FOCUS

UAH Research Magazine // Fall 2020

LET'S WORK TOGETHER

UAH and collaborators make bioscience news

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UAH leads $3.2 million solar modeling research effort

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UAH

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Leadership, collaboration and UAH research

Leadership and collaboration are hallmarks of the research enterprise at The University of Alabama in Huntsville (UAH). Collaborations are often the heartbeats of innovation and discovery at UAH, and the news-making discoveries from the UAH Department of Biological Sciences in our cover story illustrate the point well.

On page 4, UAH's Dr. Jerome Baudry teamed closely with Hewlett Packard Enterprise (HPE) to utilize the HPE Cray Sentinel supercomputer to identify 125 naturally occurring compounds that have computational potential for efficacy against COVID-19. Meanwhile, partnered with the HudsonAlpha Institute for Biotechnology in another close collaboration, UAH's Dr. Eric Mendenhall worked along with Dr. Richard Myers, HudsonAlpha president, science director and a faculty investigator, to achieve new understanding of the functions of 208 proteins responsible for orchestrating the regulation genes in the human genome.

As a public research institution, UAH is always open to entering productive and innovative research collaborations with businesses and institutions across its broad research enterprise.

UAH's leadership is guiding four projects featured here that have attracted major federal funding.

Under a $3.7 million Department of Defense grant, the university's Office for Operational Excellence will undertake a $6.2 million project focusing on the visibility, workforce training and adoption of advanced manufacturing technologies in the region, which is on page 14.

On page 16, Dr. Nikolai Pogorelov's leadership through UAH's Department of Space Science and the UAH Center for Space Plasma and Aeronomic Research (CSPAR) will advance National Science Foundation (NSF) funded research to improve solar modeling. The effort will help inform space weather forecasting, which can impact technologies here on Earth.

Through its Rotorcraft Systems Engineering and Simulation Center directed by Dave Arterburn, a story on page 18 says UAH is the lead institution for $1.1 million in disaster preparedness and response research funded by the Federal Aviation Administration to provide insight into the safe integration of Unmanned Aircraft Systems in disaster preparedness and response areas.

In Alabama, a page 20 story tells about Interim UAH Science Dean Dr. John Christy's leadership of a two-year, $600,000 effort here to create a more accurate analysis of soil moisture for drought depiction, agricultural assessments and flood potential. It's funded by the National Oceanic and Atmospheric Administration (NOAA). The system under development would especially aid farmers seeking federal assistance payments, as the region is prone to flash droughts that can decimate pastures and crops over a wide-ranging, spotty area.

The university's faculty continue to excel. Dr. Michael S. Briggs, an assistant director and senior principal research scientist at UAH's CSPAR, was awarded NASA's Exceptional Public Achievement Medal for sustained performance that embodies multiple contributions on NASA projects, programs or initiatives, according to a story on page 8.

In the Department of Chemical and Materials Engineering, a page 10 story describes Dr. Kyung-Ho Roh's research into bioengineering artificial organs that mimic the functions of human lymph nodes that won an NSF Faculty Early Career Development Program Award. The award-winning research could have broad implications for immunotherapy and cancer treatment.

In a first for the UAH campus, a page 11 story says that mechanical and aerospace engineering master's student Evan Unruh has test-fired a Rotating Detonation Engine (RDE) at Johnson Research Center. RDEs could be transformative for rocket propulsion. Also in rocketry, a mission designed, engineered and built by UAH's student rocket team earned first place in project safety and third place overall in competition at the national NASA Student Launch, says a page 13 story.

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 for more information on the efforts featured in this magazine or any other research project at UAH. ■

THE UNIVERSITY OF ALABAMA IN HUNTSVILLE

A **RESEARCH INTENSIVE** national 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.

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 Aerospace Engineering research
- **8TH** Economics research
- **11TH** NASA-sponsored research
- **11TH** Computer and Information Sciences research
- **12TH** Atmospheric Sciences research
- **12TH** Astronomy & Astrophysics research
- **28TH** Department of Defense R&D expenditures

SOURCE: National Science Foundation

RESEARCH

$489 million
Five-year contract and grant research total

$109.7 million
Fiscal 2019 research expenditure total

Over $2 million
Five-year license and royalty revenue total

[ISSUED PATENT TOTAL – 112]

▸ Cover: Dr. Jerome Baudry, left, and Dr. Eric Mendenhall both had close collaborators outside UAH to make research discoveries in the Department of Biological Sciences.

COLLABORATIVE RESULTS

Bioscience discoveries show the power of working together

Transmission electron microscopic image of an isolate from the first U.S. case of COVID-19, formerly known as 2019-nCoV.

U.S. Centers for Disease Control

Two recent research accomplishments in which the UAH Department of Biological Sciences closely collaborated with partners from outside the university illustrate the strength in such partnerships.

Dr. Jerome Baudry (pronounced Bō-dre), a molecular biophysicist and the Mrs. Pei-Ling Chan Chair in Biological Sciences, joined with Hewlett Packard Enterprise (HPE) to employ its Cray Sentinel supercomputer to rapidly identify 125 naturally occurring compounds that show promise as treatments for the COVID-19 coronavirus.

In separate research, Dr. Eric Mendenhall, a UAH associate professor of biological science, teamed with the HudsonAlpha Institute for Biotechnology to identify the function of 208 proteins responsible for orchestrating the regulation genes in the human genome. The research was published in *Nature* in July.

The partnerships were essential to the discoveries, says Dr. Paul Wolf, Biological Sciences chair, and UAH provides an ideal environment to nurture partnerships with industry and other entities.

"Solving complex problems requires integration of a diversity of thought," Dr. Wolf says.

The Department of Biological Sciences at UAH encourages faculty and students to work with each other and with local and national entities on collaborative projects, he says.

"The research successes of Eric Mendenhall and Jerome Baudry illustrate the kind of breakthroughs that can be made with such partnerships," Dr. Wolf says. "We very much hope to see these collaborations grow in the future."

POTENTIAL COVID TREATMENTS

Together Dr. Baudry's lab and HPE used the Sentinel supercomputer to rapidly assess a batch of 50,000 chemicals to identify 125 naturally occurring compounds with a computational potential for efficacy against COVID-19.

The research was noted in a keynote speech by Antonio Neri, HPE president and CEO, at the HPE Discover Virtual Experience event. Neri told over 100,000 registrants from the computing, scientific and business worlds that the HPE collaboration with Dr. Baudry "allowed his research team to deliver results in weeks versus months or years."

The idea for an alliance with HPE developed months before the COVID-19 crisis, following a meeting to discuss how to integrate natural products, artificial intelligence and supercomputing.

"One of the presenters, Dr. Rangan Sukumar, is a distinguished technologist in high-performance computing (HPC) and artificial intelligence at HPE," says Dr. Baudry. "He talked to his colleagues there and they reached out to us to inquire about the possibility of working together."

As the collaboration was becoming more operational the COVID-19 pandemic developed. Located in UAH's Shelby Center for Science and Technology, the Baudry Lab was searching for potential precursors to drugs that would help combat the global pandemic.

"At HPE we are committed to being a force for good, and since the start of the COVID-19 outbreak, we have been on a mission to extend our technologies and resources to scientists on the front line of drug discovery," says Bill Mannel, vice president and general manager of HPC at HPE.

"We found a perfect match with Dr. Baudry and his team at UAH, who have used our cloud-based supercomputer running in Microsoft Azure and a dedicated technical staff to support their research," Mannel says.

By using the supercomputer through the cloud, the team was able to increase outcomes of drug candidates through biodiversity at an unprecedented speed, he says, saving them years of research and millions of dollars in costs.

"It has also been an honor helping Dr. Baudry realize his vision and be a part of the overall journey to advance treatment efforts to combat COVID-19 and end human suffering."

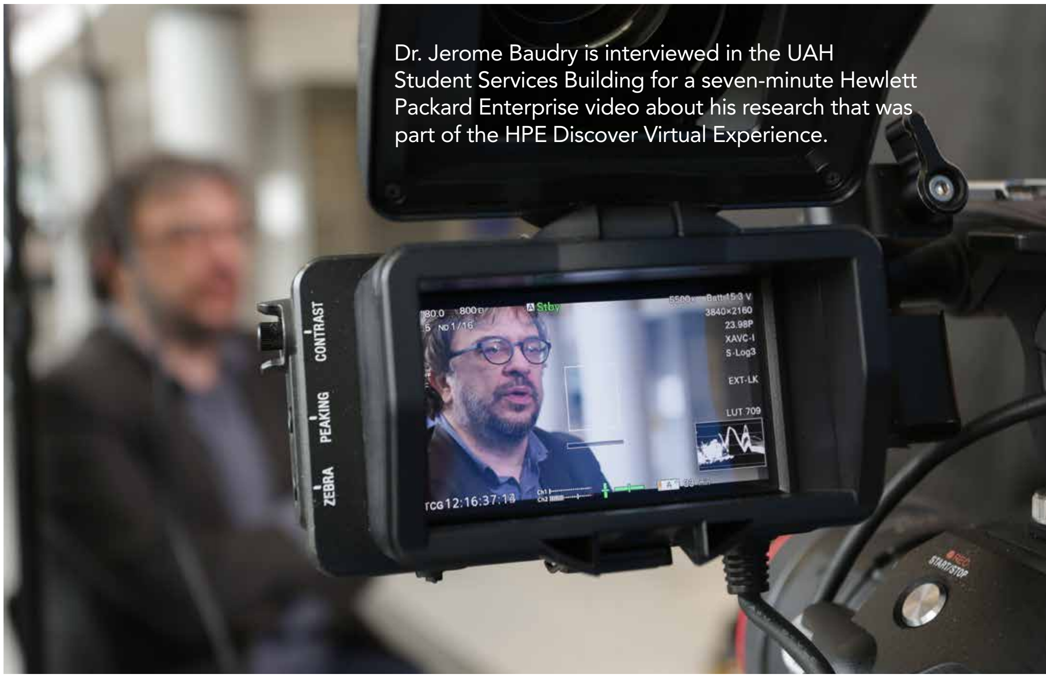
The partnership marked the first time a supercomputer was used to assess the treatment efficacy of naturally occurring compounds against the proteins made by COVID-19.

"We used supercomputers to predict natural products most likely to bind to three proteins of the SARS-CoV-2 virus," says Dr. Baudry. SARS-CoV-2 is the scientific name of the COVID-19 virus.

"Out of the 50,000 natural products that we looked at using supercomputers, we found several hundred to be predicted to be potentially binding on the proteins of interest," he says. "We further found 125 – but there may be more – that are particularly interesting because they bind right where we want to, they are not too big, not too small and they have the chemical profiles of pharmaceuticals."

There are many diverse natural sources for the chemicals of interest, Dr. Baudry says.

"Many are from relatively common medicinal plants that can be found in the U.S., and many are from more distant plants from Southeast Asia and South America, as well as from some ground and oceanic bacteria strains and fungi."



Dr. Jerome Baudry is interviewed in the UAH Student Services Building for a seven-minute Hewlett Packard Enterprise video about his research that was part of the HPE Discover Virtual Experience.

A Biological Safety Level 3 laboratory in Memphis is testing natural products that were identified by the Baudry Lab for their activity against the COVID-19 virus. Chemical molecules found most efficacious will form the basis for future testing for efficacy, tolerance and adverse effects in human trials, a process that might include chemical modifications to make the drug more efficient, better tolerated or both.

"Every drug that ends up surviving this long and winding road of development and testing starts as a hit that binds to a protein. It is this initial event that we are modeling here using supercomputers," Dr. Baudry says.

The fight against COVID-19 has created a new meeting of modern high-capacity artificial intelligence with humankind's most ancient healing knowledge, Dr. Baudry says.

"Normally it would take a very long time and a lot of money to achieve that, but with the supercomputers we can perform this initial hit discovery step much faster and cheaper," he says. "Even five years ago, this would not have been possible."

Located in a Microsoft Azure data center in Texas, Sentinel made the work more rapid than ever before possible and an HPE team helped facilitate it. Dr. Baudry's UAH team accessed Sentinel through the cloud with Microsoft Azure.

Sentinel is capable of computing 147 trillion floating point operations per second and can store 830,000 gigabytes of data. That's as fast as the Earth's entire population doing 20,000 calculations every second.

At the same time, Dr. Baudry's lab also collaborated in other COVID-19 research with the Alabama Supercomputing Network and Oak Ridge National Laboratory in Tennessee.

CELLULAR MECHANISMS

A close collaboration between the UAH lab of Dr. Mendenhall and the lab of Dr. Richard Myers, who is the president, M. A. Loya Chair in Genomics, science director and a faculty investigator at HudsonAlpha, resulted in new understanding of the function of 208 proteins responsible for orchestrating the regulation of genes in the human genome. These proteins and others play major roles in determining the type and function of new cells, a process known as differentiation.

The working partnership was a fundamental building block for the resulting discoveries, says Dr. Myers.

"We have greatly enjoyed and benefited from this close collaboration with Dr. Mendenhall and his team, which involves a combination of complex 'wet-lab' experiments and computational analysis and interpretation of large amounts of data," Dr. Myers says.

"One of the most satisfying things about this work is that we are creating a knowledge base of how human genes are regulated that is being used by thousands of researchers and clinicians around the world," he says. "The data and findings are made freely available rapidly to everyone, and this has helped to greatly speed up our understanding of the human genome."

It is critical that genes be turned on and off in different cell and tissue types, but scientists haven't had a good idea of how that was controlled, says Dr. Mendenhall.

"Ours and many other groups have been working for years to find what regions of the human genome controlled this turning on and off – what we call enhancers and promoters," he says.

"We wanted to determine what proteins control this turning on and off. These are called transcription factors, and our group looked at where 208 of them function. It was a large number and we helped to add a significant amount of information to how genes are turned on and off."

Transcription factors can make a cell into a heart cell, a liver cell or even a cancer cell. Their location along the DNA strand, or genome, is critical to what role a cell will play during its lifetime. The genome in each of our cells is identical. It's the transcription factors that act as the switches to turn on or off genetic functions and differentiate the capabilities of one cell from another.

"We have close to 20,000 genes in our genome, and about 1,800 of these belong to the class called transcription factors, which is a pretty large portion of our genes," says Dr. Mendenhall.

"These genes code for proteins that work in our nucleus to turn genes on or off by binding to the DNA. Once they bind to the DNA, which is tightly controlled by many chemical and biological mechanisms we don't yet fully understand, they find a nearby target gene to usually turn on, but occasionally turn off."

It's important to have a complete catalog to get a full picture of how genes are controlled, Dr. Mendenhall says. That's a key part of how humans develop from embryos and it's important to how our cells do their jobs and keep us healthy.

"An incomplete picture leaves we scientists unsure whether we are missing key transcription factors, or of how to explain why certain transcription factors bind here but not there, or turn this gene on but not that one," Dr. Mendenhall says. "We have a lot of outstanding questions and a lot of these questions will be easier to answer once we study all 1,800 transcription factors."

Teams led by Dr. Myers and Dr. Mendenhall employed the latest rapid genetic sequencing techniques, running dozens of parallel experiments at one time to quickly locate and flag transcription factors in a lab-grown line of liver cancer cells called HepG2 that are used for research purposes.

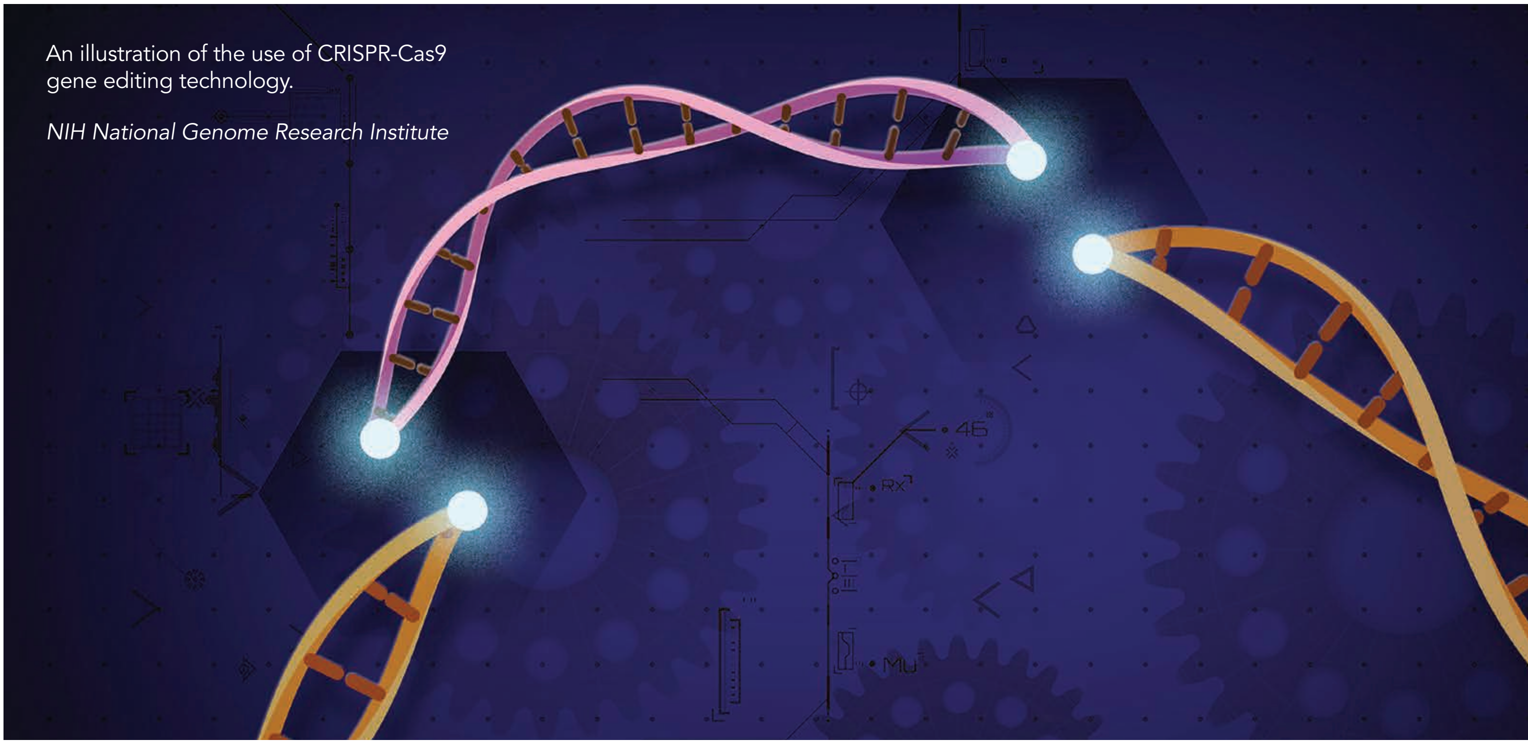
The new discoveries came as part of the $31.5 million National Institutes of Health (NIH) Encyclopedia of DNA Elements (ENCODE) Project to further the construction of a comprehensive list of functional elements in the human genome. A scientific offspring of the Human Genome Project, the ENCODE Project launched in 2003 and is a scientific consortium that is tasked with creating and sharing genomics resources that are used by many scientists to study human health and disease.

"One of the most satisfying things about this work is that we are creating a knowledge base of how human genes are regulated that is being used by thousands of researchers and clinicians around the world."

Advances in a new technology called CRISPR-Cas9 hastened progress by allowing scientists to test almost any transcription factor. Key to the research was a procedure developed in 2015 by Dr. Myers and Dr. Mendenhall called CETCh-seq.

With CETCh-seq, scientists first use the CRISPR/Cas9 genetic editing technique to design a reagent to modify a genome in cells. Once they are flagged, in the second part of the CETCh-seq method a protocol called ChIP-seq tells them where the transcription proteins are located.

"It took a lot of dead ends," Dr. Mendenhall says, "but we also found a lot of new questions to pursue that we couldn't have predicted." ■



An illustration of the use of CRISPR-Cas9 gene editing technology.

NIH National Genome Research Institute

DR. MICHAEL BRIGGS receives NASA's Exceptional Public Achievement Medal

Michael S. Briggs, an assistant director of the UAH Center for Space Plasma and Aeronomic Research (CSPAR) was awarded NASA's Exceptional Public Achievement Medal for sustained performance that embodies multiple contributions on NASA projects, programs or initiatives.

A senior principal research scientist at CSPAR, Dr. Briggs received the award for critical prior and ongoing contributions to the success of the Fermi Gamma-ray Telescope mission's Gamma-ray Burst Monitor (GBM) project.

Since his arrival at UAH in November 1991 with a NASA fellowship to do research with the Burst and Transient Source Experiment (BATSE), Dr. Briggs has closely collaborated with Marshall Space Flight Center (MSFC) scientists and engineers on NASA projects involving gamma-ray astrophysics.

BATSE overturned the previous scientific consensus that gamma-ray bursts originated from nearby neutron stars. When it wound down, Dr. Briggs became an original member of the GBM team, working on the formulation of the GBM proposal starting in 1999. Originally called the Gamma-ray Large Area Space Telescope (GLAST), Fermi is the home of GBM. It launched in 2008 and continues on-orbit as an extended mission.

"The team at NASA, MSFC and UAH spent most of the 2000s building the instrument," Dr. Briggs says.

"These space projects are team efforts, the result of hard work by many engineers, programmers and scientists. MSFC and UAH jointly worked to develop and fly the BATSE experiment. The GBM detectors were contributed by Germany, led by scientists at the Max Planck Institute in Garching."

In Huntsville, MSFC and UAH engineers and scientists worked closely together to integrate and test the instrument and to write the software, he says.

"MSFC, the Universities Space Research Association and UAH scientists and programmers continue to work closely to keep GBM running, provide the GBM data to the scientific community and to use GBM to make discoveries."

Currently GBM's deputy principal investigator, Dr. Briggs was the primary author of the flight software, which integrates 14 gamma-ray detectors with the flight data processing unit, the power unit and the Fermi spacecraft. He was a pivotal contributor during instrument development, fabrication and testing, spacecraft integration and now with mission operations.

Dr. Briggs developed an unanticipated technique for using GBM to detect terrestrial gamma ray flashes (TGFs) and adapted this method to find weaker gamma-ray bursts than are found by the flight software.

Within a few years of launch, GBM detected the strongest and closest gamma-ray bursts that had ever been recorded. GBM's high detection rate for gamma-ray bursts led to a joint science and observation partnership with the Laser Interferometer Gravity Wave Observatory (LIGO) group. The LIGO partnership resulted in GBM becoming a major player in multi-messenger astrophysics.

"A high point of GBM was waking up one morning to learn that GBM had observed a gamma ray burst in conjunction with gravitational wave observation," Dr. Briggs says.

In 2018, the GBM team received the Bruno Rossi Prize for the discovery of gamma-rays coincident with a neutron-star merger gravitational wave event. The discovery confirmed that short gamma-ray bursts are produced by binary neutron star mergers and enabled a global multiwavelength follow-up campaign. It cemented GBM's place in astrophysics history.

Dr. Briggs' expertise continues to be in demand for future funded missions such as BurstCube, a Cubesat collaboration with NASA's Goddard Space Flight Center (GSFC) that will search for electromagnetic counterparts to gravitational wave sources, and Glowbug, a gamma-ray telescope for bursts and other transients developed by the Naval Research Lab in Washington, D.C.

Dr. Briggs is also working on the LargE Area burst Polarimeter (LEAP), a mission that is one of four proposals approved by NASA for further review. Led by the University of New Hampshire, LEAP would fly on the International Space Station to study the energetic jets launched during the explosive death of a massive star or the merger of compact objects such as neutron stars.

"A high point of GBM was waking up one morning to learn that GBM had observed a gamma-ray burst in conjunction with gravitational wave observation."

Another MSFC project Dr. Briggs is involved with is the Moon Burst Energetics All-sky Monitor (MoonBEAM), a Cubesat concept to deploy gamma-ray detectors in cislunar space to probe the extreme processes in cosmic collisions of compact objects and facilitate multi-messenger time-domain astronomy to explore the end of stellar life cycles and black hole formations.

"Working with long-term and new collaborations, we are developing new projects to propose to NASA such as LEAP and MoonBEAM," Dr. Briggs says. "We hope to continue the collaborations and have opportunities for the next generation of scientists and engineers." ■

Artificial lymph node engineering research wins **NSF CAREER award** for Dr. Kyung-Ho Roh

Research into engineering artificial organs that mimic the functions of human lymph nodes has garnered Dr. Kyung-Ho Roh, a UAH assistant professor of chemical and materials engineering, a $507,777 National Science Foundation (NSF) Faculty Early Career Development Program (CAREER) Award.

The award-winning research could have broad implications for immunotherapy and cancer treatment. The NSF CAREER Award is the foundation's most prestigious honor for junior faculty members who exemplify the role of teacher-scholars through outstanding research, excellent education and the integration of education and research.

"When our body is infected with bacteria or viruses, some special immune cells are 'primed' within the lymph nodes to fight against these 'bugs,'" Dr. Roh says. "More specifically, there are immune cells named B-cells that are responsible for producing a special set of molecules called antibodies that can recognize and bind to these 'bugs' so that our body can clear them out."

The team at his Molecular and Cellular Immunoengineering Laboratory in the UAH Engineering Building is trying to achieve the priming of B-cells in an artificially created engineered system outside of the body.

"Once successful, this research can be useful for various critical biomedical applications," Dr. Roh says. "First, we can use such artificially primed B-cells as living therapeutics that can provide the useful antibodies for an extended period within the patient's body. Second, using the artificial lymph node, we can discover various antibody molecules that can recognize various pathogens or even our own cancers. Third, we can develop safer and cheaper vaccines. Lastly, the artificial system can be used as a critical research tool for studying the physiology of immune-cell related cancers such as lymphomas and leukemias."

Initial development of the hydrogels and microfluidic devices that are the basic foundation of the research project is complete. Now the project is moving forward to use and combine the individual engineering platforms to realize the collective system that can mimic the functions of the lymph nodes.

"For this project, we need a very diverse set of expertise spanning from biomaterials engineering and microfluidics to cellular and molecular biology and immunology," Dr. Roh says.

"For example, in order to mimic the mechanical properties of the physiological soft tissues we are developing novel biomaterials such as polymeric hydrogels," he says. "To culture the B-cells within a controlled chemical environment, we develop and utilize microfluidic devices. For the proper characterizations of the resulting B-cells, various methodologies from cellular and molecular biology are routinely employed."

In the lab, graduate students with diverse backgrounds are collaborating to tackle these challenging interdisciplinary research tasks. Dr. Roh's team is also collaborating with local and international partners such as the HudsonAlpha Institute for Biotechnology and CFD Research Corp.

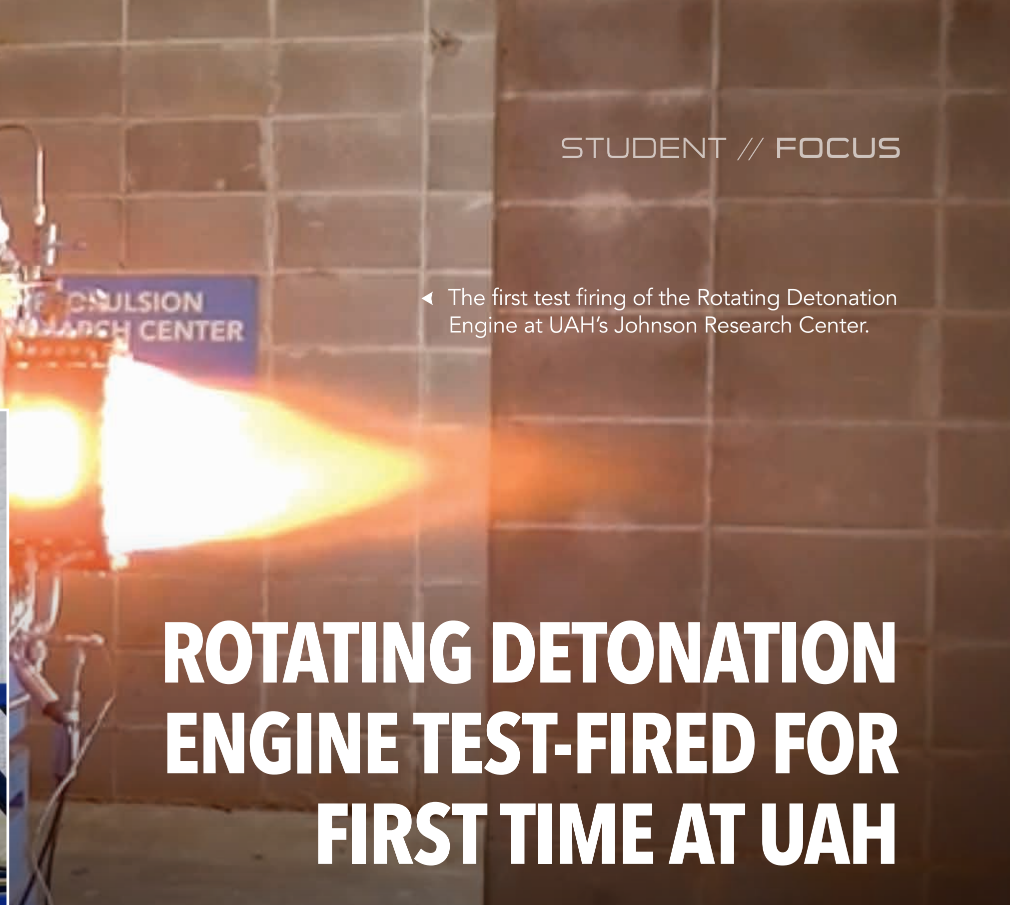
"In addition to the research activities mentioned above, I will continue to improve my role as an educator. I will develop interdisciplinary educational curricula and continue to nurture the collaborative local networks that can provide a sustainable education and research environment for immunoengineering," Dr. Roh says.

He wants to encourage the participation of the next generation of students from broader socioeconomic groups of North Alabama and to enhance public knowledge of immunoengineering research activities and their applications.

"My primary goal as an educator is to train many undergraduate and graduate students in this highly multidisciplinary topic of immunoengineering to meet the increasing societal demands for such critical skill sets."

Dr. Roh says he received the news of his CAREER Award with a mixture of emotions.

"It was exciting because it assures me that I will be able to continue working on this very significant project and because this award in a way means that the research topics and ideas that we proposed to study are highly appreciated by the leaders in the field," he says. "And the name of the award, CAREER, made me look back and be grateful to everyone who has enabled me to become what I am in my career." ■



The first test firing of the Rotating Detonation Engine at UAH's Johnson Research Center.

ROTATING DETONATION ENGINE TEST-FIRED FOR FIRST TIME AT UAH

Mechanical and aerospace engineering master's student Evan Unruh with his Rotating Detonation Engine at UAH's Johnson Research Center.

A new kind of rocket engine has been test-fired for the first time at UAH's Johnson Research Center.

It's called a Rotating Detonation Engine (RDE), and UAH mechanical and aerospace engineering (MAE) master's student Evan Unruh says it took him about a year to design and build it through UAH's Propulsion Research Center (PRC). Unruh is advised by Dr. Robert Frederick, PRC director.

Seed funding was provided by Dr. Gabe Xu, associate professor of mechanical and aerospace engineering and a PRC associate, through the National Science Foundation's Established Program to Stimulate Competitive Research: Connecting the Plasma Universe to Plasma Technology in Alabama (CPU2AL).

"Once I have finished the developmental testing of the engine, Dr. Xu and his student, Michaela Spaulding, will be using the engine for that program to research the effects of transient plasma ignition on the detonation reactions within the combustor," says Unruh.

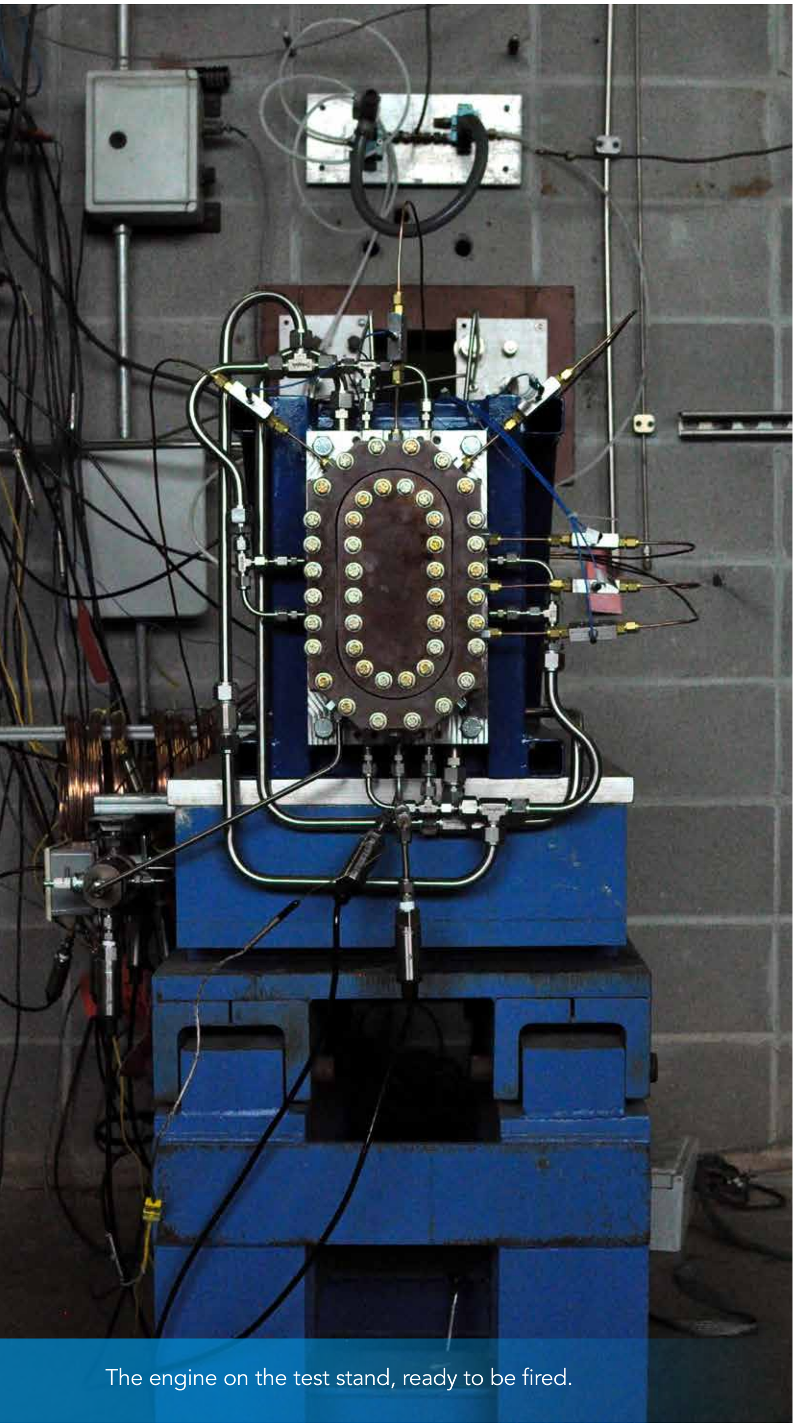
Besides Unruh, Dr. Frederick and Dr. Xu, the RDE team is Dr. David Lineberry, PRC research engineer; Tony Hall, PRC test engineer; James Venters, PRC undergraduate research assistant; Jon Buckley, shop supervisor at the UAH Engineering Design and Prototyping Facility; Scott Claflin, director of power innovations at Aerojet Rocketdyne; and Spaulding, a graduate student who is also working on detonation engine research at the PRC.

Claflin's RDE expertise has come in an unofficial capacity, Unruh said, adding, "The Propulsion Research Center is open to working with companies that are interested in researching and developing detonation engines."

RDEs are a tantalizing engineering concept that could be transformative for rocket propulsion, offering better fuel efficiency than continuous-burn solid or liquid propellant engines if the inherent instabilities that make them run can be better controlled. Instead of a continuous burn, RDEs use a continuous spinning explosion to create supersonic gas and generate thrust.

"As a concept, RDEs may facilitate the design of more efficient rocket engines. This would enable rockets that could fly higher, faster and more efficiently, thereby enabling greater access to space than what we see today," says Unruh, who completed his MAE undergraduate career at UAH before going on to his master's.

"There are still practical roadblocks to overcome before detonation engines become a viable option, but if there weren't, we wouldn't need to research



The engine on the test stand, ready to be fired.

them. We hope to overcome these obstacles by better understanding how the detonation process works inside these engines."

The UAH engine is intended as a test-bed to allow researchers at the PRC to study various phenomena related to detonation combustion in RDEs, Unruh says. Designed for research versatility, the engine runs on a variety of propellants. It's currently being tested on liquid propane and gaseous oxygen. Most RDEs are cylindrical but Eagle Creek, Oregon, native Unruh's engine is designed in a racetrack-like shape.

"By designing ours to have a racetrack shape, we are able to add optical windows in the straight sections that allow us to directly observe the detonation wave inside the combustor," he says. "In particular, this optical access will allow us to observe interactions between the detonation wave and the spray plumes of the propellants as they are injected into the engine."

Another innovation is the use of shear-coaxial injectors, the spray nozzles that inject the propellants into the engine. Shear-coaxial injectors have previously been used extensively in traditional rocket engine designs, most notably in the Rocketdyne J-2 engines on the Saturn V rocket, and in the U.S. Space Shuttle's main engines, but not commonly in RDEs.

"As you might expect, exploding propellants are harder to understand and control," Unruh says. "The RDE is one concept for an engine that shows promise of being a design that can detonate propellants in a controlled fashion and finally provide a practical realization of the theoretical promise of an increase in efficiency through detonation."

RDE theory has been around since the 1940s and some primitive experiments were conducted in the past, but Unruh says that modern data acquisition equipment, better modeling and a greater historical collection of research is leading to a resurgence of RDE research. Engineers now have the capability to design engines that function in a rotating detonation mode.

"The next challenge," he says, "is to further understand the detonation phenomenon so we can figure out how to finally build an engine that is more efficient than traditional deflagration-based engines." ■

◀ The student team with Baedor, its entry for the NASA Student Launch. The photo was taken prior to the COVID-19 pandemic.

STUDENT ROCKET TEAM TAKES THIRD OVERALL, FIRST IN SAFETY AT NASA STUDENT LAUNCH

UAH's student rocket team earned first place in project safety and third place overall at the COVID-shortened national NASA Student Launch competition.

"The students worked really hard and faced a lot of technical challenges this year, not to mention a shutdown at the end of the spring semester," says Dr. David Lineberry, team advisor and a research engineer at the UAH Propulsion Research Center (PRC).

"This would not have happened without support from the College of Engineering, the Department of Mechanical and Aerospace Engineering, the Alabama Space Grant Consortium and the PRC," he says.

The UAH team was mentored by Jason Winningham, who assisted in rocket launches and advised the project.

"We are very proud of the accomplishments of the students and their UAH instructors and mentors," says PRC Director Dr. Robert Frederick. "These experiences will serve them well as they transition to industry."

Designed by the UAH Mechanical and Aerospace Engineering 490/491 Rocket Design team, the rocket named Baedor carried a rover payload. It uses a solid fuel motor, is 136 inches long and 6.17 inches in diameter and weighs 61.5 pounds loaded.

Little Dipper, the rover, is piloted by remote control. Its mission was to deploy from the vehicle, advance to a collection area and use its scoops to collect simulated ice.

"During the spring semester, as segments of the country started to close down, the team recognized the potential impacts on the project and felt a sense of urgency to complete a demonstration flight," Dr. Lineberry says. "After a busy couple of weeks, they were able to demonstrate the full vehicle and payload missions at a launch in Woodville, Ala., with the Huntsville Area Rocketry Association."

Baedor achieved an apogee of 4,454 feet in its final demonstration flight, days before the UAH campus closed as a precautionary measure for COVID-19. When it landed, the rocket successfully deployed Little Dipper, which achieved its collection mission.

NASA Student Launch challenges middle school, high school, college and university teams from across the United States to build and fly a high-powered amateur rocket carrying a complex payload to over 4,000 feet. The rocket then must land safely before its scientific or engineering payload begins work. This year's competition drew teams from 19 states and Puerto Rico. ■

UAH team members are:

- Nicholas Roman, project manager; senior, aerospace engineering, Cullman, Ala.
- Joshua Jordan, chief engineer; senior, mechanical engineering, Mount Vernon, Wash.
- Peter Martin, vehicle team lead; senior, mechanical engineering, Coopersburg, Penn.
- James Venters, payload team lead; senior, mechanical engineering, Huntsville, Ala.
- Jessy McIntosh, safety officer; senior, mechanical engineering, Beaufort, N.C.
- Maggie Hockensmith, technical writing coordinator and vehicle safety deputy; senior, aerospace engineering, Lexington, Ky.
- Claudia Hyder, payload safety deputy; senior, mechanical engineering, Knoxville, Tenn.
- Patrick Day, project management team; senior, aerospace engineering, Johnson City, Tenn.
- Will Snyder, project management team; senior, aerospace engineering, Cleveland, Ohio
- Rodney L Luke, vehicle team; senior, aerospace engineering, Pleasant Grove, Ala.
- Roman Benetti, vehicle team; senor, aerospace engineering, Woodbury, Minn.
- Rachel O'Kraski, vehicle team; senior, aerospace engineering, Huntsville, Ala.
- Ben Lucke, vehicle team; senior, aerospace engineering, Saint Petersburg, Fla.
- Jeremy Hart, vehicle team; senior, aerospace engineering, Gainesville, Ga.
- Jacob Zilke, vehicle team; senior, aerospace engineering, Wilmington, N.C.
- Joseph Agnew, payload team; senior, mechanical engineering, New Market, Ala.
- Johnathon Jacobs, payload team; senior, aerospace engineering, Valley Head, Ala.
- Thomas Salverson, payload team; senor, mechanical engineering, Gretna, Neb.
- Kevin Caruso, payload team; senior, mechanical engineering, Lawrenceburg, Tenn.
- Jacob Moseley, payload team; senior, aerospace engineering, Gaylesville, Ala.

UAH has leading role in establishing DoD advanced manufacturing center

Image courtesy of Pixabay

UAH has a leading role in a U.S. Department of Defense funded regional project that will establish an Advanced Manufacturing Innovation and Integration Center (AMIIC) in Huntsville.

The university's Office for Operational Excellence (OOE) will spearhead UAH's efforts under a $3.7 million grant from the U.S. Department of Defense (DoD) to facilitate a $6.2 million project that focuses on the visibility, workforce training and adoption of advanced manufacturing technologies in a 22-county Alabama region including Madison County.

UAH is the lead organization for the regional Alabama Defense Advanced Manufacturing Community (ADAMC), which will work to emphasize advanced manufacturing in the modernization of aviation, missiles and ground vehicle systems.

"OOE is leading the effort for UAH involvement, including examining needs, gaps and barriers to effective workforce development and technology adoption and managing the effort to develop new and enhance existing education and workplace development programs," says Brian Tucker, a research scientist at OOE.

The grant comes under the Defense Manufacturing Community Support Program (DMCSP) through the Office of Economic Adjustment (OEA). The university will directly interface with OEA for management of the grant.

In August, the U.S. Under Secretary of Defense for Acquisition and Sustainment designated six Defense Manufacturing Communities during a competitive process and the ADAMC was among those selected.

The ADAMC is a consortium composed of members of academia, the defense industry, nonprofit organizations and state and local government organizations. The region being served connects north Alabama with Birmingham, Tuscaloosa, Auburn and the southeastern part of the state around Fort Rucker.

"It was designed to capture the majority of the aerospace and defense industry in the state focused on aviation, missile and ground vehicles," Tucker says.

UAH led the ADAMC's proposal development and grant funding and will act as the spokesperson presenting the consensus opinion of the consortium, as well as coordinating strategy implementation. The consortium will focus on supporting and growing the capabilities of the defense industrial base in Alabama.

As ADAMC lead, UAH will pull together existing programs throughout the region to assist the National Center for Defense Manufacturing and Machining (NCDMM) as it leads the effort to establish the AMIIC facility in Huntsville. AMIIC is a wholly owned 501(c)(3) subsidiary of NCDMM.

"As well as managing the overall grant and program, OOE will be supporting NCDMM in the layout and establishment of the facility and its operation," says Tucker. "In addition to supporting facility establishment, UAH's OOE and other departments and centers will also support new and enhanced workforce development programs and technology adoption projects that may utilize the new AMIIC facility."

Implementation will be supported by three thrust areas, each with a lead organization:

- UAH will develop new and enhance existing education and workplace development programs.
- Auburn University will conduct pilot technology adoption projects with industry.
- The University of Alabama will be responsible for initiating a technology development program.

The efforts are designed to benefit U.S. Army modernization priorities through product, process, human capital and STEM education.

The STEM and manufacturing education workforce development process in K-12 will carry forward through two-year and four-year academic career paths. Industry will have the opportunity to engage prospective students and employees while demonstrating product and process advancement on key technologies.

Displaced and military veteran workers will be able to undergo retraining, skills enhancement or continuing education and certification to reenter the workforce or obtain position advancement.

About one-third of the federal money funding the effort is staying at UAH, while the remainder is funding activities by other ADAMC members.

"The ADAMC consortium is sizable and growing," says Joe Paxton, OOE director. "Like UAH, many of its members are key players in this regional effort to enhance critical skills, research and development, and small business support." ■

Dr. Nikolai Pogorelov is the principal investigator for research to develop open-source solar atmosphere and inner heliosphere software models useful to predict space weather.

UAH leads $3.2 million solar software model effort to aid in space weather predictions

UAH leads a project to develop open-source solar atmosphere and inner heliosphere software models useful to predict space weather that was awarded $3.2 million over three years by the National Science Foundation (NSF) and NASA.

"We will develop an innovative, publicly available software that would make it possible to perform space weather simulations starting from the sun's photosphere and extending to Earth's orbit," says Dr. Nikolai Pogorelov, the project's principal investigator and a distinguished professor in UAH's Department of Space Science and the UAH Center for Space Plasma and Aeronomic Research (CSPAR).

It is one of seven projects awarded. The team includes UAH, Lawrence Berkeley National Laboratory (co-principal investigator Brian Van Straalen), Goddard Space Flight Center (GSFC; co-principal investigator Charles N. Arge), Marshall Space Flight Center (MSFC; co-principal investigator Ghee Fry), and two private companies, Predictive Science Inc. (co-principal investigator Jon Linker) and Space Systems Research Corp. (co-principal investigator Lisa Upton).

The fastest NASA and NSF supercomputers will be employed. Dr. Pogorelov is one 49 awardees nationwide to get NSF-approved 2020-2021 supercomputing time on Frontera, the fastest NSF supercomputer.

"This project is aimed to develop a new data-driven, time-dependent model of the solar corona and inner heliosphere to predict the solar wind's properties at Earth's orbit," he says.

"This software will have a modular structure, which will make it possible for its users to modify the individual components when new observational data sets become available from emerging space missions and our knowledge of the physical processes governing solar wind acceleration and propagation improves."

In addition to the inner heliosphere model, the team will develop new solar surface transport and potential field models to describe the solar atmosphere. That work will be done at Predictive Science Inc. and Space Systems Research Corp.

"All our codes will be easily extensible for further development," Dr. Pogorelov says.

"We expect that our software will serve the heliospheric and space weather research communities for many years."

SPACE WEATHER SIMPLIFIED

The effort focuses on the physical and computational aspects of software development but the team will use MSFC's expertise to develop operational codes and add features to simplify the space weather community's efforts to create new tools to improve space weather predictions.

"The development of successful numerical models and their application to space weather modeling strongly depends on the observational data used to run the codes," says Dr. Pogorelov. "The expertise of GSFC and MSFC in data assimilation and analysis, and operational software design, will be of major importance for this project."

Dr. Pogorelov is the leading developer of the Multi-Scale Fluid-Kinetic Simulation Suite (MS-FLUKSS), which will be used as a basis of the new software. He will coordinate the software development.

"We expect that our software will serve the heliospheric and space weather research communities for many years."

Together with Dr. Pogorelov and a to-be-hired postdoctoral researcher, CSPAR researchers and co-investigators Dr. Tae Kim and Dr. Mehmet Yalim will supervise simulations in the inner heliosphere and perform quantitative evaluation of the simulation results.

Accurate space weather forecasting is important to a high-tech Earth, Dr. Pogorelov says.

"The solar wind emerging from the sun is the main driving mechanism of solar events, which may lead to geomagnetic storms that are the primary causes of space weather disturbances that affect the magnetic environment of Earth and may have hazardous effects on space-borne and ground-based technological systems, as well as human health," he says. "For this reason, accurate modeling of the solar wind is a necessary part of space weather forecasting."

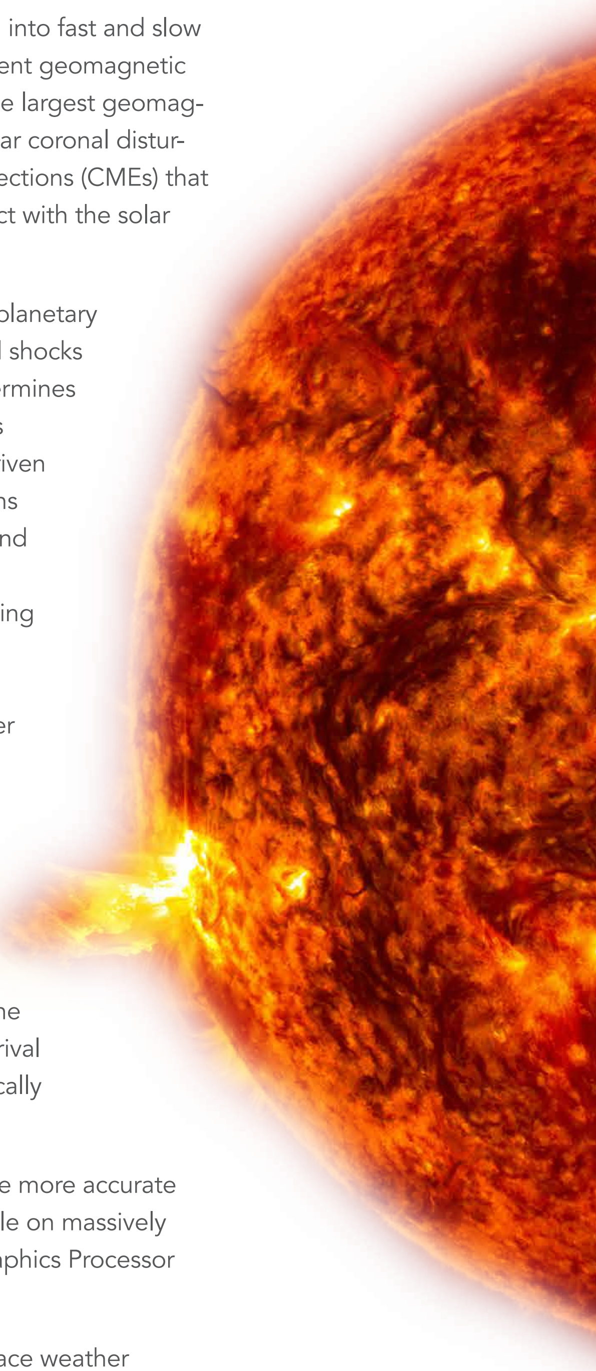
Structuring of the solar wind into fast and slow streams is the source of recurrent geomagnetic activity, Dr. Pogorelov says. The largest geomagnetic storms are caused by solar coronal disturbances called coronal mass ejections (CMEs) that propagate through and interact with the solar wind.

"The connection of the interplanetary magnetic field to CME-related shocks and impulsive solar flares determines where solar energetic particles propagate," he says. "Data-driven modeling of stream interactions in the background solar wind and CMEs propagating through it are necessary parts of space weather forecasting."

Currently, the National Oceanic and Atmospheric Administration Space Weather Prediction Center forecasts the state of the ambient solar wind and the arrival time of CMEs using an empirically driven solar wind model.

"The new models will provide more accurate solutions and will all be scalable on massively parallel systems, including Graphics Processor Units," he says.

"In addition to improving space weather predictions at Earth, our developed models and software will be data driven. They will be based on the observational data and shed light onto physical processes occurring on the sun and in interplanetary space." ■



RESEARCH LEADERSHIP IN SAFE USE OF DRONES IN DISASTERS AN IMPORTANT STEP FOR UAH

▲ Jerry Hendrix, RSESC director of Unmanned Aerial Systems Programs responsible for UAS research, is the principal investigator.

UAH's leadership role in $1.1 million in research to provide insight into the safe integration of Unmanned Aircraft Systems (UAS) into disaster preparedness and response is an important step in the evolution of UAS research at the university, says Dave Arterburn, director of UAH's Rotorcraft Systems Engineering and Simulation Center (RSESC).

The university received the funding as part of $3.3 million in research, education and training grants awarded to universities that comprise the Federal Aviation Administration's Air Transportation Center of Excellence for UAS, also known as the Alliance for System Safety of UAS through Research Excellence (ASSURE).

"This is an evolution in our growth as a leading university within the ASSURE team to meet the needs of the nation in terms of integrating UAS into the national airspace so they can be broadly used to the benefit of society," says Arterburn, who since becoming RSESC director has developed the UAS research enterprise at the university.

There are currently 1.65 million recreational and commercial drones in the active UAS fleet. That number is expected to grow to as high as 2.31 million by 2024. The ASSURE grants are aimed at continuing the safe and successful integration of drones into the nation's airspace.

UAH joined the ASSURE team in May 2015 and has grown from a single project in 2015 to executing or completing over eight projects in support of the FAA UAS Center of Excellence.

"We continue to submit projects and our leadership among the team has been recognized," Arterburn says.

In early 2019, Jerry Hendrix joined RSESC as the director of Unmanned Aerial Systems Programs responsible for UAS research.

"Jerry Hendrix certainly fulfilled my vision of wanting to operationalize our research from the basic research tasks we have done and to continue in the areas of UAS ground and airborne collision," Arterburn says.

"ASSURE was just renewed for a second five-year effort for the FAA and we are excited about future projects that are planned," Arterburn says. "UAH continues to grow our work within the greater Huntsville community and we have some exciting opportunities with our research partners outside of the FAA UAS Center of Excellence."

The newly FAA funded research will look at how UAS can aid in disaster preparedness and response to different natural and human-made disasters. It will focus on procedures to coordinate with the Department of the Interior, the Department of Homeland Security, the Federal Emergency Management Agency and other federal, local and state organizations to ensure proper coordination during those emergencies.

As the principal investigator, Hendrix leads the University of Alaska Fairbanks, the University of Vermont, New Mexico State University, Oregon State University, North Carolina State University and Mississippi State University in the effort.

The research results will be used to develop requirements, technical standards, policies, procedures, guidelines and regulations needed to enable emergency response operations for use in cases using UAS. The results will enable safe use of UAS as a tool to assist first responders in saving lives faster and accelerating personnel and infrastructure recovery.

"The research is guided by a program management plan using an integrated master schedule and with a research task plan that provides a step-by-step approach to how our team will answer all of the intended research questions and objectives," Hendrix says.

He envisions future phases of the program that will exercise requirements, technical standards, policies, procedures, guidelines and regulations in disaster use scenarios across the country and also will establish credentialing processes for first responders.

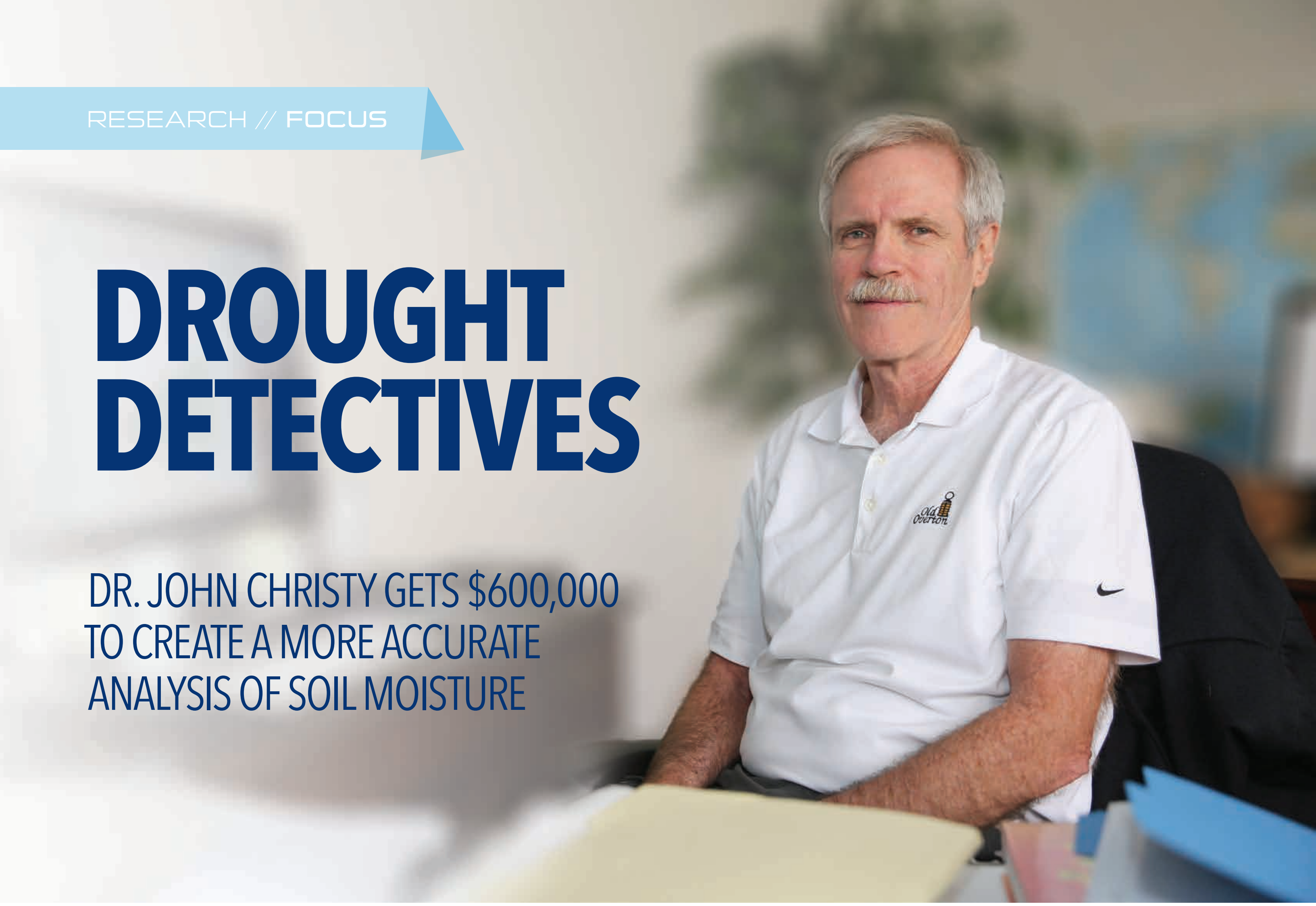
"UAH will continue to lead the program and grow our training capacity to help instill safe UAS operational practices supporting disaster response," Hendrix says. "This also gives UAH the opportunity to work closely with government, industry and academia to bring in the best solutions, platforms, sensors and ideas."

The team will host a series of national and regional collaborative events to develop partnerships and allow a voice to be heard from those already using UAS in disaster response.

"This research, along with UAH's UAS institutional research, the leadership of the Science Advisory Review Panel and ASSURE, and the Department of Defense and NASA programs, will continue to help UAH stand out as a nationally recognized UAS research organization," Hendrix says.

"Our focuses are ground and airborne collision, UAS testing, autonomous operations, counter-UAS operations, projected future UAS technologies, STEM and Education Outreach and now UAS use in disaster recovery." ■

Dave Arterburn, RSESC director, says the grant is an evolution in UAH's growth as a leading university within the ASSURE team.



DROUGHT DETECTIVES

DR. JOHN CHRISTY GETS $600,000 TO CREATE A MORE ACCURATE ANALYSIS OF SOIL MOISTURE

Better drought depiction, agricultural assessments and information about flood potential are the goals of a two-year, $600,000 grant to create a more accurate analysis of soil moisture that has been awarded to UAH's interim College of Science dean by the National Oceanic and Atmospheric Administration (NOAA).

The interim dean, Dr. John Christy, is a distinguished professor of atmospheric science and director of UAH's Earth System Science Center (ESSC). He's also the Alabama state climatologist and the grant's principal investigator.

"We will deploy state-of-the-art sensors at our 16 Alabama climate stations, along with other types of sensors for cross-validation, that will aid in producing consistent measurement values because these various sensors are used throughout the nation," Dr. Christy says. "To fill in the area surrounding the point measurements, we will develop and improve remote sensing soil moisture products using satellites and drones."

The system under development would especially aid farmers seeking federal assistance payments, as the region is prone to flash droughts that can decimate pastures and crops over a wide-ranging, spotty area.

"We had a serious flash drought in September 2019 that devastated pastures in Alabama, Georgia and north Florida that supported our livestock industry," Dr. Christy says.

"The typical metrics for determining stress for federal assistance payments relied on tools that did not capture this event, so many livestock producers were not eligible for assistance," he says. "This work will provide not only high resolution but a more accurate depiction of the stresses that such crops experience and thus be used as an additional indicator of agricultural losses."

Dr. Christy's team is Dr. Walter Ellenburg, ESSC research engineer; Dr. Vikalp Mishra, ESSC research associate; Dr. Udaysankar Nair, associate professor of atmospheric and Earth science; Dr. John Mecikalski, professor and chair of the Department of Atmospheric and Earth Science; Dr. Christopher Hain, research scientist, Short-term Prediction Research & Transition Center (SPoRT), Earth Science Branch, NASA Marshall Space Flight Center; and Cameron Handyside, ESSC research engineer.

Currently, much of federal drought assistance for farmers is based on U.S. Drought Monitor status, says Handyside.

"The problem with the Drought Monitor is that it is a conglomeration of many factors that go into a general drought condition," Handyside says. While it's a good indicator of general drought, the Drought Monitor does not always reflect agricultural drought, he says.

"Spot droughts are one of the biggest challenges facing farmers in Alabama. Alabama can go from flood to drought in seven days and often the Drought Monitor is slow to respond."

Much of the Drought Monitor data is reported at the county level, yet conditions can vary widely across a county.

"We see cases where a farmer in northern Madison County is doing great, plenty of rain and so on, while farmers in the southern part of the county have not seen a drop of rain in weeks," says Handyside. "We believe that agricultural drought is driven mostly by soil moisture and that a high-resolution map of recent and current soil moisture is a better indicator of crop stress that leads to agricultural drought."

Soil moisture monitors installed under the grant at the climate stations and at North Alabama sites used by Baron Services will have an accuracy of ± 1%. Each station will record soil moisture at three depths – 5 cm, 20 cm and 50 cm – for direct comparison with the standard measurements at the NOAA and U.S. Department of Agriculture (USDA) Natural Resources Conservation Services reference sites. Soil samples will also be collected and analyzed from each site.

Where available, stations will use electric power and internet service, but otherwise stations will be designed to be independent of power or internet, using cell service and solar to power internal batteries.

The sensor network will be used to develop, test and regionally calibrate remote-sensed and model products. One goal is to evaluate low- to moderate-cost sensors to determine reliability and how well the data returned compares to more expensive sensors used by USDA and NOAA.

"Alabama soils and weather make the state much different than conditions in the Midwest or Plains states, where so much of the soil moisture research is conducted," Handyside says. "The remote-sensed and model data from satellites, drones and crop models are intended to fill in the gaps between the sensor stations and create a more complete picture of current soil moisture conditions in Alabama."

As well as the Alabama research, the overall NOAA funding incorporates separate but cooperative projects in Georgia and Florida.

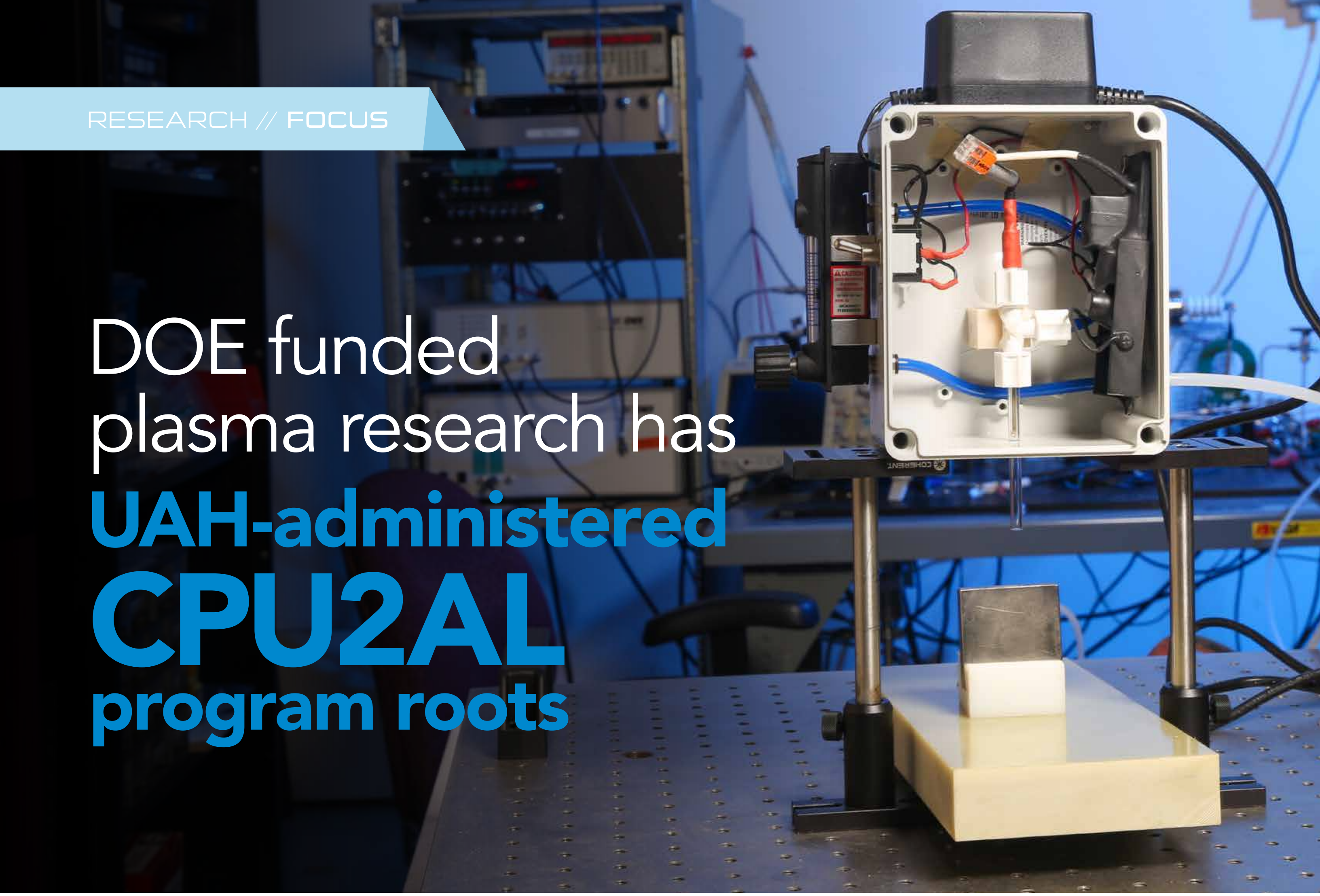
"As part of the Alabama project, we are working to develop an online repository that will allow access to sensor data and maps," Handyside says. The Alabama research will be made available to the National Soil Moisture Network's effort to standardize soil moisture data.

"We hope to work with the USDA National Agricultural Statistics Service office in Alabama, since they are responsible for publishing crop progress reports," Handyside says. "We have had success working with them in the past to provide data to help them develop a clear picture of conditions during the growing season." ■

◄ Spot droughts are one of the biggest frustrations for farmers, who may miss out on federal assistance payments.

Photo courtesy Laura Warner

DOE funded plasma research has UAH-administered CPU2AL program roots



Two U.S. Department of Energy (DOE) grants awarded to UAH professors have as a common touchstone the $20 million statewide UAH-administered program called Connecting the Plasma Universe to Plasma Technology in Alabama: The Science and Technology of Low-Temperature Plasma (CPU2AL).

Dr. Vladimir Kolobov, a principal research scientist at UAH's Center for Space Plasma and Aeronautic Research (CSPAR), was awarded a $750,000 grant from the DOE Established Program to Stimulate Competitive Research (EPSCoR) for low temperature plasma (LTP) research. He is working to enable development of theory, computational tools and experimental studies of LTP to control plasma stratification and filamentation, plasma-induced processes at gas, liquid and solid interfaces for applications in material synthesis, nanoelectronics, biomedicine and food safety.

For the last three years, Dr. Kolobov has been a co-director of the CPU2AL, which is led by Dr. Gary Zank, CSPAR director and the Aerojet Rocketdyne chair of the UAH Department of Space Science.

Dr. Gabe Xu, an associate professor of mechanical and aerospace engineering, was awarded a one-year, $98,930 grant by the DOE for plasma research that could advance pulsed fusion propulsion for spacecraft. As part of a larger study at UAH's Propulsion Research Center (PRC), the DOE grant funds work by Dr. Xu's team to determine how the deflection magnetic nozzle for a fusion propulsion system would work and how to scale it up to the size needed for a spacecraft.

Dr. Zank, the principal investigator for the nine-university partnership CPU2AL program that's operating under a five-year grant from the National Science Foundation (NSF) EPSCoR program, says the UAH grants are two more indicators of the kinds of research funding the consortium has been able to attract to UAH and the State of Alabama.

"The incredible investment – whether financial or time – from the NSF, UAH, and of course all the CPU2AL members, is paying off significantly with the capture of grants like this," says Dr. Zank, who is a member of the National Academy of Sciences and a University of Alabama System trustee professor, its highest award for a faculty member. "They demonstrate the importance of Alabama-wide collaborative research and our growing ability to reach into the national and federal lab community to develop joint projects."

The grants reflect a primary goal of the CPU2AL project, which is to develop Alabama-wide skills and research capabilities while building a highly capable workforce in plasma science and engineering, says Dr. Zank, adding that the UAH research also represents some of the priorities in plasma science and engineering identified by the Plasma 2020 Decadal Assessment that he co-chaired.

"All of these activities are beginning to contribute to the development of an impressive national recognition for Alabama in plasma science," he says.

Other CPU2AL partners are the University of Alabama, the University of Alabama at Birmingham, Auburn University, Tuskegee University, the University of South Alabama, Alabama A&M University, Alabama State University and Oakwood University, with additional assistance from CFD Research Corp. (CFDRC), a computational fluid dynamics software company located in Cummings Research Park.

LOW TEMPERATURE PLASMA

Dr. Kolobov's project at UAH is collaborative research between UAH, CFDRC. and the Plasma Research Facility at Sandia National Laboratories (SNL). It leverages both the current CPU2AL and the previous DOE Plasma Science Center administered by the University of Michigan, at which Dr. Kolobov was also a co-principal investigator during the last decade.

"The present DOE project complements and leverages these two projects and expands plasma research to the interactions of Low Temperature Plasma with solid and liquid surfaces, transport phenomena and heterogeneous chemical reactions at interfaces, and self-organization and pattern formation in non-equilibrium reactive plasmas," Dr. Kolobov says.

LTP is a mixture of electrons, ions and neutral species with electron temperature exceeding the gas temperature by two orders of magnitude. Such a highly non-equilibrium system is prone to instabilities, which lead to the formation of ionization waves, current filamentation into narrow channels and the formation of spots at plasma contacts with solid and liquid surfaces.

"Plasma interactions with surfaces can be incredibly complex," says Dr. Kolobov. "The surface can evolve according to the fluxes of plasma species and inject electrons and other species into plasma."

Liquid surfaces can deform, evaporate or inject droplets, he says, and chemical reactions can occur in both gas and liquid phases.

"We will try to improve the understanding of transport processes, plasma-induced chemistry and self-organization such as stratification and filamentation, formation of anode spots, liquid droplets ejection from cathodes and plasma electrolysis," Dr. Kolobov says.

"We will improve the theory and use computational tools developed by the project participants to understand plasma-based surface functionalization

▲ Dr. Kolobov will research the interactions of Low Temperature Plasma with solid and liquid surfaces, transport phenomena and heterogeneous chemical reactions at interfaces.

and plasma-enabled pattern nucleation in a wide range of scales from nano- to millimeters. We will use experimental methods and facilities available at UAH and SNL to understand and control plasma processes, reaction pathways and structures at the plasma-exposed interfaces."

The partnership with SNL will help establish a sustainable research partnership of Alabama researchers with a DOE National Laboratory devoted to understanding and controlling LTP environments, strengthening the research capacity and building an inclusive workforce in plasma science and technology in the State of Alabama, Dr. Kolobov says.

"The project will provide opportunities for UAH students and postdocs to use superior experimental facilities and advanced computational tools at national laboratories and interact with lead scientists at SNL and in industry," he says.

SNL hosts one of two newly established DOE Plasma Research Facilities with unique experimental equipment for electrical, optical and mass-spectroscopy characterization of plasma-surface interactions and advanced computational tools for plasma simulations.

"These facilities and tools will be used in the proposed research," says Dr. Kolobov. "This is another opportunity for collaboration of the UAH-CFDRC team with SNL for experimental, theoretical and computational studies of charge transport at plasma-material interfaces."

PLASMA AND PROPULSION

At UAH's PRC, the DOE grant will provide Dr. Xu's team with the opportunity to use more powerful equipment located at CPU2AL partner Auburn University to study how to control plasma for spacecraft propulsion.

"In the lab at the PRC, we're doing small-scale experiments using relatively low magnetic fields, a few hundred to 1,000 Gauss, which is about the conventional limit in the lab," says Dr. Xu, who is also a co-principal investigator for Dr. Kolobov's research.

That PRC plasma source at UAH was developed under a CPU2AL program to study new predictive plasma-surface interaction technologies.

"With this funding, we'll be able to use the specialized high magnetic field facility at Auburn University that can generate magnetic fields up to 40,000 Gauss," Dr. Xu says.

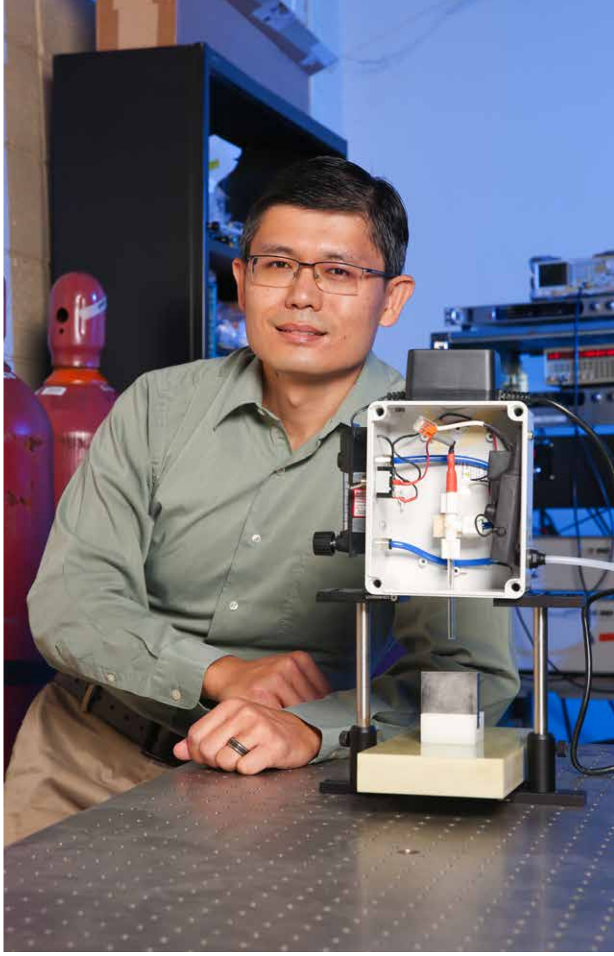
On the team are Dr. Jason Cassibry, an associate professor of mechanical and aerospace engineering; doctoral student Zachary White, who is doing his dissertation based on the project; Declan Brick, a mechanical and aerospace engineering junior; NASA's Marshall Space Flight Center; and a post-doctoral researcher.

The researchers are studying how to deflect a spherically expanding plasma from a fusion reaction into an axially directed thrust needed for spacecraft propulsion. The fusion reaction creates a ball of expanding plasma in all directions. But the half of that ball that is directed forward toward the spacecraft is not producing thrust, and can damage the spacecraft.

"So, we need to turn that plasma around so it all goes out the back similar to a rocket nozzle," Dr. Xu says. "But we can't use a physical nozzle to turn the plasma, since the plasma would dissipate and lose energy when it hits a physical object."

Instead, the UAH team uses a magnetic field to electromagnetically turn the plasma.

"Our work focuses on finding the mechanisms that create thrust in deflection magnetic nozzles, investigating plasma detachment from the magnetic fields and the instabilities that occur between the plasma and the magnetic field interface that could hinder thrust, and designing nozzle configurations and operating conditions that minimize instabilities and maximize thrust," says White, the doctoral student.



▲ Dr. Gabe Xu will study how to control plasma for spacecraft propulsion.

"The DOE grant allows us to explore high magnetic field regimes that otherwise would not be available to us," White says. "Our hope is that this will give us some insight into the plasma detachment in a near force-free field – a high magnetic pressure and low plasma pressure regime."

"How to construct a magnetic field to do that, how the plasma responds and what kind of power is needed are the main questions of the research," says Dr. Xu. "This is a great opportunity to conduct plasma research at very high magnetic fields that you cannot normally generate in the lab." ■

TOGETHER

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