FOCUS

UAH Research Magazine // Spring 2021

COMMENCING COUNTDOWN

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TOP OF CLASS

Six research programs in top 20 in federal funding

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FLASH OF INSPIRATION

How a humidifier prompted a new atomic layer deposition process

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Dr. Robert Lindquist
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Charger eyes will look to the sky for telescope launch

These are exciting times for UAH and our research partners, filled with discovery and innovation!

Charger eyes will again look excitedly to the sky later this year when NASA's James Webb Space Telescope launches. Promising to open up vast new vistas to scientific exploration by gathering infrared energy from the most distant stars and galaxies ever viewed, the Webb telescope is the product of more than two decades of crucial design and testing work that closely teamed UAH's Center for Applied Optics (CAO) with NASA and private industry. UAH and the CAO were essential partners in the design and testing of the 18 gold-coated beryllium segments that make up the telescope's 6.5-meter primary mirror. Our cover story about the university's deep research involvement is on page 4.

The number of UAH research programs ranking among the top 20 nationally in federal expenditures reported by the National Science Foundation has risen to six, and UAH ranks 13th nationwide in overall NASA research expenditures and 26th in overall Department of Defense research expenditures. All the details are on page 8.

Sometimes an idea arrives as a flash of inspiration, and that's what happened to UAH postdoctoral research associate Dr. Moonhyung Jang as he shopped for home humidifiers by comparing features. His flash of insight resulted in a new process of atomic layer deposition that he and Dr. Yu Lei invented in Dr. Lei's laboratory. The new process allows the use of a wider array of materials at greater temperature ranges, as a story on page 11 relates. Atomic layer deposition is a thin-film deposition technique used in microelectronics manufacturing.

When businesses face disruptive corporate crises, new research from Dr. Yongchuan "Kevin" Bao of the UAH College of Business says that the way chief executive officers perceive or interpret the crises matters to their companies' adaptation to the changes, as a story on page 13 explains. To better see the big picture, business leaders should strive to adopt an ambivalent mindset that embraces the contradictory presence of both threats and opportunities.

Safe drinking water is a priority for everyone. That's why the U.S. Environmental Protection Agency is funding research by Dr. Tingting Wu, an associate professor in the Department of Civil and Environmental Engineering, and Dr. Lingze Duan, a professor in the Department of Physics and Astronomy, on a novel turbidity sensor network that uses glass fibers to safeguard supplies, a story on page 15 says.

UAH faculty and staff work closely with the university's research partners to achieve shared goals. A story on page 17 is about NASA awarding Sue Estes, a research scientist at UAH's Earth System Science Center, with its Exceptional Public Service Medal for her work as senior associate program manager for Health and Air Quality Applications in the Applied Sciences Program of the NASA Earth Science Division.

Besides the technical challenges of designing and building its first liquid-fueled rocket project, UAH's student-led Space Hardware Club has faced constraints imposed by COVID-19. But the pandemic's strictures haven't dampened the team's enthusiasm, according to Project Manager Spencer Christian, a sophomore in aerospace engineering. Project Tartarus' progress is updated on page 18.

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

SOURCE: National Science Foundation

NATIONALLY

- **6TH** Federally-financed Aerospace/ Aeronautical/Astronautical research
- **10TH** Federally-financed Atmospheric Sciences research
- **11TH** Federally-financed Computer and Information Sciences research
- **13TH** NASA R&D expenditures
- **14TH** Federally-financed Astronomy research
- **15TH** Federally-financed Economics research
- **17TH** Federally-financed Industrial and Manufacturing Engineering research
- **26TH** Department of Defense R&D expenditures

RESEARCH

$489 million
Five-year contract and grant research total

$131.6 million
Fiscal 2020 research expenditure total

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

ISSUED PATENT TOTAL – 112

COVER

RESEARCH FOCUS

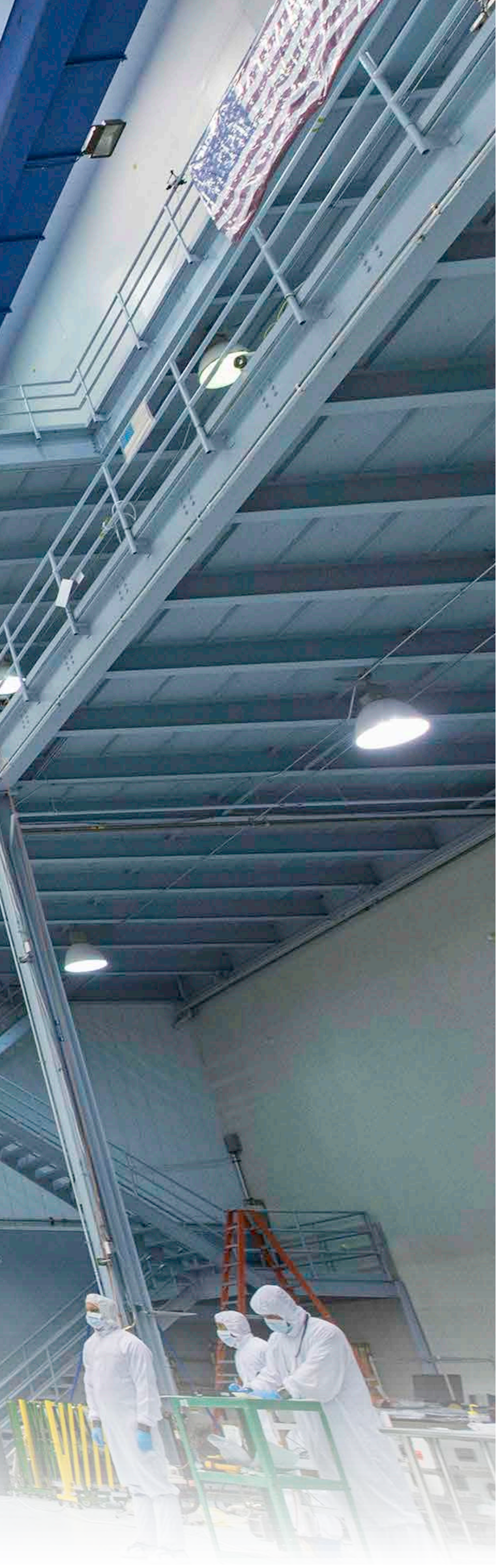
STAFF FOCUS

STUDENT FOCUS

▸ Cover: UAH Center for Applied Optics (CAO) Principal Research Scientist Dr. James Hadaway, left, has been involved with research and development of NASA's James Webb Space Telescope since its inception in 1996. CAO Director Dr. Patrick Reardon became involved in support of Dr. Hadaway's work starting in 1998.

OPENING NEW SCIENTIFIC VISTAS

When the James Webb Space Telescope unfurls its primary mirror, 25 years of UAH R&D involvement will bloom with it



The fully deployed James Webb Space Telescope being moved by crane inside a clean room at NASA's Goddard Space Flight Center in Maryland.

NASA

After a scheduled October launch, when NASA's James Webb Space Telescope (JWST) achieves orbit and unfurls the 18 gold-coated beryllium segments of its 6.5-meter primary mirror, over two decades of crucial UAH partnership in the project will also blossom.

The technical challenges of JWST allied UAH as a partner in the international project with NASA's Goddard Space Flight Center (GSFC), Marshall Space Flight Center (MSFC), Johnson Space Center (JSC) and private industry.

The telescope will launch aboard a European Space Agency Ariane 5 rocket from French Guiana. JWST will open vast new vistas to scientific exploration, viewing them via an "eye" that researchers at UAH's Center for Applied Optics (CAO) have had critical partnership roles in conceiving, perfecting and testing.

For CAO Principal Research Scientist Dr. James Hadaway in particular, it will be a watershed event.

"I remember many times during my work on JWST when I would just stop and think to myself, 'Wow, I'm working on the largest space telescope ever built, how cool is that?'" Dr. Hadaway says. "It is very exciting to be nearing the launch, after which I will be able to see the fruition of all that work."

A long hauler, Dr. Hadaway (Ph.D., Optical Science and Engineering, 2004) has been deeply involved in JWST since 1996.

"I did want to be a part of the optical testing of the telescope optics from the beginning through to the end," he says. "I thought that if at least one person was there for the entire process, it would provide a valuable opportunity to use the experience gained along the way to help ensure a successful overall testing program."

For Dr. Patrick Reardon, currently the CAO director, who began in 1998 to support the design and testing work led by Dr. Hadaway, the coming launch marks a remarkable concentration of public and private research.

"First, it is hard to believe that something I and so many others here at UAH and across the city have invested so much time and talent into is finally culminating with a launch. I started on this 23 years ago – the same time my daughter was born!" says Dr. Reardon (MS, Physics, 1990; Ph.D., Physics, 1993).

"Second, I am proud that I was able to be a part of this project, especially given the great work we did and the excellent leadership James Hadaway provided as the UAH project lead."

In March, the telescope completed its final functional tests at Northrop Grumman in Redondo Beach, Calif., to prepare for launch. Designed to observe the most distant stars and galaxies ever viewed, JWST works by gathering their faint infrared energy with its large primary mirror. During flight, the telescope's mirror will be folded up before it flowers.

"I had been working on potential optical designs for a 20- to 30-meter diameter space telescope for Marshall Space Flight Center's Advanced Concepts group," Dr. Hadaway says. "When JWST came along, planned as a 6- to 8-meter telescope, NASA asked

Dr. Pat Reardon inside a six-foot diameter tube used for early mirror evaluation.

NASA

me to lead a team to develop an initial optical design."

After that effort, Dr. Hadaway was asked if UAH could take the lead in developing and operating an optical measurement system for testing various mirror technologies that could potentially meet the requirements for the JWST primary mirror. JWST's mission depends on a near-perfect mirror, and that meant lots of testing on Earth at temperatures approximating the extreme cold of outer space.

"So, I put together a team within the CAO to work with the folks at MSFC's X-Ray and Cryogenic Facility (XRCF) to test these mirrors in their large vacuum chamber, which cooled them to the JWST operating temperature of minus 378 degrees Fahrenheit," Dr. Hadaway says.

Dr. Reardon supported Dr. Hadaway, the project's principal investigator, by assisting in the design and development of the optics test system, and then working at the XRCF performing a series of tests on different candidate mirror technologies.

"The mirrors had to be lightweight and there were several competing technologies from different organizations that had to be tested to see which was the best for JWST," says Dr. Reardon, adding that the mirrors were both parabolic and off-axis.

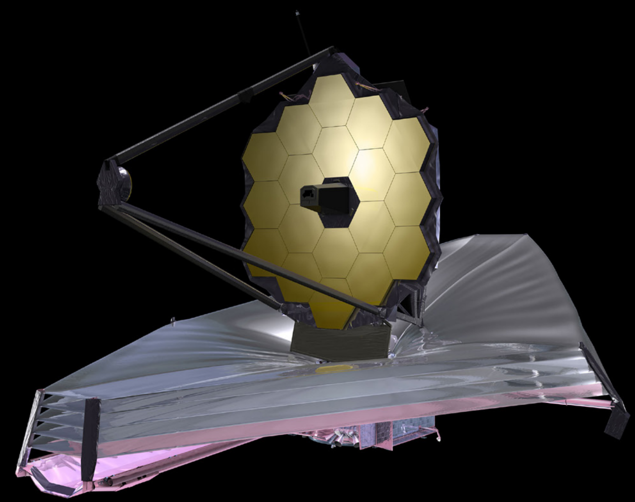
"A parabolic mirror is a rotationally symmetric form, however a section that is not centered on the axis of rotation is no longer rotationally symmetric," he says. "That meant the testing of the mirror was considerably more complicated."

A lot of time was invested in developing a method and procedure to verify the mirror alignment, and on analysis of the system.

"I was then testing the candidate mirrors, applying the test procedures we had developed," Dr. Reardon says. "These tests were completed and NASA made a selection of the mirror technology."

After the flight hardware was developed, exacting appraisal of the 18 JWST flight primary mirror segments began. Working as part of a subcontractor team for Ball Aerospace & Technologies Corp. (BATC) that included Dr. Reardon, Dr. Hadaway was about to find out how the lightweight mirrors would perform in space conditions.

From 2010-2012, the 18 mirrors arrived in six batches for examination. As anticipated, once cooled with liquid nitrogen and gaseous helium in a bus-sized chamber at the XRCF, the mirrors deformed in the extreme cold.



The James Webb Space Telescope is an orbiting infrared observatory that will look much closer to the beginning of time and hunt for the unobserved formation of the first galaxies, as well as look inside dust clouds where stars and planetary systems are forming today.

NASA

Data from the first round of testing was then used by BATC to re-polish the mirrors to correct the deformations. Finally, a second round of testing was performed to ensure the mirrors were near-perfect at their cryogenic operational temperature.

MSFC backup generators saved the day once when a carefully cooled test batch reached its target temperature just as a supercell, multiple tornado event swept the area on April 27, 2011, cutting power.

In addition to working on mirror evaluation, Dr. Reardon supported a 24/7 testing cycle for the backplane that holds the mirror segments.

"Measurements were needed to verify that the structure the mirrors were going to be attached to was stable, and that its changes when going from ambient to cryogenic temperatures were well understood," Dr. Reardon says.

The involvement of the CAO and Dr. Hadaway didn't end there.

"With the experience we had gained in testing mirrors at cryogenic temperatures, the project leaders at GSFC then asked us to support the testing of the full telescope in an eight-story vacuum chamber at JSC," Dr. Hadaway says. "I worked for several more years with ITT-Exelis, now part of Harris Corp., to successfully complete that testing."

Though there were many technical challenges throughout UAH's involvement in the JWST program, Dr. Hadaway says the biggest was aligning the 18 primary mirror segments during the full telescope testing at JSC.

"We had to align them to each other to within 150 nanometers, or 0.000006 inch, without being able to actually touch them, since they were inside a vacuum chamber," he says. "But with a lot of great people on our team, we were able to meet the requirement."

Working on JWST accelerated the growth of UAH's CAO in optical systems modeling, optical fabrication and testing, Dr. Reardon says. As well as the research the project yielded, the telescope supported CAO student research projects, master's theses and doctoral dissertations. At least five doctoral degrees and five master's degrees were conferred because of the work.

"We learned a lot on this project. Optical modeling techniques. Optical test procedures for complex surfaces. Cryogenic testing. Large, lightweight optics," Dr. Reardon says. "We were able to leverage the success and growth we had from this project to acquire our first major equipment upgrade in 15 years, the Moore Nanotech 250UPL diamond turning machine, thanks to U.S. Sen. Richard Shelby."

The Nanotech enabled the CAO to produce optics for many local, regional and national companies. It can produce non-rotationally symmetric optical surfaces up to about 300 mm diameter.

"Having this diamond turning machine helped us win the National Science Foundation proposal to acquire the Zeeko IRP600X free-form polisher, an instrument that can produce optics up to about 600 mm diameter that we have successfully applied to many substrate materials including aluminum, Zerodur, borosilicate and even 3D printed Invar 36," Dr. Reardon says.

"With some recently acquired advanced metrology equipment, from both donations and purchases, our testing now matches our fabrication capability."

The JWST brought UAH – a university founded on America's space quest – into close developmental partnership with NASA, the ESA and the Canadian Space Agency, all of which are involved in the telescope.

"JWST is a massive international collaboration," says Dr. Hadaway. "The interactions with the dedicated people within all of these organizations were very rewarding for us, with many permanent relationships established." ■

SIX UAH RESEARCH PROGRAMS RANK IN TOP 20 NATIONALLY FOR FEDERAL FUNDING

Research activities at UAH continue to rank among the top federally-funded programs in the United States, according to the latest information available from the National Science Foundation (NSF).

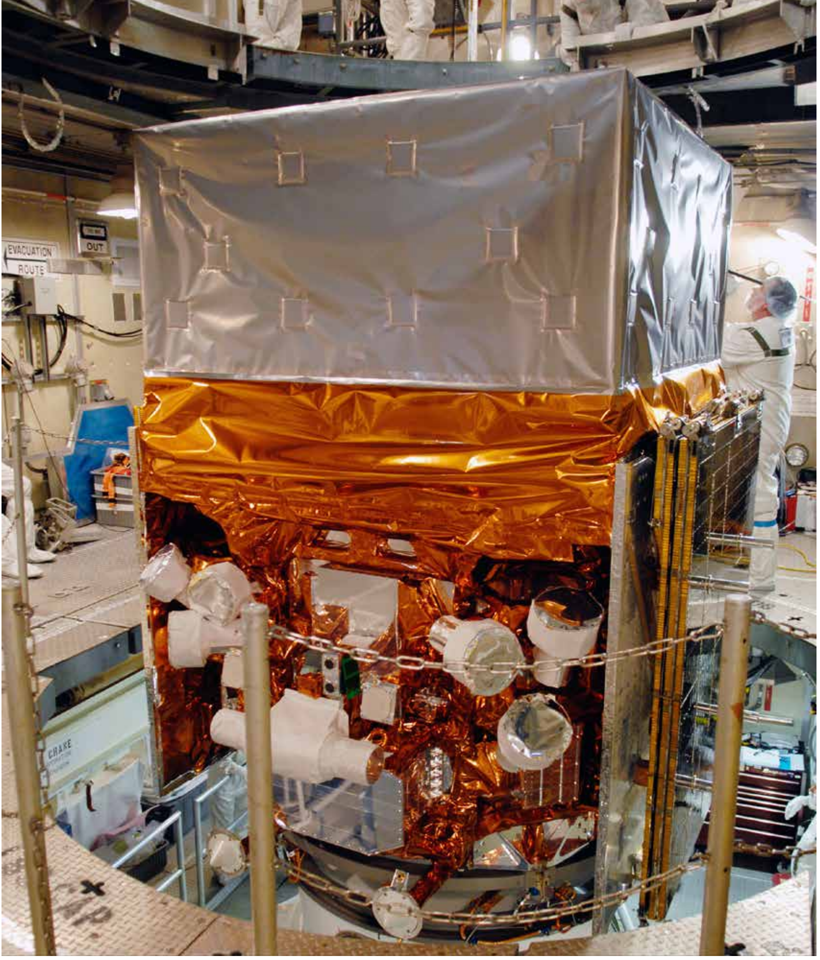
The annual NSF Higher Education Research and Development (HERD) Survey ranked six UAH programs in the top 20 nationally, up one from last year. UAH ranks 13th nationwide in overall NASA research expenditures and 26th in overall Department of Defense research expenditures for fiscal year 2019, the latest data available.

"UAH strives to continuously improve in areas that provide support to the federal agencies on Redstone Arsenal and the corporate presence in Cummings Research Park," says Dr. Bob Lindquist, vice president for research and economic development.

"The success in ranking is possible through the valuable partnerships that have existed for decades in the Huntsville community, and UAH is proud of its researchers who strive to provide effective and innovative outcomes to the technological challenges that exist in the world today."

The HERD Survey of federal funding ranks UAH as:

- **#6** in aerospace/aeronautical/astronautical research expenditures
- **#10** in atmospheric sciences research expenditures
- **#11** in computer and information sciences research expenditures
- **#14** in astronomy research expenditures
- **#15** in economics research expenditures
- **#17** in industrial and manufacturing engineering research expenditures ■



▲ The new discovery was made by the Gamma-ray Burst Monitor, an instrument aboard the Fermi Gamma-ray Space Telescope.

NASA

UAH PART OF DISCOVERY **OF FIRST GIANT NEUTRON STAR FLARE OUTSIDE THE MILKY WAY**

Researchers at The University of Alabama in Huntsville (UAH) Center for Space Plasma and Aeronomic Research (CSPAR) were part of a team that for the first time discovered a giant flare from a neutron star that's outside Earth's galactic neighborhood.

The new discovery was the subject of a research paper in the journal *Nature* that has four UAH co-authors.

"This is the first time we could claim, without a doubt, a giant flare from outside of our galactic neighborhood," says co-author Dr. Peter Veres, a CSPAR research scientist.

Only three such giant flares had been detected since satellites have observed the gamma-ray sky. All three are nearby by space standards. Two are located in the Milky Way and one in the neighboring Large Magellanic Cloud galaxy.

The find was made by the Gamma-ray Burst Monitor (GBM), an instrument aboard the Fermi Gamma-ray Space Telescope with 12 low-energy sensors and two high-energy sensors that's monitored from UAH's Cramer Research Hall. There, UAH scientists share the data from GBM with colleagues from NASA's Marshall Space Flight Center (MSFC), the Universities Space Research Association (USRA) and the Max Planck Institute for Extraterrestrial Physics in Germany.

The bulk of the new discovery is based on GBM data with additional measurements from the Burst Alert Telescope instrument aboard the Neil Gehrels Swift Observatory's Swift Gamma-Ray Burst Mission satellite and some radio observations.

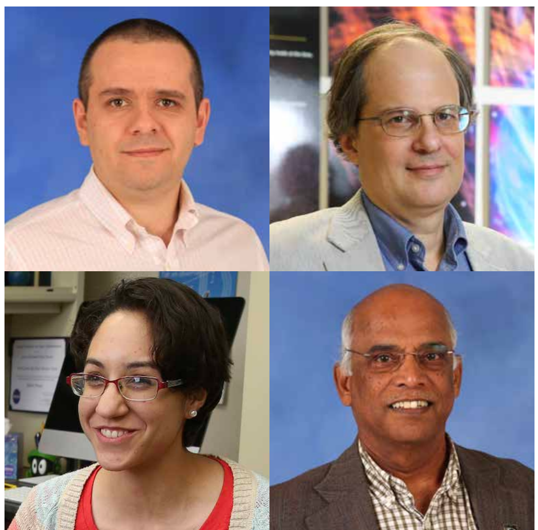
The UAH research team contributed data analysis, mitigation of instrumental effects and data interpretation. Dr. Michael Briggs, CSPAR assistant director and senior principal research scientist, and Dr. Narayana Bhat, a CSPAR research scientist, used their expertise with GBM to show where the data needed correction. Dr. Veres analyzed the spectrum, calculated the total energy involved and worked on interpreting the findings. Rachel Hamburg, a UAH graduate research assistant, put the event in context of other observations from GBM to show it was unlikely to be a gamma-ray burst.

The principal investigator for the *Nature* paper is Dr. Oliver Roberts of USRA, headquartered in Maryland. All four UAH researchers are co-authors. Co-authors are from nine universities and also include UAH alumna Dr. Colleen Wilson-Hodge of MSFC, who is the principal investigator for Fermi GBM, as well as authors from NASA's

Goddard Space Flight Center and the National Radio Astronomy Observatory.

Early in this decade UAH developed GBM's performance requirements and its ground and flight software. Dr. Briggs, who this year won NASA's Exceptional Public Achievement Medal in part for his GBM work, is the deputy principal investigator for the Fermi GBM. The instrument was built through a collaboration between UAH, NASA and the Max Planck Institute.

The giant flare was observed as a short burst of gamma-rays by the GBM instrument on April 15, 2020, Dr. Veres says.



UAH co-authors of the Nature paper are, clockwise from top left, Dr. Peter Veres; Dr. Michael Briggs, Dr. Narayana Bhat and Rachel Hamburg.

"Neutron stars are very compact, city size objects with mass that is somewhat larger than the mass of the sun," Dr. Veres says. "These flaring neutron stars have extra strong magnetic fields and also go by the name magnetars."

Giant flares are also very bright, he says.

"The three known flares were all so bright that every instrument observing them was blinded by the huge number of gamma-rays."

Because the photons from those earlier discoveries were arriving faster than the instruments could count them, Dr. Veres says that even though scientists know how a giant flare looks in broad terms, measuring their detailed properties was elusive.

"Now, with the observation of this giant flare, we can see details of the event that were not possible to discern before," he says. "The picture we have for this giant flare is that the magnetic field became strong enough to produce cracks in the neutron star."

As a result, an energetic jet was released and hurtled toward the GBM instrument at very high speed.

"For the first time we were able to determine the speed, which turns out to be very close to the speed of light," Dr. Veres says. "Through all of this the magnetar should be rotating and we also find signs of this rotation. We don't know exactly how fast, but a good estimate is once every eight seconds – that is consistent with our observations and interpretation."

Even at such a large distance, the giant flare was bright enough that it caused problems in a small segment of the GBM data.

"We overcame this issue by using data from the BAT and patched up this short part," Dr. Veres says.

The entire event was unusually short, lasting less than two-tenths of a second.

"For me, the outstanding result is that we observed even shorter variations, about 1/10,000th of a second," Dr. Veres says. "This is a record among cosmic gamma-ray flash sources. The variations tell us about the size of the object responsible for the emission and point to a neutron star origin."

Research for the new discovery was funded by NASA and the National Science Foundation and it's another accolade for the 12-year-old Fermi satellite and its GBM, which launched in 2008 with a five-year lifespan. ■

NEW ATOMIC LAYER DEPOSITION PROCESS INVENTED AT UAH

◂ The invention was created and tested in the UAH lab of Dr. Yu Lei, who says it will open a new window to many ALD processes.

A new way to deposit thin layers of atoms as a coating onto a substrate material at near room temperatures has been invented at UAH.

UAH postdoctoral research associate Dr. Moonhyung Jang got the idea to use an ultrasonic atomization technology to evaporate chemicals used in atomic layer deposition (ALD) while shopping for a home humidifier.

Dr. Jang works in the laboratory of Dr. Yu Lei, an associate professor in the Department of Chemical Engineering. The pair published a paper on their invention that has been selected as an editor's pick in the *Journal of Vacuum Science & Technology A*.

"ALD is a three-dimensional thin film deposition technique that plays an important role in microelectronics manufacturing, in producing items such as central processing units, memory and hard drives," says Dr. Lei.

Each ALD cycle deposits a layer a few atoms deep. An ALD process repeats the deposition cycle hundreds or thousands of times. The uniformity of the thin films relies on a surface self-limiting reaction between the chemical precursor vapor and the substrates.

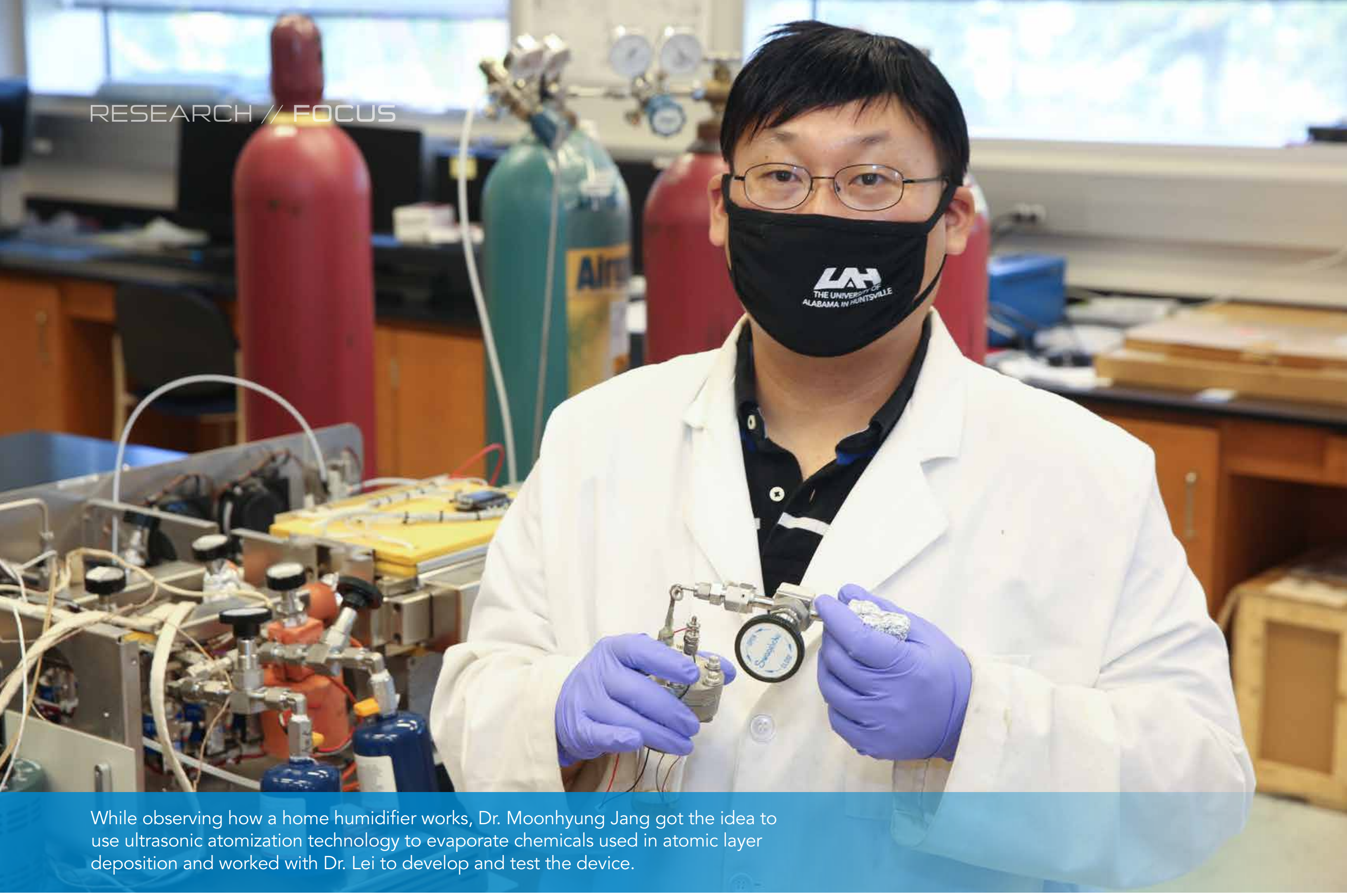
"ALD offers exceptional control of nanometer features while depositing materials uniformly on large silicon wafers for high volume manufacturing," Dr. Lei says. "It is a key technique to produce powerful and small smart devices."

While browsing online for a safe and easy-to-use home humidifier, Dr. Jang observed that humidifiers on the market use either direct heating at high temperature or ultrasonic atomizer vibration at room temperature to generate the water mist.

"Moon suddenly realized that the latter could be a safe and simple way to generate vapors for reactive chemicals that are thermally unstable," says Dr. Lei.

"The next day, Moon came to discuss the idea and we designed the experiments to prove the concept in our research lab. The whole process took almost a year. But the great idea came to Moon like a flash."

ALD processes typically rely on heated gas-phase molecules that are evaporated from their solid or liquid form, similar to room humidifiers that use heat to vaporize water. Yet in that ALD process, some chemical precursors are not stable and can decompose before reaching a sufficient vapor pressure for ALD.



While observing how a home humidifier works, Dr. Moonhyung Jang got the idea to use ultrasonic atomization technology to evaporate chemicals used in atomic layer deposition and worked with Dr. Lei to develop and test the device.

"In the past, many reactive chemicals were considered not suitable for ALD because of their low vapor pressure and because they are thermally unstable," says Dr. Lei. "Our research found that the ultrasonic atomizer technique enabled evaporating the reactive chemicals at as low as room temperature."

The UAH scientists' ultrasound invention makes it possible to use a wide range of reactive chemicals that are thermally unstable and not suitable for direct heating.

"Ultrasonic atomization, as developed by our research group, supplies low vapor pressure precursors because the evaporation of precursors was made through ultrasonic vibrating of the module," Dr. Lei says.

"Like the household humidifier, ultrasonic atomization generates a mist consisting of saturated vapor and micro-sized droplets," he says. "The micro-sized droplets continuously evaporate when the mist is delivered to the substrates by a carrier gas."

The process uses a piezo-electric ultrasonic transducer placed in a liquid chemical precursor. Once started, the transducer starts to vibrate a few hundred thousand times per second and generates a mist of the chemical precursor. The small liquid droplets in the mist are quickly evaporated in the gas manifold under vacuum and mild heat treatment, leaving behind an even coat of the deposition material.

"Using the room-temperature ultrasonic atomization reported by our manuscript, new ALD processes could be developed using low volatility and unstable precursors," Dr. Lei says. "It will open a new window to many ALD processes."

In their paper, the UAH researchers demonstrate proof of concept by comparing titanium oxide ALD using thermally evaporated and room-temperature ultrasonic atomized chemical precursors, respectively.

"The TiO2 thin film quality is comparable," says Dr. Lei.

The research was sponsored by the Department of Defense, the National Science Foundation and NASA's Established Program to Stimulate Competitive Research. The inventors are seeking a patent through UAH's Office for Technology Commercialization. ■

UAH BUSINESS RESEARCH

CEOs SHOULD DEVELOP AN AMBIVALENT MINDSET IN CRISES

The way chief executive officers (CEOs) perceive or interpret disruptive corporate crises matters to their companies' adaptation to the changes, according to research by a UAH associate professor of marketing.

"Our study advocates that in response to a crisis, company executives should develop an ambivalent mindset that embraces the contradictory presence of both threats and opportunities," says Dr. Yongchuan "Kevin" Bao of the College of Business.

The co-authored research article was published in *IEEE Transactions on Engineering Management*, and received the Best Papers award of the Technology and Innovation Management Division at the Academy of Management Annual Meeting 2020.

"In the empirical test of the hypotheses, we adapted measures of ambivalence towards a crisis from prior research," Dr. Bao says. "CEOs may use these measures to check the level of their ambivalence in a crisis situation."

When disruptive changes occur, such as an economic crisis or the emergence of a new technology that renders obsolete a company's core competence, CEOs who are highly ambivalent about the change can better identify innovation agendas that help firms adapt, the research found.

In response to a business environment change, firms face two distinctive yet contradictory paths of innovation, Dr. Bao says: exploitation of existing knowledge and competence versus exploration of new knowledge and competence.

"It has been well acknowledged that simultaneous pursuit of exploitation and exploration – a strategy called ambidexterity – can spur firm growth and enhance performance," Dr. Bao says.

Yet the study finds that increasing CEO ambivalence does not necessarily lead to a higher level of ambidexterity.

"CEOs should be especially cautious when they perceive vague opportunities but distinct threats. This is a low ambivalence trap, where CEOs tend to reconcile the weak cognitive frame with the salient or strong cognitive frame in order to suppress the cognitive tension," says Dr. Bao.

If a CEO falls into the trap, resulting decisions may undermine the firm's organizational ambidexterity to address a disruptive change.

> ***Adopting an ambivalent mindset that embraces the contradictory presence of threats and opportunities can be useful for CEOs in crises, says Dr. Yongchuan "Kevin" Bao.***

For example, a Kodak engineer invented the world's first digital camera. Yet Kodak executives perceived that the invention exposed conspicuous threats to its core competence of film-based photography. At the same time, they thought that the emerging technology had only vague market opportunities.

With this mindset, they attempted to reconcile film with digital technology by implementing a policy called film-based digital imaging. The effort to blend digital with film technology compromised both the company's exploration of digital imaging and the exploitation of film technology. That led to reduced investments in color film and also the market failure of exploratory digital products.

To sidestep this low ambivalence trap, Dr. Bao says CEOs should collect a wide range of information on a crisis and develop the cognitive flexibility to embrace possible contradictory interpretations and detect the structural linkages between the positive and negative aspects of a crisis.

"As a result, the high ambivalence of a company leader enables a synergy between exploitation and exploration in a crisis situation," Dr. Bao says. "That is, a high level of exploitation improves the success rate in the exploration of new product markets, while a high level of exploration enhances the efficiency of exploitation in related domains."

The research also examined whether firms' technological capability inhibited or facilitated a CEO's ability to adapt to a disruptive change with innovations.

"We find that technological capability acts as a double-edged sword," Dr. Bao says.

If a CEO mainly perceives threats of a disruptive change, a strong technological capability may reinforce rigidity and spur a retreat to the firm's core competence or business model, he says. Increasing ambivalence may undermine organizational ambidexterity even more as the firm loses the flexibility to explore new ways of innovation.

For example, Polaroid made similar mistakes to Kodak's when digital imaging technology emerged. Although the firm's instant photography core competence was unparalleled in the industry, its technological supremacy led company executives to cling to the belief that consumers preferred instant cameras over digital offerings.

In an attempt to preserve its core competence and business model in the face of the digital camera threat, Polaroid decided to bundle the digital camera with instant film. The compromise delayed the development and commercialization of its own digital camera, while in the meantime diminishing investments in instant photography.

"When CEO ambivalence is above a threshold, we observe that increasing ambivalence accelerates organizational ambidexterity even more for firms with high technological capability," Dr. Bao says.

"This is because when CEOs clearly recognize and embrace the joint presence of threats and opportunities, they tend to detect creative, unusual linkages between the distinct aspects of a crisis situation," he says. "As a result, they can consider novel applications of technological capability in unexpected ways to cope with a crisis and preserve a firm's core business." ■

EPA FUNDS RESEARCH ON NOVEL GLASS FIBER DRINKING WATER MONITOR NETWORK

▲ The research is a collaboration between Dr. Tingting Wu (left) from the Department of Civil and Environmental Engineering and Dr. Lingze Duan (right) from the Department of Physics and Astronomy.

A novel sensor network using glass fibers to safeguard drinking water supplies is being developed under a U.S. Environmental Protection Agency (EPA) grant in a cross-campus collaboration.

The grant is through the EPA's P3 Awards: A National Student Design Competition Focusing on People, Prosperity and the Planet.

Led by Dr. Tingting Wu, an associate professor in the Department of Civil and Environmental Engineering, and Dr. Lingze Duan, a professor in the Department of Physics and Astronomy, the research team will include students and will utilize glass fibers to develop a novel sensor network with distributed fiber probes and a centralized interrogation, detection and data processing system for real-time water quality monitoring.

"Turbidity is caused by the existence of suspended particles, organic matter and chemicals, and is widely measured in natural resources, irrigation water, the food and beverage industry, and drinking water," says Dr. Wu. "As an important water quality parameter, turbidity not only indicates the efficiency of some treatment processes but also reflects water quality changes in the distribution systems."

Increased turbidity has been correlated with contamination with *Giardia* and *Cryptosporidium* and it is used as a surrogate measure for risk of contamination by those pathogens. Studies also revealed a strong temporal relationship between turbidity and gastrointestinal events during and preceding the major waterborne disease outbreak in Milwaukee in 1993.

Glass fibers have advantages over plastic in water monitoring, says Dr. Lingze Duan.

"All these findings emphasize the importance and necessity of turbidity monitoring in a contamination warning system," she says.

Current turbidity measuring systems are lab-based or are bulky and expensive. The high costs and limited timeframe for measurements can prohibit their application in drinking water distribution systems. A limited lifetime and high maintenance are also prohibitive.

"On the other hand, fiber optical turbidity sensors possess some important advantages such as low cost, compactness, great flexibility, high stability over a wide temperature range, immunity to electromagnetic interference, water and corrosion resistance, and compatibility with multi-sensor schemes," says Dr. Wu.

Using glass fibers rather than the commonly used plastic fibers also provides system advantages, researchers think.

"Glass fibers have much lower loss than plastic fibers, permitting long-distance light delivery and enabling true distributed networks," Dr. Duan says. "They are also more compact and corrosion-resistant than plastic fibers."

In Phase 1, the team is focusing on developing and evaluating the glass fiber-based optical system under drinking water relevant conditions. Later, it will build the architecture of the hub-spoke monitoring system from scratch.

"In a hub-spoke sensing network, a large number of sensor stations are linked together via a small group of central hubs, much like the nation's airline system, where a handful of large airports connect flights from hundreds of smaller cities," Dr. Duan says.

The advantage of the network topology is its efficiency in lowering the cost of interrogation-detection systems, as many sensor stations can share the service of one central hub.

Since a single interrogation-detection system can support a large number of sensors, the investigators note that it's economically feasible to develop more complicated multi-function interrogation-detection systems, allowing future multi-parametric sensor networks. ■

NASA AWARDS EXCEPTIONAL PUBLIC SERVICE MEDAL TO ESSC'S **SUE ESTES**

NASA has awarded its Exceptional Public Service Medal to Sue Estes, a research scientist at the Earth System Science Center (ESSC) at the University of Alabama in Huntsville (UAH), a part of the University of Alabama System, who also has a role at NASA.

For NASA, Estes serves as senior associate program manager for Health and Air Quality Applications in the Applied Sciences Program of the NASA Earth Science Division. The program promotes the use of Earth observations in air quality management and public health, particularly involving environmental health and infectious diseases. Estes performs duties that include education, outreach and general management of public health projects within the Applied Sciences Program.

With over 30 years of experience working in public health as a hospital and nursing home administrator, Estes has been involved with UAH and NASA in research utilizing public health data with remotely sensed data and analyzing the health impacts of the environment. Her current research focuses on establishing partnerships between NASA environmental researchers and public health professionals in academia, federal, state and local government.

"I am humbled by this award. It was a great honor and had no idea I had been nominated," Estes says. "This is the greatest honor I have received in my career and I know it is a very prestigious award."

She works in the National Space Science Technology Center at UAH's Robert "Bud" Cramer Research Hall.

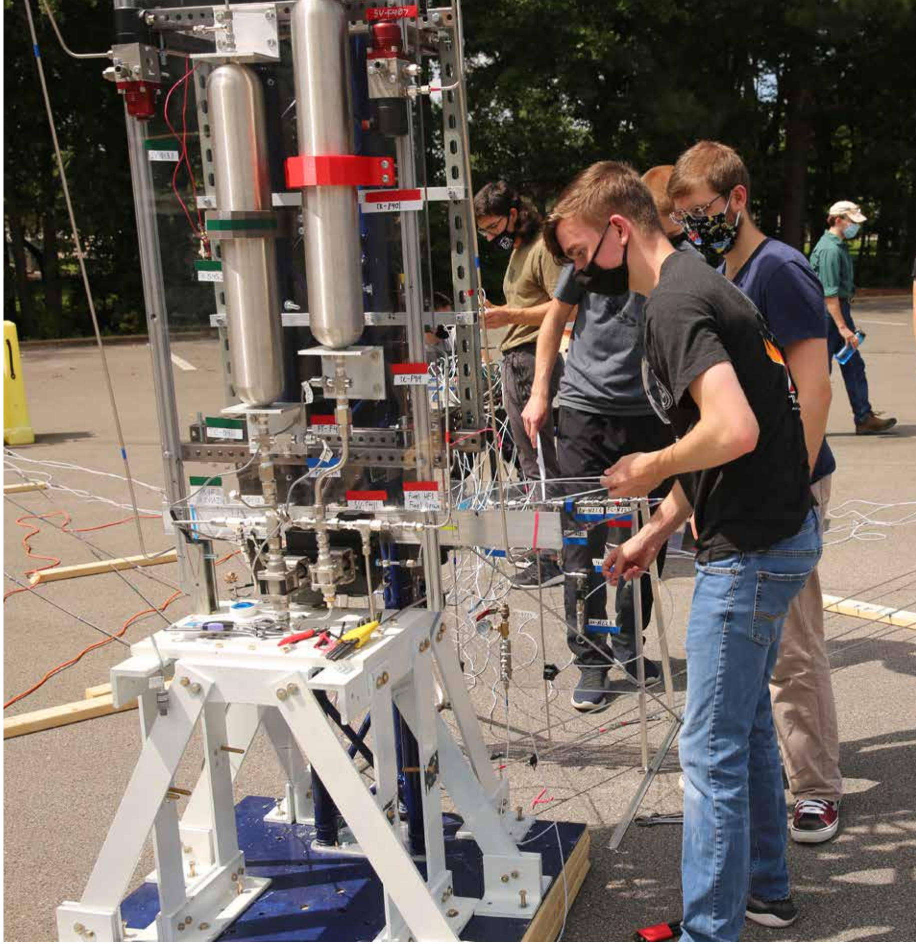
"Working for UAH has provided me the opportunity to use my health background as well as using the background that I obtained while at UAH in remote sensing, satellite data and Earth observations," Estes says. "UAH ESSC is very much involved in the public health and air quality applications at NASA and this position has given me the opportunity to work with colleagues at UAH on projects. This is a great collaboration for NASA and UAH and shows the flexibility that working at UAH has offered me."

NASA's Exceptional Public Service Medal is a United States government medal awarded to any non-government individual or to an individual who was not a government employee during the period in which the service was performed for sustained performance that embodies multiple contributions on NASA projects, programs, or initiatives.

The criteria for the award must include all of the following:

- Sustained performance has made a significant improvement to NASA deliverables, operations, or image;
- Employee's record of achievements sets a benchmark for other non-government contributors to follow; substantial improvement to a NASA program that yielded high quality results or improvements;
- Impact and importance of the employee's services have made a lasting impact on the success of the agency.

Estes was nominated for the award by NASA's Science Mission Directorate. ■



'AMAZING PROGRESS'

PANDEMIC SETBACKS HAVEN'T DIMINISHED RESOLVE OF SHC'S TARTARUS ROCKET TEAM

Team Tartarus is making "amazing progress" toward flying its ambitious liquid-fueled rocket despite setbacks imposed by the COVID pandemic, says Project Manager Spencer Christian, a sophomore in aerospace engineering from Nixa, Mo.

In March, the UAH Space Hardware Club (SHC) team was working toward high pressure inert integration testing of its ground system, where the test stand that will hold and supply Tartarus' engine during its own testing was to be pressurized to 800 psi using inert nitrogen – 10 times the pressure it would see in normal operation.

"During the high-pressure test there are a lot of things that can go wrong, but if we can pull through and ensure the system functions as intended under these pressures, we will have passed our biggest obstacle," Christian says.

That testing is crucial to a later hot fire test of the engine itself, now scheduled for fall of 2021.

"With or without COVID-19 interference, I have absolute confidence that we will finally be able to fire our engine in 2021," he says.

COVID restrictions kept the team from meeting in January and pandemic considerations cancelled two test days in February, but team members are resolute.

"So far, 2021 promises to be a huge year for the team, and everyone is very optimistic about our chances at the ever-postponed hot fire test," Christian says. "We have been connecting with alumni, learning and reaching goals more than ever before, and we don't plan to slow down."

Data acquisition and analysis work was focused on what the measurements from 24 instruments will mean in terms of engine design.

"For example, if the chamber pressure is far lower than anticipated, we want to be able to know exactly what might cause that problem," Christian says. "If we succeed in this area, we will be able to make our engine into a real powerhouse."

He reports that the team is becoming increasingly robust and motivated.

"We plan to expand our research horizons and write papers about the findings of our engine research," Christian says. "This year, no matter what gets thrown at the team, we are still making incredible progress."

The project marks the first time SHC has attempted to engineer, construct and fire a liquid-fueled engine. A bedrock goal has been to fly its liquid bipropellant rocket up to 30,000 feet for the annual Spaceport America Cup in New Mexico. Equally important is that team members learn about the theory that drives the design of the rocket.

"Tartarus encourages all of its team members to learn about the science behind what we're doing, and we have

◂ Members of the UAH Space Hardware Club work on Tartarus' engine test stand in the parking lot of Olin B. King Technology Hall.

developed much more collective knowledge because of that," says Christian. "This knowledge further fuels people's interest in liquid rocketry, and many team members have secured internships or even full-time jobs at rocketry companies in part due to their time on Tartarus."

Testing is on a rural property in Tennessee owned by Dr. Richard Tantaris, a lecturer in the Department of Mechanical and Aerospace Engineering (MAE) who along with Dr. Gang Wang, an associate MAE professor, advises SHC.

Others involved in project support are Dr. David Lineberry, (MS, Mechanical Engineering, 2003; Ph.D., Mechanical Engineering, 2007; Propulsion Research Center Graduate) a Propulsion Research Center research engineer; Scott Claflin, director of power innovations at Aerojet Rocketdyne; and former SHC members and UAH graduates McKynzie Perry (BS, Aerospace Engineering, 2020), a propulsion engineer at NASA's Marshall Space Flight Center; Aaron Hunt (BS, Aerospace Engineering, 2020), an aerospace engineer at Dynetics; Michael Angeles (BS, Aerospace Engineering, 2020), an engineer at QTEC Aerospace; Dalton Hicks, a test facilities engineer at Blue Origin; Daniel Corey (BS, Mechanical Engineering, 2019; Propulsion Research Center Graduate), a test engineer at Blue Origin; and a Corgi dog, Gemini Perry, called by Christian "a local canine space enthusiast."

Since its start in 2017, the from-scratch nature of the project has presented SHC teams with numerous deep challenges, since there was no prior experience with the new and difficult challenges presented by liquid-fueled engines.

"Our team members signed up knowing how difficult this project would be," Christian says, "and everyone is always ready and excited to face these challenges."

Besides Christian, the Tartarus team members are:

- Noah Adams, sophomore, aerospace engineering, Birmingham, Ala.
- Michael Broome: graduate student, MBA–business analytics, Washington, D.C.
- Sawyer Bryson, junior, aerospace engineering, Gadsden, Ala.
- Manav Dave, sophomore, aerospace engineering, Herrin, Ill.
- Jacob Dodd: freshman, aerospace engineering, Hartselle, Ala.
- Garett Ellis, sophomore, aerospace engineering, Bakersfield, Calif.
- Alexandra Fedrigo, freshman, aerospace engineering/mathematics, Grand Rapids, Mich.
- Alexander Jones, freshman, aerospace engineering, Oneida, Tenn.
- Jacob Jones, sophomore, aerospace engineering, Owensboro, Ky.
- Jackson Miles, sophomore, aerospace engineering, Wausau, Wis.
- Luke Orwick, junior, aerospace engineering, Lexington, Ky.
- Elias Perez, freshman, aerospace engineering, Bakersfield, Calif.
- Sean Rabbitte: sophomore, aerospace engineering, Chicago, Ill.
- Spencer Rubottom, junior, aerospace engineering, Waxhaw, N.C.
- Ben Schartung: sophomore, aerospace engineering, Owensboro, Ky.
- Kenton Supplee, sophomore, mechanical engineering, Sevierville, Tenn.
- Christian Suray: senior, aerospace engineering, Franklin, Tenn.
- David Tutunzhiu, senior, aerospace engineering, Raleigh, N.C. ■

TEAM FALCON TAKES THIRD IN COLLEGIATE NASA HUMAN EXPLORATION ROVER CHALLENGE

UAH's Team Falcon, one of two rover teams competing from the university, won third place overall in the collegiate division at NASA's Human Exploration Rover Challenge (HERC).

Team Falcon relied on light weight and simplicity when it redesigned a rover from a previous class for the pandemic altered competition. The rover weighed in under 150 pounds, extremely light compared to other rovers in the UAH fleet.

"We based the design concepts on pure simplicity. This is different from most of the other UAH teams because we have no major suspension components, a single speed, independent drivetrain and an extremely lightweight frame," says Falcon Team Lead John Baggett, a senior in mechanical engineering from Clarksville, Tenn.

HERC judging was virtual this year and the in-person moon obstacle event at the U.S. Space & Rocket Center was cancelled. In January, MAE 490/1-05 Senior Design Moon Buggy class teams Falcon and Twisted Metal presented a design review to a NASA panel consisting of subject matter experts. The teams then presented an operational readiness review to the same NASA panel in March. The competition also included video presentations.

David Fikes, a mechanical and aerospace engineering lecturer who teaches the class, praised both teams.

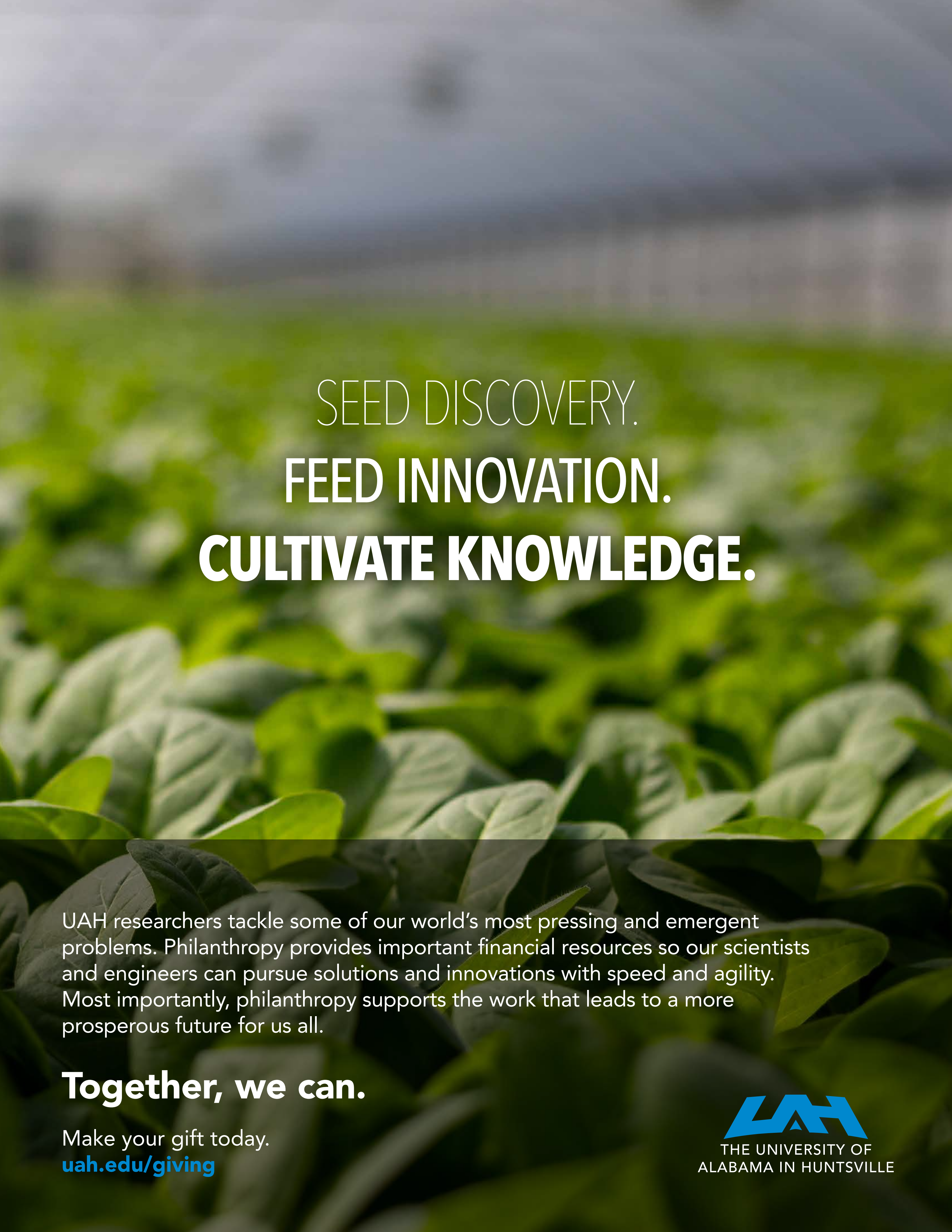
"The students were willing to put in the time that it took to do the extra things that are required to successfully build a rover," Fikes says. "They met a lot on weekends to get the work done. The pandemic didn't seem to slow them down that much. Some put in many, many extra hours to complete their project."

For more than 25 years, the annual NASA HERC has tasked high school and college teams from around the world to design, build and test a human-powered rover capable of traversing simulated terrain from the moon, Mars and other rocky planets. Along the way, teams are also required to complete scientific tasks, reflecting spacewalks that were completed during NASA's Apollo Program and may be completed during NASA's Artemis Program.

HERC is managed by the Office of STEM Engagement at NASA's Marshall Space Flight Center in Huntsville. The competition reflects the goals of the Artemis program, which seeks to put the first woman and first person of color on the moon. NASA's Office of STEM Engagement uses competitions to further the agency's goal of encouraging students to pursue degrees and careers in the science, technology, engineering and mathematics fields.

Besides Baggett, Falcon team members are:

- Susan Duron, rider and practice course lead, senior, mechanical engineering, Fairview, Tenn.
- Maggie Fielder, social media lead, senior, mechanical engineering, Kennesaw, Ga.
- Julia Fullinwider, team financial lead, senior, mechanical engineering, Huntsville, Ala.
- Lindsey Kaesemeyer, task design and integration lead, senior, mechanical engineering, Lebanon, Ohio
- Robert Lewallyn, rider and design team, senior, mechanical engineering, Dunwoody, Ga.
- Haley Schumann, financial team and backup rider, senior, mechanical engineering, Hazel Green, Ala.
- Luke Smith, financial and design team, senior, mechanical engineering, Raleigh, N.C. ■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