

FOCUS

The UAH Research Magazine // Spring 2022



GOING UP

UAH powers into an elite group of national research universities

page 8

HOT SHOT

'Bubble-through' nuclear engine could be a ticket to deep space

page 10

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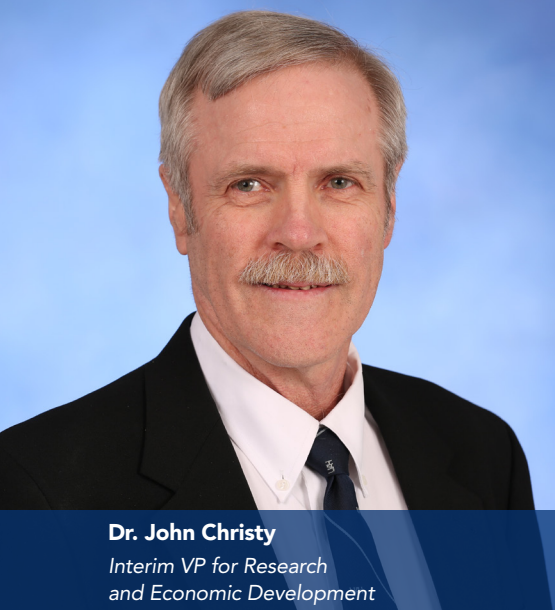
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Dr. John Christy

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UAH moving forward with research successes and leadership

It's said that success perpetuates itself, and the past year at UAH has been replete with research examples.

Back in 1987, Dr. Gary Maddux and James Clark were two entry-level UAH computer programming employees trying to solve some technical issues for the U.S. Army at Redstone Arsenal. Since then, their efforts have grown into the Systems Management and Production Center, UAH's largest organizational center and largest student employer. We trace their pathway of success in our cover story on page 4.

Early 2022 also brought recognition of UAH's research successes. Six of the university's programs were ranked by the National Science Foundation (NSF) in the top 25 nationally for federal funding. In addition, the university joined an elite group when it was ranked "R1 – Very high research activity" by the Carnegie Classification of Institutes of Higher Education, and UAH's three-year performance in attracting NSF Faculty Early Career Development Program (CAREER) awards ranks it among some well-known institutions nationally, according to a story on page 8.

With Dr. Dale Thomas as principal investigator, UAH is leading a national group of collaborators in cutting-edge research to explore the promise of a

centrifugal "bubble-through" liquid nuclear thermal propulsion engine that could become an eventual NASA workhorse for deep space missions, a story on page 10 says.

Successes involving significant UAH research and development for the James Webb Space Telescope and the Parker Solar Probe paved the way for the university to play science leadership roles in two coming NASA missions. A story on page 12 explains that Dr. Gary Zank, director of the Center for Space Plasma and Aeronomic Research and the Aerojet Rocketdyne chair of the Department of Space Science, will be the science lead for IMAP, set to launch in 2025, and HelioSwarm, set to launch in 2026.

Meanwhile, Dr. Tathagata Mukherjee is part of a three-university collaboration to develop a cell phone forensics device that uses artificial intelligence to seek evidence on phones volunteered to law enforcement by witnesses after mass crimes like shootings or bombings, according to our story on page 14.

A physics team led by Dr. Ming Sun has pioneered research quantifying galactic gas tail mixing, and an image the team produced appears on the cover of the journal that published its research. Find out more on page 15.

Dr. Rogelio (Roger) Cruz-Vera has identified for the first time the precise genetic operational structure of a key

system in *Escherichia coli* bacteria. That's led to a new structure to design sensors of molecules of interest and could lead to new antibiotic therapies to treat *E. coli*, says a story on page 16.

In NSF CAREER award successes, Dr. Biswajit Ray is researching how to make computer solid state drives more resilient, durable and energy-efficient (page 18) and Dr. Haihong Che is exploring how solar flares explosively release magnetic energy and create energetic particles (page 20).

Congratulations go to Gloria Greene, assistant vice president for contracts and grants in the UAH Office of Sponsored Programs, on becoming the president-elect of the Society of Research Administrators International, as described in the story on page 21.

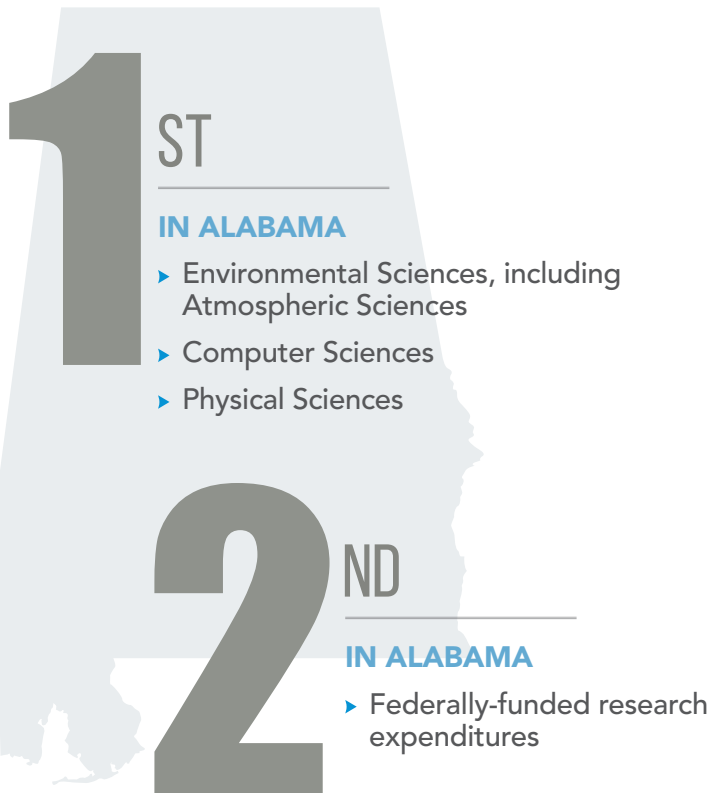
Students are integral to our research efforts and UAH's Space Hardware Club has designed and built a rover for potential use on Mars that will compete this summer at the University Rover Challenge in Utah. A story about the two-year effort is on page 22.

We are proud of the accomplishments of our faculty, staff, students and alumni and 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



/ NATIONALLY

- 6TH** Federally-financed Aerospace/Aeronautical/Astronautical research
- 9TH** Federally-financed Computer and Information Sciences research
- 10TH** Federally-financed Atmospheric Science and Meteorology research
- 12TH** NASA-funded research
- 13TH** Federally-financed Astronomy and Astrophysics research
- 18TH** Federally-financed Industrial and Manufacturing Engineering research
- 19TH** Department of Defense-funded research
- 22TH** Federally-financed Economics research

SOURCE: National Science Foundation

/ RESEARCH

\$489 million

Five-year contract and grant research total

\$5.9 million

Ten-year license and royalty revenue total

\$149.8 million

Fiscal 2021 research expenditure total

133

Issued patent total

COVER

- 4 CAN-DO**
SMAP has grown into the university's largest center organizationally

RESEARCH FOCUS

- 8 RESEARCH ELITE**
Rankings and CAREER award success place UAH among the best
- 10 TINY BUBBLES**
UAH leads investigation of liquid nuclear thermal propulsion engine
- 12 BEYOND THE SKY**
Dr. Gary Zank is the science lead for two future NASA missions
- 14 CRIME STOPPER**
AI cellular forensics tool will aid law enforcement in mass events
- 15 HAPPY TRAILS**
Physics team pioneers quantify galactic gas contrail mixing
- 16 STICKY SITUATION**
Genetics behind how E. coli attaches may lead to new therapies

FACULTY & STAFF FOCUS

- 18 MEMORY MANAGEMENT**
Dr. Biswajit Ray's CAREER award funds solid state drive improvements
- 20 ENERGETIC PARTICLES**
Dr. Haihong Che explores solar flare magnetism with CAREER award
- 21 NEW LEADERSHIP**
Gloria Greene is president-elect of SRAI organization

STUDENT FOCUS

- 22 RED ROVER**
Space Hardware Club team's Martian rover will compete in Utah finals

- Cover: Systems Management and Production Center Director Dr. Gary Maddux, left, and Associate Director James Clark have built the center into the largest organizationally, and in student employment, at UAH.

WHEN EVERYBODY WINS

Can-do SMAP Center was built
**'ONE TASK AND ONE
EMPLOYEE AT A TIME'**

What began with two new UAH Research Institute employees trying to serve a couple of specific needs for the Army has evolved over 36 years into the Systems Management and Production (SMAP) Center, the largest organizational center and the largest student employer at the university.

Directed by Dr. Gary Maddux (Ph.D., Industrial and Systems Engineering, 1999), SMAP is an example of what adhering to a win-win paradigm can produce over time.

"What we do with potential clients is, we sit down with them and say, 'What do you need done, and how can we help you to do that?'" says Dr. Maddux. "We don't tell them what to do; we ask them what they need."

When SMAP meets those needs, everybody wins.

Today, SMAP has 300 employees, 100 of whom are students, and offers Science, Technology, Engineering, Arts and Math (STEAM) students from UAH and other universities opportunities to work part-time for SMAP clients like the U.S. Army Space and Missile Defense Command, the U.S. Army Combat Capabilities Development Command Aviation & Missile Center, or other entities located on Huntsville's Redstone Arsenal.

"Almost any tenant out there on Redstone, we have worked for," says Dr. Maddux.

By employing SMAP students, the Army gains a pre-screened, teachable, part-time workforce with full time potential after graduation. The students

gain a foothold in the employment door that includes mentorship, real-world experience, connections and a potential career path after graduation.

The combination has proven so successful that, since its formal 2002 creation as a center by the University of Alabama System Board of Trustees, SMAP has brought \$100 million in indirect returns to UAH.

"Indirect returns means that you've covered the direct cost of labor, travel and materials, and indirect is what comes back to the university," Dr. Maddux says. "Nobody else has come close to matching that."

SMAP's student employees are not limited to UAH. Students from universities as far away as Texas and Colorado are working with the Army through SMAP.

It all started back in 1987, when Dr. Maddux and the man he calls his "principal associate director," James Clark, started as entry-level UAH computer programming employees.

"When we were hired, we were the first two non-engineering, non-science employees on the UAH Research Institute's payroll," says Dr. Maddux, a first-generation college graduate who grew up in Jackson County.

The university even had to create a new employment category for the pair.

"We were just a couple of overachiever guys, and nobody gave us much of a chance of doing very much," he says. "Now, 36 years later, we are the largest research center."

Clark's first Army contract task was in networking.

"He was asked by an Army employee to network two computers to a single printer," Dr. Maddux says. "That grew over the years into an Aviation & Missile Center relationship that now includes over 11,000 users there that we provide services to."

For Dr. Maddux, the first Army contract involved developing a reliable paperless supply system.

"From there, we just kept adding students and employees and tasks," he says.

"So, we grew to be as big as we are one task and one employee at a time. It took us 36 years to get here. You don't just anoint yourself as being excellent in something, you have to grow into it."

The pair quickly spotted the advantages for all concerned of employing university students who were studying in the STEAM fields as part-time SMAP workers, and that eventually evolved into the Students Working for the Army in Parallel (SWAP) program, through which student workers are contracted to the Army.

"We hire just about any version of students in fields including engineering, finance, logistics, accounting, management, information technology, even psychology and political science," says Dr. Maddux.

One result of getting a couple of business students to run a center is that it then runs like a business, Dr. Maddux says. "Ninety percent of what I do is accounting. I count everything."

That's how he knows that since 2004, the SWAP program has had 290 students hired as civil servants by the Army. Defense contractors hired another 391, and 47 are employed by other government agencies.

"Seventy-four percent of students we hired ended up in defense, for a contractor or as a civil servant," Dr. Maddux says. "So, every time I hire four students, three of them have a career out of it."

"You don't just anoint yourself as being excellent in something, you have to grow into it."

Students benefit by working with SMAP in a variety of ways.

"If you're working with us, you're working in your field, and it's going to make you a better student because you are applying your classroom learning to a real-world situation, and that keeps you more interested. Your experience informs your education," Dr. Maddux says.

"The second thing is, a student working with us is going to have a security clearance," he says. "On your

resume, you are going to be able to list real-world experience. You're also going to know people, people you have met as a result of your work experience."

Part-time SMAP student employees also have the benefit of being eligible to be promoted by the center to full time once they graduate. Once they become full time, they are eligible for UAH's tuition assistance as they pursue master's and even doctorate degrees.

SMAP's full-time employees work for clients on a variety of projects including 3D printing, CubeSat technologies and an increasingly recognized capability in visualization.

Once a student is hired away, Dr. Maddux follows them in their careers. Over time, that practice has built up a large contingent of former SMAP employees who are now in decision-making roles.

"We have an infrastructure of former SMAP students and so we are recognized as an entity that is a great civil service recruiting arm for the Army," he says.

A portion of the center's indirect returns go into a discretionary fund, and some of that is used for outreach projects across north Alabama and the state.

For example, during the COVID-19 pandemic every county in north Alabama benefited when, under a program through the UAH Foundation, SMAP's internal "bullpen" of student employees who are not yet working for clients 3D printed personal protective gear for healthcare facilities.



▲ A SMAP Center-produced face shield in use at Highland Medical Center in Scottsboro.

The center has worked with Jackson County Schools on enhancing security systems to keep students safer. And SMAP student employees have been involved in STEAM outreach to primary and secondary schools, assisting in the development of the next generation of students.

"It's grooming our students to work on real projects with real outcomes and to make a difference," Dr. Maddux says.

A recent STEAM project aligned SMAP with Bullock County in Alabama's Black Belt. SMAP student employees helped convert an old school bus into a portable greenhouse, complete with solar panel power. The home of Bonnie Plants Inc. and a site location for solar farms, Bullock County's students are learning about STEAM in ways that directly impact their locale, Dr. Maddux says.

"This keeps the kids interested, and they can learn about agriculture, solar and green energy, all from this one bus that can travel to the schools in Bullock County," he says. "I want to address what is relevant to their own county. I want them to develop into the best they can be, whatever they want to be."

The goal is to expand STEAM outreach into other Black Belt counties and eventually develop a network of shared projects between them.

Looking back over 36 years of evolution of the SMAP Center, Dr. Maddux says its future relies on the win-win framework of values that he and James Clark laid down as they took on their first contracts in the late '80s and early '90s.

"The best talent James and I have is recognizing talent in others and promoting it," he says. "If you hire based on the intangibles, on talents, and then put people into a different system that is oriented toward their success, then things usually work out well. You have to treat your employees well and set them up for success." ■

UAH IN AN ELITE GROUP OF NATIONAL RESEARCH UNIVERSITIES

Six university programs are among the top 25 in federal funding.

In the latest National Science Foundation (NSF) Higher Education Research and Development (HERD) Survey, six UAH programs were ranked among the top 25 federally-funded programs in the United States. The survey covers fiscal year 2020 and ranks UAH overall:

- **#6** in federally-financed aerospace/aeronautical/astronautical engineering research expenditures;
- **#9** in federally-financed computer and information sciences research expenditures;
- **#10** in federally-financed atmospheric science and meteorology research expenditures;
- **#13** in federally-financed astronomy and astrophysics research expenditures;
- **#18** in federally-financed industrial and manufacturing engineering research expenditures;
- **#22** in federally-financed economics research expenditures.

◀ A powerful laser beam is generated in the Physics Department's Optical Turbulence Lab, where laser light propagates a total distance of 150 meters indoors for research conducted by Dr. Don Gregory, distinguished professor of physics.

The recent Carnegie Classification of Institutes of Higher Education ranked UAH as “R1 – Very high research activity” status among doctoral-granting universities.

The university ranks 12th in NASA-funded research expenditures and 19th in Department of Defense-funded research expenditures.

The recent Carnegie Classification of Institutes of Higher Education ranked UAH as “R1 – Very high research activity” status among doctoral-granting universities. The R1 ranking places UAH, which was launched from America’s quest to conquer space, in an elite group of doctoral-granting universities nationally that apply the most resources and scientists to research at their institutions. The rankings are announced every three years.

Plus, from 2019 to 2021, seven coveted NSF Faculty Early Career Development Program (CAREER) awards were won by faculty at UAH, a number that puts the university in an elite group of very high research universities nationally, according to its Office for Proposal Development (OPD).

Among R1 ranked universities, UAH’s CAREER awards in the last three years were equal to or greater than those achieved by many leading R1 research institutions, including the California Institute of Technology, Dartmouth College, Emory University, Georgetown University, Harvard University, Miami University, Tufts University, Vanderbilt University and Yale University.

“UAH is producing advanced research and leadership in research that ranks among our nation’s best,” says Dr. Chuck Karr, interim UAH president.

“The HERD rankings and the R1 designation are strong indications that UAH’s research enterprises are among the best in the United States,” says Dr. Karr. “The CAREER awards show one primary indicator of the university’s research density, and there are many more

talented and dedicated researchers who are successful in other NSF awards and in securing funding from many sources, including state, local, federal and foundations.”

The high level of achievement is because of the confidence and support of UAH’s Huntsville partners in government and industry, the support of state and federal delegations and the outstanding work of UAH’s research centers, faculty, students and administration, says Dr. Karr.

“Recruiting and developing talented faculty members who can receive such outstanding recognition is critical to our continued success as a major research university,” he says.

UAH’s investigators conduct research in engineering, the sciences, business, nursing, education, the arts, humanities and social sciences, and the university has robust capabilities in fields such as astrophysics, cybersecurity, data analytics, logistics and supply chain management, optical systems and engineering, reliability and failure analysis, rotorcraft and unmanned systems, severe weather, space propulsion and more.

UAH is home to 17 centers and institutes dedicated to research. The university supplies a highly-educated workforce to the State of Alabama, with 72% of its alumni residing in-state.

“Being rated at the highest level of research activity attracts the brightest and most curious minds, both in our students and our researchers, to become part of our team,” says Dr. John Christy, interim vice president for research and economic development. “It alerts those who need new knowledge and discoveries that we have the expertise to provide answers.” ■

FIZZ FORWARD

**'BUBBLE-THROUGH' NUCLEAR ENGINE
COULD BE A FUTURE NASA WORKHORSE**

▲ Mitchell Schroll, a graduate research assistant and doctoral student in aerospace systems engineering, watches as air bubbles rise in a water column inside the Ant Farm static test apparatus at UAH's Johnson Research Center.

A cutting-edge nuclear thermal propulsion (NTP) rocket engine using what's called centrifugal liquid fuel bubble-through could one day be a ticket for NASA to go directly into deep space.

Under an NTP research contract for the Space Nuclear Propulsion Project Office at NASA's Marshall Space Flight Center (MSFC), UAH is leading a collaboration of universities across the nation including the University of Rhode Island (URI), Drexel University, the Massachusetts Institute of Technology (MIT), Pennsylvania State University and the University of Michigan (U-M) to research the concept.

NASA has made substantial advances toward a solid fuel NTP design. The bubble-through concept under study by the university collaborators is one of three proposed hydrogen-based designs for a next generation liquid fuel NTP rocket.

The bubble-through centrifugal NTP concept heats hydrogen gas propellant to super-hot temperatures, but there is no combustion. Hydrogen is literally bubbled through a rotating liquid uranium core in the engine via a porous cylinder wall, causing the gas to rapidly expand. As it exits the nozzle, the expanding hydrogen provides thrust for the spacecraft.

The design's advantages include significantly higher performance over conventional liquid fuel rocket engines that combust hydrogen and oxygen, says Dr. Dale Thomas (B.S., Industrial and Systems Engineering, 1981; Ph.D., Industrial and Systems Engineering/Physics, 1988), the project's principal investigator and an eminent scholar in systems engineering at UAH.

"In conventional liquid fuel engine combustion, the resulting propellant

molecules – H_2O in the case of hydrogen and oxygen – are much heavier due to those relatively heavy oxygen atoms, and they will not exit the nozzle as fast, providing more thrust but less impulse,” Dr. Thomas says.

Thrust is the force supplied by the engine, for example to lift a spacecraft away from Earth’s gravity. Impulse is the change in momentum per unit of fuel, and that matters when it comes to getting a spacecraft where it’s going in space.

“Think of your car,” Dr. Thomas says. “Think of thrust as torque and impulse as miles per gallon (mpg). Both matter, just like both torque and mpg matter in your car.”

Hotter, relatively lightweight hydrogen atoms will make the ship go farther.

“If we get the propellant hotter, it has more energy and will exit the nozzle faster, which provides more impulse,” Dr. Thomas says. “Since this is a higher performing engine, it has the potential to power spacecraft on trajectories other than the minimum energy trajectories, providing options for higher energy trajectories that will shorten the trip time to and from Mars and other destinations throughout the solar system.”

Conceptually intriguing, the bubble-through engine presents a number of technical challenges, not the least of which is developing a material for its porous cylinder wall that can withstand direct contact with the molten uranium fuel.

“We’re in the very early stages on this,” Dr. Thomas says.

“This bubble-through concept has been around since the ‘60s,” he says. “The physics are well understood, but the engineering challenges have precluded getting this concept off the drawing board in the past. We’re attempting to see whether today’s technologies will let us develop a viable liquid fuel NTP engine prototype.”

The UAH work focuses in three areas, he says.

“The first part is liquid uranium and gaseous hydrogen thermodynamic heat transfer modeling and analysis. Second, we’ll be doing modeling and analysis of geometry and trajectory of gaseous hydrogen bubbles in a liquid uranium medium, and third, we’ll perform experimentation to confirm the analytical predictions of dynamic and thermodynamic models.”

Besides Dr. Thomas, who is in charge of modeling missions, faculty involved in the research from UAH are Dr. Keith Hollingsworth, professor and department chair of mechanical and aerospace engineering, in charge of thermodynamics; Dr. Robert Frederick, professor of mechanical and aerospace engineering and director of the Propulsion Research Center, overseeing experimentation; and Dr. Jason Cassibry, associate professor of mechanical and aerospace engineering, in charge of bubble dynamics.

Aerospace systems graduate research assistants involved are Mitchell Schroll, a doctoral candidate; Pongkrit Darakorn na Ayuthy (a.k.a. Boom), a doctoral candidate; Ben Campbell, a master’s student; Jacob Keese, a master’s student; and Will Ziehm, a master’s student.

At MSFC, the researchers are working with Dr. Michael Houts, nuclear research manager.

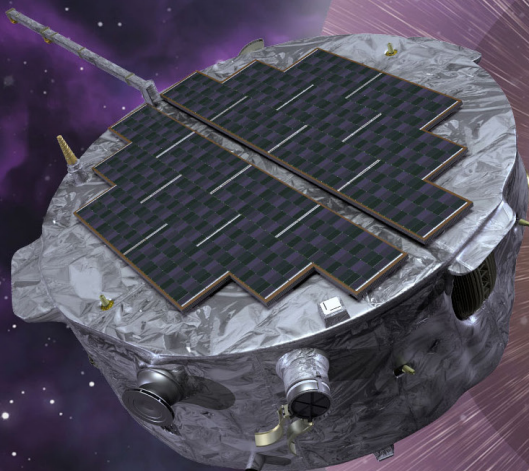
Partner URI is doing senior design projects on the drive systems for the engine’s centrifugal fuel elements, including how to spin them up to operating speed, keep them at the desired rotational speed and spin them down. Drexel is developing the material properties of the cylinder wall and MIT is studying bubble dynamics. At U-M, researchers will look experimentally into the physics of the reactor itself, which is called neutronics. Penn State is researching neutronics and heating.

At Johnson Research Center, UAH’s scientists are building experimental apparatus to confirm their analytical predictions of heat transfer and bubble dynamics. Two exist so far, called the Ant Farm and the Bubbling Liquid Experiment Navigating Driven Extreme Rotation, or BLENDER. The devices use air bubbles in water to simulate the bubbling of hydrogen through the engine’s core.

The centrifugal NTP engine could help enable direct trajectory travel, where a spacecraft flies directly to a destination. Current chemical propulsion systems must rely on proper planetary alignments to take advantage of gravity assists when flying by planets.

“Those planetary alignments only come around once every few years,” Dr. Thomas says. “With this liquid fuel NTP, you can perhaps even get to the Kuiper Belt on a direct trajectory.”

That would be quite a ride. The Kuiper Belt starts 4,400,000,000 km from the sun. ■



NASA's IMAP mission will investigate the acceleration of energetic particles and the interaction of the solar wind with the interstellar medium.

NASA

The sky is not the limit

UAH HAS CENTRAL SPACE SCIENCE ROLES IN TWO NASA MISSIONS

Fresh off successful direct involvement in NASA's James Webb Space Telescope (JWST) and Parker Solar Probe (PSP) in roles that included optics, hardware, software, testing analytics, computational modeling and big data processing and dissemination, UAH is looking beyond the sky again.

UAH investigators are gearing up for a major computational analytics role when NASA's \$492 million Interstellar Mapping and Acceleration Probe (IMAP) launches. That's scheduled for 2025 and likely will bring in more UAH personnel to work on the project. And the university will play a key science role in the new HelioSwarm, a \$250 million mission that will position a constellation of

spacecraft to study magnetic turbulence. It could launch in 2026.

UAH's Center for Applied Optics and its Center for Space Plasma and Aeronomic Research (CSPAR) were integral to JWST and PSP, respectively. Now CSPAR again takes the science center stage with IMAP and HelioSwarm. Dr. Gary Zank, CSPAR director and the Aerojet-Rocketdyne chair in the Department of Space Science, is a co-investigator and the science lead on both missions.

The fifth mission in NASA's Solar Terrestrial Probes program portfolio, IMAP will investigate two important issues in space physics, the acceleration of energetic particles and the interaction of the solar wind – the energetic bubble

driven by the sun in which humanity lives – with the interstellar medium, which is the material that fills the space between the stars.

Dr. Zank will focus on the science expectations and the data analysis, as well as its relation to current theory and simulations.

"I will be leading that part of the mission, aided by the UAH team, and this will involve extensive analysis of the new data and relating it to the current theories for particle acceleration, modulation and solar wind models, as well as its interaction with the interstellar medium," says Dr. Zank, who is also a University of Alabama System Board of Trustees trustee professor and a distinguished professor.

- ▶ Dr. Gary Zank is a co-investigator and the science lead for IMAP and HelioSwarm.



"IMAP's instrumentation offers a major leap forward in studying how cosmic rays are modulated by the heliosphere and accelerated throughout the heliosphere, and in our understanding of how solar energetic particles are accelerated by both shock waves driven by coronal mass ejections from the sun and by solar flares on the sun," Dr. Zank says.

"It will also offer unprecedented capabilities for discovering the physics of energetic particles called pickup ions that originate from the interstellar medium but can be found in the solar wind," he says.

IMAP will also be able to measure neutral particles originating from interstellar space, providing new insights into how the solar wind interacts with its galactic neighborhood.

"We expect to develop a much better understanding of how some particles gain their fantastic energies, with

speeds very close to the speed of light; how this affects the physics of the solar wind dynamically; and how the solar wind and interstellar medium interact, which is a highly complex and nonlinear interaction that represents one of the most challenging problems in both plasma physics and its application to the space environment," Dr. Zank says.

Beyond IMAP, the relatively new HelioSwarm mission will launch a large swarm of nine spacecraft, all traveling fairly closely in a random formation, to measure different regions of volume while being separated in both space and time.

"It is a new NASA mission that will make revolutionary advances in our understanding of turbulence in the interplanetary and interstellar medium," Dr. Zank says.

Now that NASA has green-lighted it, through mid-2024 Dr. Zank says that the HelioSwarm mission will be involved

in instrument development and integration into the instrumentation suite, as well as designing the nodes and the hub spacecraft that will control everything and communicate with the spacecraft and the deep space network.

"Then there will be the final building and integrating," Dr. Zank says. "It will be a very busy time for the experimentalists and engineers."

After launch, HelioSwarm will reside in near-Earth orbit but it will be positioned outside the Earth's magnetosphere so it will be in the reasonably pristine solar wind.

"It will examine magnetic, velocity and density fluctuations in the solar wind," Dr. Zank says. "This has never been done before on this sort of scale, and will completely revolutionize our understanding of how turbulence moves energy around in space, as well as in phase space." ■

SOLVING MASS CRIMES

UAH HELPS CREATE NEW AI CELL PHONE FORENSICS TOOL FOR LAW ENFORCEMENT



▲ Dr. Tathagata Mukherjee says UAH is responsible for implementing the AI and machine learning algorithms for a new AI system for law enforcement cell phone forensics.

There can be lots of forensic evidence on many people's cell phones when a mass incident like a shooting or bombing happens, but winnowing out the relevant material and putting it in context can be a time-consuming and tedious affair for law enforcement.

That's why UAH, Florida State University (FSU) and Purdue University have teamed to develop an artificial intelligence (AI) tool to help law enforcement target, extract and collate cell phone evidence related to an incident. The research is funded by a two-year, \$600,000 grant from the National Institute of Justice (NIJ).

"So, for example, during the Boston Marathon bombing, several people witnessed the event and had taken videos, etc., on their phones," says Dr. Tathagata Mukherjee, an assistant professor in the UAH Department of Computer Science.

"Law enforcement was given access to this data but had to manually sift through it and create the context for what had happened," he says. "Here, we want to use AI to do exactly that to help law enforcement with the investigation."

The targeted forensics tool under development will not be used in any way for tracking people, Dr. Mukherjee emphasizes. Rather, it will be a tool for collecting evidence that is obtained from phones voluntarily provided to law enforcement by witnesses.

"This is pure forensics work. We had developed a targeted phone forensics application on a NIJ award back in 2016, and this work builds upon that and extends the application for multi-phone forensics targeted towards mass incidents like terrorist attacks or mass shootings."

That 2016 work is under test by NIJ. It was developed with input from the Florida Department of Law Enforcement, and researchers hope to involve law enforcement in development of the new system, as well.

It's expected that the new work will also lead to patents. UAH will be responsible for implementing the AI and machine learning algorithms for the endeavor, FSU for the forensics and Purdue for the forensics and systems portion.

"The assumption is that the witnesses to an incident have evidence in their phones and this evidence needs to be extracted and correlated with data from other phones owned by other witnesses," Dr. Mukherjee says.

"Moreover, only evidence related to the incident needs to be extracted, hence it is targeted," he says. "Naturally, AI needs to be involved in order to implement the targeted aspect of this work and we need to build the whole system for acquiring data from multiple phones and correlating it for creation of the context for the event under consideration." ■

GALACTIC CONTRAILS

PIONEERING ASTROPHYSICS RESEARCH QUANTIFIES GAS TAIL MIXING

▲ The processes by which galactic gas tails mix with the surrounding intracluster medium are poorly understood, says Dr. Ming Sun.

In work that is promising for future galactic modeling, an astrophysics team led by Dr. Ming Sun at UAH has quantified processes involved in gas mixing in the tails of galaxies being stripped of their gas envelopes.

The research is pioneering because the processes by which the gas tails mix with the surrounding intracluster medium are poorly understood, says Dr. Sun, an associate professor of physics and astronomy.

An image created by the UAH astrophysics team was featured on the cover of the February issue of the journal *Nature Astronomy*. The magazine also published a paper about the findings authored by Dr. Sun, his UAH postdoctoral research team members Dr. Chong Ge and Dr. Rongxin Luo and other collaborators, and it mentions physics graduate student Sunil Laudari, who helped with the image. *Nature Astronomy* initially published the paper online in December.

Galaxies soar in clusters at high speeds of 1,000-2,000 kilometers per second (km/s). During their journey inside clusters, the drag force from the gas between galaxies in the cluster, called the intracluster medium, removes cold gas from galaxies. That process

leaves long trails of stripped gas behind them, somewhat similar to airplane contrails and comet tails.

"Those trails, initially composed of cold gas originated from galaxies, will mix with the hot intracluster medium to produce multi-phase gas with various temperatures," Dr. Sun says. "We all experience mixing of cold and hot gas and fluid in daily life, like when we pour cold milk into hot coffee, or cold air meeting warm air in our atmosphere."

The energy transfer and mixing in the multiphase medium is an outstanding question in astrophysics that is important to galaxy formation and evolution. Since Dr. Sun discovered the X-ray tail behind ESO 137-001 in 2005, the full story about these interactions has evolved as scientists began to get better and better data with new telescopes.

"Recent observations began to reveal such tails behind galaxies for gas at different phases or temperatures, in other words neutral atomic gas, molecular gas, ionized gas as shown in H-alpha – which is a specific deep-red visible spectral line – or hot gas in X-rays," he says. "However, the relationship between gas in different phases in the tails is poorly known."

The X-ray observations were made by NASA's Chandra X-ray telescope and the European Space Agency's XMM-Newton. Optical observations were made by the European Southern Observatory Very Large Telescope, the National Astronomical Observatory of Japan Subaru Telescope and the Southern Astrophysical Research telescope.

For the first time, the paper reports a simple linear correlation between the X-ray surface brightness and the H-alpha surface brightness of the diffuse gas, as a ratio of approximately 3.5, for a universal correlation between warm and hot gas in the stripped tails of cluster galaxies, says Dr. Sun.

"Moreover, a similar X-ray to H-alpha ratio is also observed in the only example of galactic winds – the outflows from galaxies that are important to regulate galaxy formation – suggesting this ratio may also apply in other multi-phase environments," he says. "This new correlation provides an important test for models of energy transfer in the multi-phase gas, again important for studies of galaxy formation and evolution."

Dr. Sun is working with theoreticians on modeling that uses the results of the research. ■

Unlocking *E. coli* genetics

Key system could open door to new drug therapies

Research led by UAH has identified for the first time the precise genetic operational structure of a key system in *Escherichia coli* (*E. coli*) bacteria, opening the door to possible new antibiotics to treat the infections it causes.

"The gene that we studied is involved in producing a bacterial hormone that is important for bacterial colonization. This hormone induces the production of sticky substances used by bacteria to adhere to inert surfaces, as well as plant and animal tissues," says Dr. Luis Rogelio (Roger) Cruz-Vera, an associate professor in the Department of Biological Sciences.

"Our new structure will be used in future studies to obtain compounds that can modulate the production of this hormone in bacteria, reducing bacterial colonization by altering the bacterial cell's capacity for attachment to surfaces and reducing communication with other cells."

Most infectious *E. coli* cases are mild and result in vomiting, diarrhea, cramps, and fatigue, but some strains can cause severe illness and even life-threatening complications.

In 2015, Dr. Cruz-Vera teamed with Dr. Emily Gordon and Dr. Arnab Sengupta, both of whom were doctoral students in

UAH's Biotechnology Science and Engineering program at the time, and whose work during their graduate tenure produced the genetic and biochemical assays used in the recently published research the trio performed with other collaborators.

The two doctoral candidate researchers graduated in summer 2015. Currently, Dr. Gordon is a research associate at HudsonAlpha Institute for Biotechnology and Dr. Sengupta is an assistant professor at Georgia State and College University in Milledgeville, Ga.

"We determined with high accuracy the site of interaction of the essential amino acid tryptophan at its molecular sensor," says Dr. Cruz-Vera.

"Bacteria use the machinery for production of proteins, named ribosomes, as sensors of small molecules like tryptophan," he says. "Bacteria sense their environments, as we do for example with our nose, to detect molecules that will be used as food."

E. coli and other bacteria can sense L-tryptophan, and then the sensor induces the expression of two genes, one that helps the bacteria to get L-tryptophan inside of its

cells and another one that transforms L-tryptophan into energy and an adhesion hormone.

"We got the most precise operational structure of this system," Dr. Cruz-Vera says.

To accurately identify the structure, Cruz-Vera's group and collaborating scientists used genetic tools to isolate mutants that produced a more efficient tryptophan sensor. They then used biochemical approaches to discern which mutants were the most efficient at sensing tryptophan. Lastly, they identified the structural approaches to determine the location of L-tryptophan within the ribosome.

If this system is disrupted by an antibiotic yet to be developed, then *E. coli* cannot attach to tissues and cannot communicate with other bacteria.

"Our future goals include testing several compounds, based on computer analysis, to find possible molecules that can block the interaction of tryptophan, which will reduce the expression of the genes that produce the bacterial hormone," says Dr. Cruz-Vera.

Researchers can also use the new structure to design sensors of molecules of interest, he says.

"This is one goal that my group shares with Dr. Jerome Baudry's group," says Dr. Cruz-Vera. "We would like to generate customizable biosensors, which could be used for molecular detection and bioremediation."

A molecular biophysicist, Dr. Baudry is the Mrs. Pei-Ling Chan Chair and professor in the Department of Biological Sciences and has experience in drug discovery and computational biology.

Dr. Cruz-Vera says his group has been studying this complex since he started at UAH in summer of 2007.

"I am recognized in the world for all my work on this complex," he says. "My group generated the genetic and biochemical analysis, and once we got them, I made collaborations with three other worldwide recognized groups to obtain the final product, the structure of the complex."

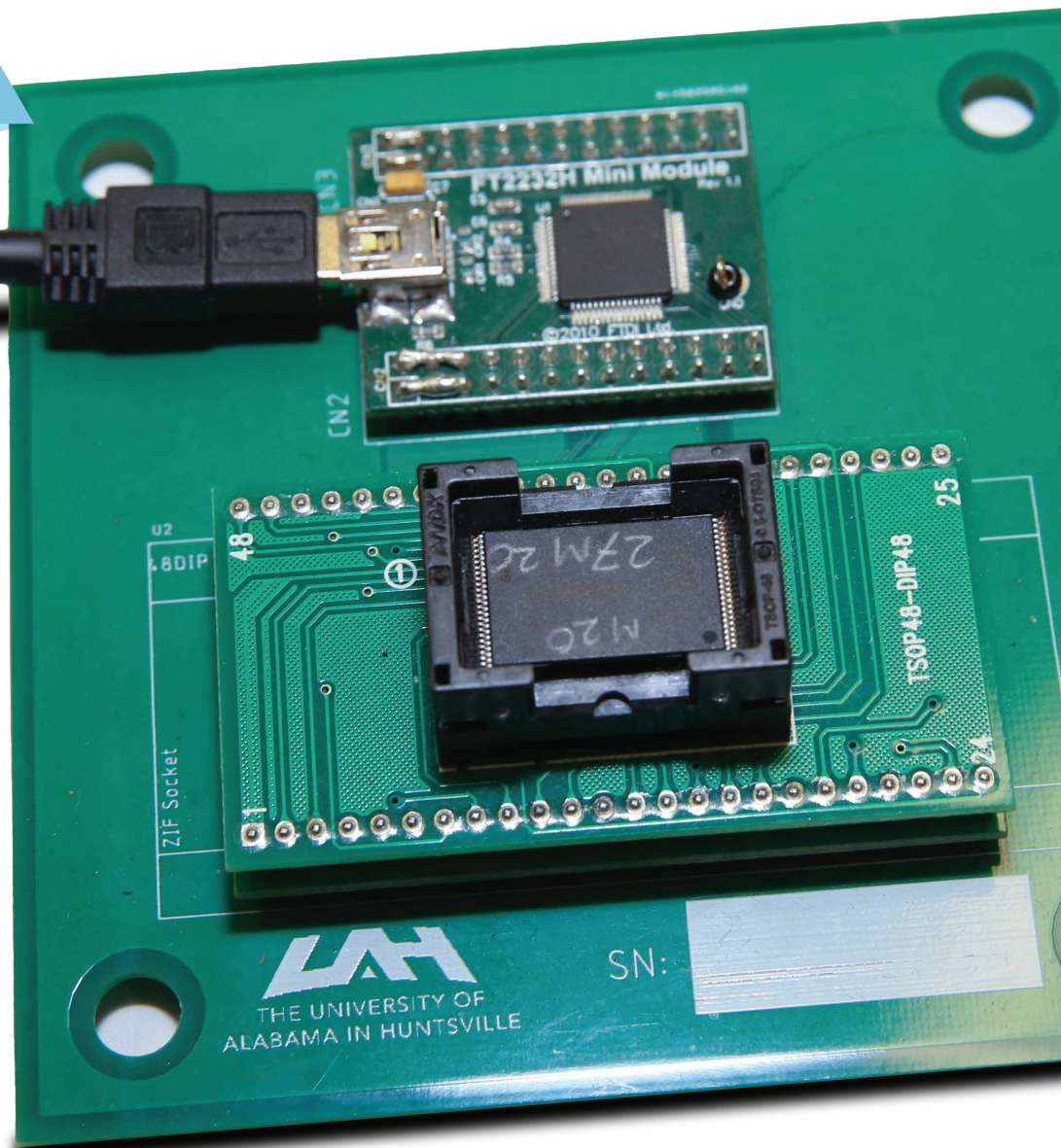
Collaborators include Texas A&M University, the University of Chicago and University Bordeaux in Pessac, France. ■

Courtesy U.S.
Food and Drug
Administration

- In addition to using the structure as a platform to generate antibiotics, researchers can also use it to design new sensors of molecules of interest, says Dr. Luis Rogelio (Roger) Cruz-Vera.



- ▶ UAH research aims to make future computer solid state drives more resilient, durable and energy-efficient.



Fighting CORRUPTION

\$650,000 NSF CAREER AWARD
FUELS WORK TO IMPROVE
COMPUTER SOLID STATE DRIVES

New research to make future computer solid state drives (SSDs) more resilient, durable and energy-efficient has attracted a five-year, \$650,000 National Science Foundation Faculty Early Career Development Program (CAREER) award for Dr. Biswajit Ray, as well as the interest of two manufacturers.

Dr. Ray, an assistant professor in the Department of Electrical and Computer Engineering, is the director of the Hardware Reliability and Security Laboratory at UAH. Three doctoral students – Matchima Buddhanoy, Md Raquibuzzaman and Umeshwarnath Surendranathan – are working on related topics in the lab and the award provides support for two graduate research assistants.

“My work will allow system designers to create new memory management functions that go beyond the algorithmic techniques and assess the memory health

- In the Hardware Reliability and Security Laboratory, from left, are doctoral student Matchima Buddhanoy, Dr. Biswajit Ray, and doctoral students Umeshwarnath Surendranathan and Horace Wilson with flash memory and MRAM/SRAM testing equipment.



in real-time to optimize its reliability and performance,” says Dr. Ray.

“I have a partnership with Western Digital and Infineon Technologies,” he says. “They are very much excited on the outcome of the project. They will provide technical mentorship and related resources for the success of the project.”

The research aims to develop new software-based storage management techniques that can double the lifetime of SSDs. Currently, system designers rely largely on algorithmic functions to manage the data integrity and reliability of storage media.

“It is quite challenging to measure physical properties of memory bits using digital-only interfaces of commercial-off-the-shelf memory chips, but we will develop novel testing methods to probe the physical properties of

memory bits using standard user mode commands,” Dr. Ray says.

“We will also formulate new system functions for system integrators to more efficiently utilize the physical properties of memory bits and create new functions for enhancing the security and reliability of future storage solutions.”

The project is expected to enable near-term disruptive data-intensive applications for artificial intelligence and enable predictive analytics using low-end computing platforms operating in extreme environments, such as nuclear environments and space, where flash drives are attractive due to their light weight, high density and small size.

“One of the challenges with space and the nuclear environment is the radiation effects that corrupt stored information,” Dr. Ray says. “The project will enhance the radiation tolerance of the flash-based storage solution through intelligent error management

techniques that can be implemented through a firmware solution.”

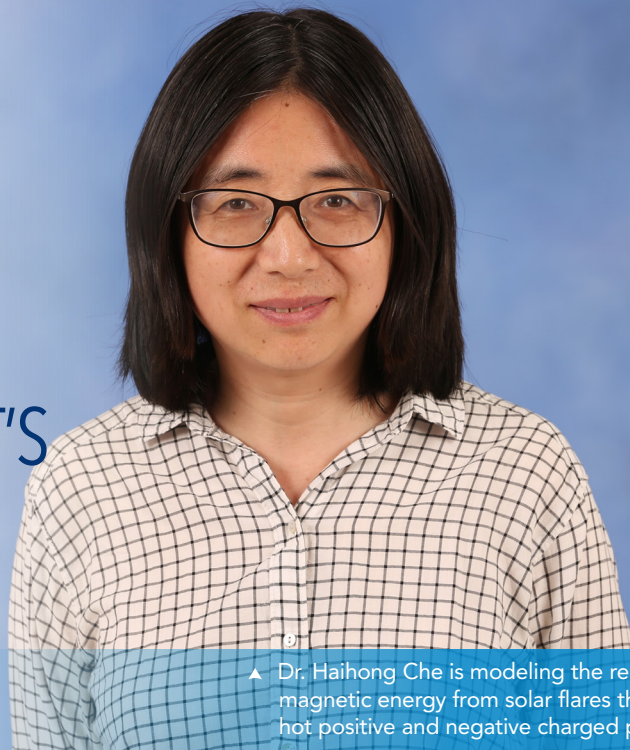
Flash memories as the main building blocks of SSDs are rapidly evolving, Dr. Ray says.

“I find recent technological developments very exciting,” he says. “Manufacturers are releasing chips that can hold over 1.33 terrabits of information, and these chips are three-dimensional structures with storage cells placed in multiple layers.”

The quest for larger capacity and faster non-volatile memories needs to include research about energy-efficiency, security and the privacy of the information stored, Dr. Ray says.

“The project addresses these issues through intelligent memory management techniques which can be implemented through software-based solutions in the storage firmware,” he says. “We will evaluate these techniques on state-of-the-art flash memory chips.” ■

\$616,000 NSF CAREER GRANT FUNDS PHYSICIST'S STUDY OF SUPER-HOT SOLAR PROCESSES



▲ Dr. Haihong Che is modeling the release of magnetic energy from solar flares that distributes hot positive and negative charged particles.

A solar physicist at UAH has been awarded a five-year, \$616,000 National Science Foundation CAREER award to study how solar flares explosively release magnetic energy and create energetic particles.

"What happens when these energetic particles escape from the solar corona, enter space and travel to the Earth?" asks award recipient Dr. Haihong Che, an assistant professor in the Department of Space Science, who will be doing her research at the university's Center for Space Plasma and Aeronomic Research (CSPAR).

The outermost atmosphere of the sun is super-hot at around 3 million degrees Fahrenheit, she explains. Under such high temperature, the gas is ionized and becomes hot plasma that's composed of hot positive and negative charged particles.

"These hot charged particles are confined by the gravity and magnetic field of the sun and form the corona, but because the corona is turbulent and unstable, explosive events called solar flares at different spatial scales occur at each moment, and the release of

magnetic energy leads to the production of a huge number of energetic particles," says Dr. Che.

"These energetic particles can escape from the solar corona and propagate into space with a speed close to the speed of light," she says. A decent-sized fraction of these energetic particles travel to Earth.

"The sudden increase of cosmic ray intensity can endanger life and affect human activities in space, such as astronauts in the international space station and spacecraft," Dr. Che says. "That's why the study of solar flares and energetic particles is important to us."

Under the new grant, a novel electron acceleration mechanism that Dr. Che has been working on will be extended to ions, and researchers will build a solid physical foundation for the new mechanism.

Dr. Che's team includes Dr. Bofeng Tang, a CSPAR postdoctoral researcher, and Space Science graduate students Chris Crawford, Atit Deuja and Rubaiya Shikha. Their research will rely on big data super-computation

through NASA's High-End Computing Program at the NASA Advanced Supercomputing Division at Ames Research Center in California. It will also utilize data from NASA's Parker Solar Probe to test the model.

"During solar flares, energetic particles can produce multi-band emissions in the corona, and we can obtain the particle energy distribution and information about the magnetic field through the observation of the emissions," she says. "With this information, we can test our model and investigate the dynamic process of solar flares to further advance our understanding of solar activities."

The processes are essential for the sun to generate heat, so modeling them is fundamental to informing the evolving field of solar weather prediction, Dr. Che says.

"Also, since the sun is a natural controlled fusion process, understanding how the sun confines the plasma and releases the energy can inform research into human-made plasma fusion reactors to produce clean energy." ■

GLORIA GREENE IS PRESIDENT-ELECT OF SOCIETY OF RESEARCH ADMINISTRATORS INTERNATIONAL

▲ Gloria Greene says her number one goal is to build upon the outstanding accomplishments of the society.

Gloria Greene (B.S., Business Administration – Management, 2001; M.A., English Language and Literature, 2006), assistant vice president for contracts and grants in the UAH Office of Sponsored Programs (OSP), is the first woman of color to become president-elect of the Society of Research Administrators International (SRAI).

SRAI is the premier global research management society providing education, professional development and the latest comprehensive information about research management to professionals from over 40 countries.

Greene became the first woman of color elected to the SRAI board of directors in 2016. She credits the support of the UAH Office of the Vice President for Research and Economic Development and the OSP staff.

"The best part about this position is that I learn new things that I can adapt here at UAH to assist our faculty and research staff in making their jobs much easier and less cumbersome when engaging with the Office of Sponsored Programs," says Greene.

Her three-year term begins in November 2022 and includes time as

president-elect from 2021-2022, president from 2022-2023 and immediate past president from 2023-2024.

"My number one goal is to build upon the outstanding accomplishments of the society," says Greene, who adds that her emotions ran the gamut when she found out she had been elected. "I am humbly honored by those who voted for me."

She plans to work with the SRAI headquarters staff, the board of directors and the membership to develop and offer educational programs, including developing a program explicitly designed for principal investigators and post-doctoral researchers.

"I believe we can do this with the support of the headquarters staff, our membership and one of our newest board members, Dr. Jennifer E. Woodward, vice chancellor for Sponsored Programs and Research Operations at the University of Pittsburgh Department of Immunology," Greene says. "She is also a professor of surgery and immunology who I am looking forward to working with on this project."

SRAI executive director Evan Roberts says that Greene's contributions to the profession of research administration have been broad and deep and are

among the many reasons SRAI is excited that she has been elected to serve as president.

"Gloria's tireless dedication to investing in the future of our field, while providing the practical day-to-day knowledge essential to success, can be seen through her daily updates in our Connect social media platform, her highly regarded training sessions at conferences and her intellectual contributions to our strategic planning," Roberts says.

"UAH is fortunate to have such an exceptional leader within your midst," he says, "and SRAI is grateful that your organization has supported her in helping lift the technical proficiency and professional prospects for the larger research administration community."

SRAI maintains the largest network of research managers in the world, and it is the only research management society in the world whose membership spans the entire spectrum of research institutions, including colleges and universities, research hospitals and institutes, government agencies, non-profit funders of research and industry. ■

SPACE HARDWARE CLUB TEAM'S ROBOTIC ROVER ADVANCES TO SUMMERTIME COMPETITION IN UTAH

After two years of work, a robotic rover developed for use on Mars by a 21-person Space Hardware Club (SHC) team at UAH will be in summer competition at the University Rover Challenge (URC) finals in the desert of southern Utah.

The Adaptable Service Transport Research Apparatus (ASTRA) team earned a perfect score in the science category for its URC System Acceptance Review to advance. "This is one of the most impressive SAR submissions by a novice team I have ever seen," a reviewer wrote. "Kudos to you all."

Outfitted with a very dexterous main arm, ASTRA is equipped with cameras, a microscope,

a spectrometer and the hardware and chemicals needed to test for life. A YouTube video entitled "ASTRA System Acceptance Review - URC 2022 SAR" shows the rover in action.

The URC, a project of The Mars Society, is the world's premier robotics competition for college students. Under URC rules, the rover has to fit inside a cube-shaped space that is 1.2 meters on all sides, or almost 4 feet. Once deployed, the rover can get bigger.

"Our rover has a footprint that is 1.19 x 0.9 meters and is 1.19 meters tall when stowed," says team lead Shelby Tull, a senior in aerospace engineering



◀ Michael Sorrell uses a remote to control the ASTRA rover's dexterous manipulator arm while Thomas Bennett gives him some tips.

from Nashville, Tenn., who founded the project. "It gets taller when we deploy its antenna. At its heaviest, the rover weighs 46.9 kg, or 103.4 pounds."

The rover is designed to accomplish four unique missions, Tull says.

"One of those missions is life detection. More specifically, it has to look at rocks and soil and tell whether there is extant life, extinct life or no life," she says. "The other missions are extreme retrieval and delivery involving picking up heavy objects and carrying them

across difficult terrain, equipment servicing involving dexterous tasks like using a keyboard, and autonomous navigation."

Using a vacuum and cyclonic separator, the rover can pick up either Earthly dirt or Martian regolith and perform a bicinchoninic acid (BCA) test by adding a mixture of copper sulfate and BCA to the sample. If the chemicals turn purple, that indicates protein, which can only exist if there is extant life.

"We use our onboard spectrometer to look for pigments that are also only found with life, such as chlorophyll and carotenoids," Tull says.

For rock samples, the rover has a rudimentary arm with a camera and a microscope to take a closer look.

"On rocks, we are really looking for endoliths and hypoliths – those are colonies of organisms that grow on, inside and underneath the rock," Tull says. "We might see streaks of green or gray, which indicate plant or bacterial life."

For extinct life, the rover's cameras allow the team to search out two types of fossils: cast fossils and trace fossils.

"Cast fossils are what you usually think of when you think about a fossil, the actual shape of the organism petrified into rock," Tull says. "Trace fossils are other things that organisms leave behind, such as footprints or nests."

Primarily operated manually, ASTRA is also able to autonomously drive to Global Positioning System (GPS) waypoints over flat terrain

using an on-board GPS sensor and magnetometer.

Advised by Dr. Gang Wang, an associate professor of mechanical and aerospace engineering, and Dr. Richard Tantaritis, a mechanical and aerospace engineering lecturer, the SHC team is working to enable the rover to detect obstacles in its path so it can operate autonomously on rougher terrain.

The main arm is remarkably precise in operation, and that's the result of a lot of design work upfront, says electrical lead Thomas Bennett, a graduate student in aerospace systems from Charleston, S.C.

"Getting it to be so dexterous didn't really take much fine tuning at all, it was basically that good from when we first turned it all on!" Bennett says. "That's not to say we just got lucky though. We really did our homework when designing it. We selected components and designed it from the beginning to have the best balance of strength and dexterity."

Weight is a consideration in long-distance spaceflight, so the arm went through several revisions to implement the same mechanical structure using lighter components, Bennett says.

"As for the software that controls it, I have to thank UAH's Dr. Farbod Fahimi," he says. Dr. Fahimi is an associate professor of mechanical and aerospace engineering.

"Taking his MAE 664 class taught me everything I needed to know," Bennett says. "I even used one of my old assignments as a basis for the control software."



◀ ASTRA team members are, from left: Front – Thomas Bennett, Shelby Tull, Victoria Tarpley, Michaela Tarpley, Michael Sorrell and Arnav Maraju. Back – Aiden St. Hilaire, Areeb Mohammed, Andrew Adams, Tristan Carter, Jacob Keese, Peter Bowers and Alex DiBenio.

Courtesy Space Hardware Club

Tull says that for her, the most challenging part was designing the biosensor module used to detect life.

"We have no biology or chemistry majors on the team at this time, so we had to do a lot of homework to get it right. It was very difficult to sort through scholarly research without being familiar with all the vocabulary used in biochemistry," she says.

"We were also in uncharted territory when designing the spectrometer, which involved a lot of research in optics. Thomas actually wrote an optical simulation program in MATLAB, which simulated the path that rays of light follow in our spectrometer. He got it right to within 60 microns."

Other team members think the arm's design and fabrication were the most challenging parts, she says. Most mechanical components were fabricated in the UAH Research Machine Shop under the guidance of Jon Buckley, prototype development specialist. Final assembly and all electronics work was done in the Space Hardware Club's lab in UAH's Optics Building.

Testing has revealed opportunities for improvement in the suspension, wheels and drivetrain. For the Utah final, the team is also working to enclose exposed electronics, fine tune the camera placement and smooth operation through upgraded software. ■

ASTRA team roster

- Andrew Adams, junior, mechanical engineering, Madison, Ala.
- George Beaton, freshman, mechanical engineering
- Thomas Bennett, graduate student, aerospace systems, Charleston, S.C.
- Peter Bowers, senior, mechanical engineering, Nashville, Tenn.
- Skyler Buckley, freshman, mechanical engineering, Toney, Ala.
- Tristan Carter, junior, mechanical engineering, Haleyville, Ala.
- Alex DiBenio, sophomore, mechanical engineering, Crownsville, Md.
- Jacob Keese, graduate student, mechanical engineering
- Arnav Maraju, junior, aerospace engineering, Charlotte, N.C.
- Areeb Mohammed, junior, computer science, Brentwood, Tenn.
- David Niederweiss, junior, computer science
- Caleb Philen, junior, electrical engineering
- Nick Schilders, junior, mathematical sciences
- Michael Sorrell, junior, mechanical engineering, Huntsville, Ala.
- Aiden St. Hilaire, junior, electrical engineering, Waxhaw, N.C.
- Victoria Tarpley, junior, mechanical engineering, Roxana, Ill
- Michaela Tarpley, junior, aerospace engineering, Roxana, Ill.
- Shelby Tull, senior, aerospace engineering, Nashville, Tenn.

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