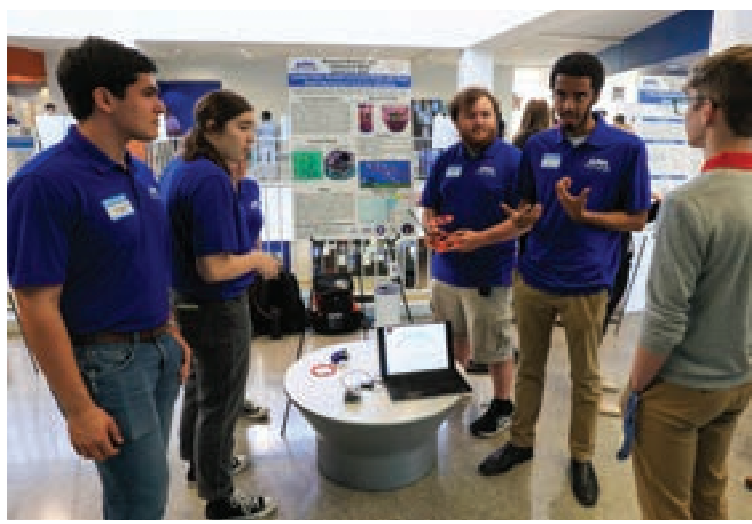
"Visitors to the event, besides being able to learn more about undergraduate research, were able to support this valuable learning experience by providing our undergraduate researchers with feedback and advice," says Dave Cook, director of undergraduate research. "Sharing your research with others in the community is an important part of inquiry-based learning, and it's the reason Research Horizons was launched nine years ago."

The event is intended primarily as a learning experience for the participants rather than a competition, though visitors are able to show their appreciation for researcher excellence and creative scholarship by voting for their three favorite presentations.









This year's People's Choice awardees included,

First Place

Ella James (Physics), "Polarization Properties of Optical Elements with Azimuthally Varying Phase Retardance,"

Second Place

Macie Morgan (Communication Arts), "Mnemonicide: The Killing of American Public Memory" and

Third Place

Claire Bergner (Economics), "2019 SBIR/STTR Economic Impacts." ■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