National Aeronautics and Space Administration

THE SPARK

TECH TRANSFER, PARTNERSHIPS, AND SBIR/STTR AT GODDARD

PATENT EDITION

Bringing Goddard Technology to Private Industry

VOLUME 21 | NUMBER 4 | FALL 2023

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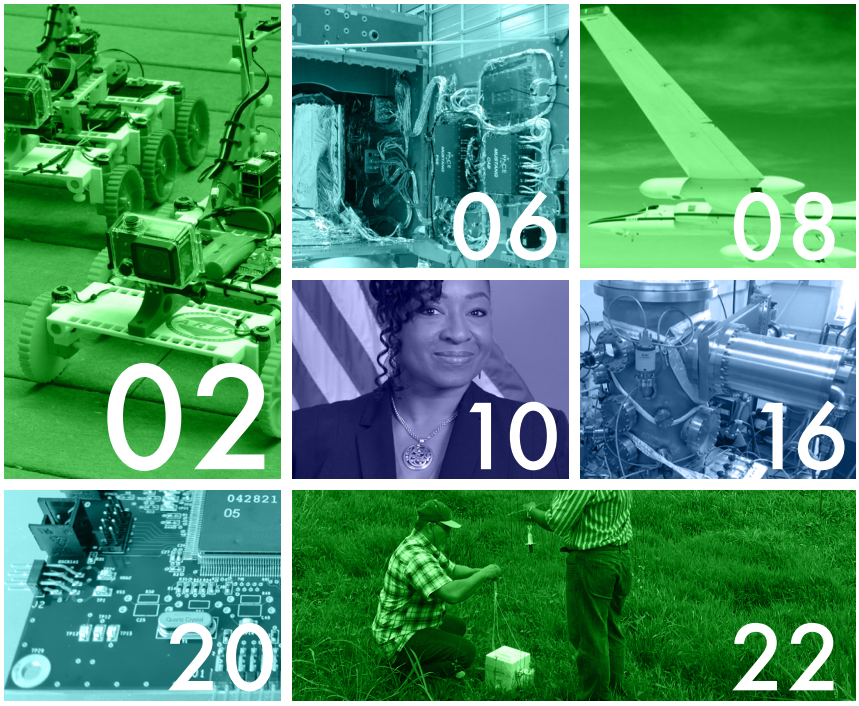

ABOUT THE COVER

Artist montage of Robert Goddard photos and rocket patent over a textured backgreound.

Photo Credit: NASA

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OFFICE OF THE CHIEF

According to the National Institute of Standards and Technology, "tech transfer (or technology transfer) is a way to describe the overall cycle of bringing knowledge and technologies to society through actions such as commercialization and publication." Federal engineers and scientists are constantly developing new technologies, from the design board to the lab table. Instead of being left on a shelf, these cutting-edge inventions should be made known to those who can bring them to the market.

What many people do not realize is just how many products and technologies used in our daily lives were originated in NASA laboratories, and then ultimately reached the marketplace in large part through technology transfer efforts. Some of the more well-known commercial products from NASA include freeze-dried food, space blankets, DustBusters, cochlear implants, LZR Racer (Speedo) swimsuits, LASIK technology, and CMOS (Complementary Metal Oxide Semiconductor) camera sensors.

Technology transfer is important. At Goddard, engineers and scientists are developing technologies designed for specific NASA mission objectives. Some of these innovations will help guide spacecraft to the Moon's surface, keep the instruments on a satellite from overheating, shield a spacecraft from radiation, or see the farthest reaches of the universe. However, these innovations may be commercialized by private industry, and used in a completely different field.

Bringing new technologies out of Goddard labs and into the marketplace by partnering with businesses, universities, state, and local government will help improve the economy, society, and national security. In short, technology transfer will make everybody's lives better. That is why developing new technologies and getting them commercialized is a key role of Goddard's Strategic Partnership Office (SPO).

In recent years, savvy entrepreneurs and businesses like Mapbox, Perennial, Baker Family Farm, and Johnson & Johnson Vision have benefited from Goddard innovations by utilizing Goddard-developed technologies to help grow their business and the economy. At Goddard in the past fiscal year, there have been 167 New Technology Reports (NTRs) filed by engineers and scientists, 19 patents issued from the U.S. Trademark and Patent Office, and seven licenses signed with private industry.

Innovation is about imagining what might be possible in the future but isn't here today and working to achieve those goals. Goddard is fortunate to have some of the best and brightest minds in science and engineering. This issue of The Spark focuses on some of those new patented or patent-pending technologies, whose commercialization potential we at SPO are excited about. We are eager to learn how these innovations may one day benefit us all.

Darryl R. Mitchell, Chief

Strategic Partnerships Office
NASA's Goddard Space Flight Center

Batteries Not Included

Goddard Innovators Develop the TerraROVER

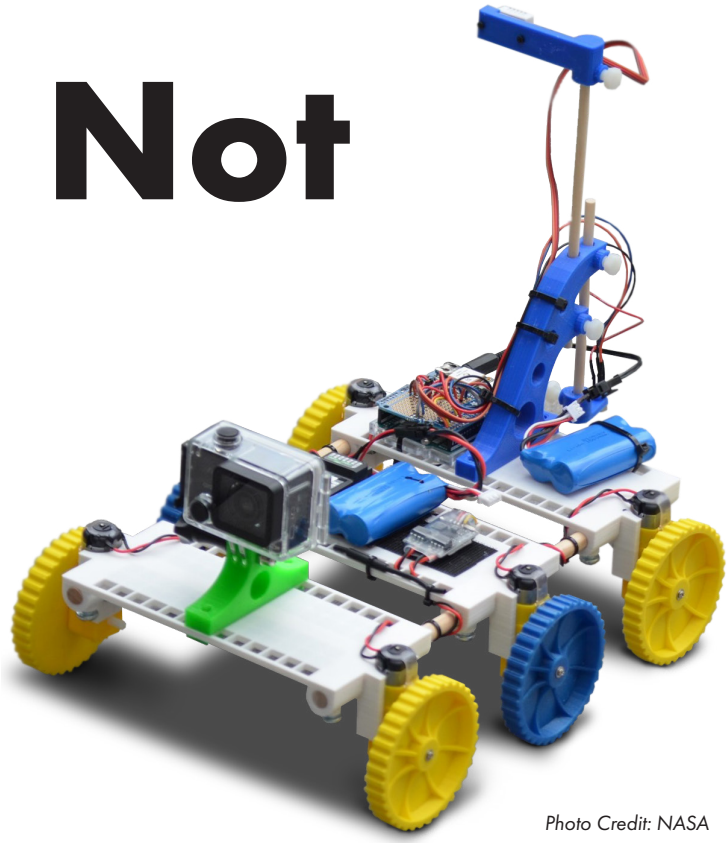

Photo Credit: NASA

The science and engineering that happens at NASA and other institutions can seem like a world away to students. To train the next generation of engineers and scientists in the realm of Earth science, many high schools and colleges want to take their students out of strictly classroom-based learning and instead use technology to transport them into real-world settings to collect data and conduct research. However, to get students out of the lecture hall and into the field for real-world experiences, learning institutions need to find the right technologies or equipment to use.

To help schools in this endeavor, NASA created the Science Activation (SciAct) sponsored AEROKATS and ROVER Education Network (AREN), which is designed to introduce NASA technologies and practices in authentic, experiential learning environments. AREN technologies and lesson development are NGSS (Next Generation Science Standards) aligned and provide necessary science literacy skills for students. AREN provides training and STEM (Science, Technology, Engineering and Math) challenges to advance student research projects investigating Earth science and related phenomena.

For education and research, the two low-cost instrumented systems AREN developed for in-situ and remotely sensed Earth observations are kite-based or "AEROKATS," and remotely controlled aquatic and land-based "ROVERS." Geoffrey Bland, a Goddard research engineer in the Science and Exploration Directorate's Climate and Radiation Laboratory (Code 613) developed the TerraROVER, a 14-inch remotely controlled surface measurement vehicle driven by an electric motor on a wheeled chassis. Bland developed the TerraROVER along with several AREN team members. Other primary developers include Ted Miles with Black Swift Technologies LLC, James Moon-Dupree, and Andy Henry with the Wayne Regional Educational Services Agency.

TerraROVER is a patent-pending wheeled vehicle that can be controlled at any speed and direction. This unique vehicle is built using 3-D plastic printed parts, electric motors, gearboxes, radio control links, and batteries. It is equipped with an Urban Heat Island Package (UHIP) to collect GPS position, relative humidity, and air and surface temperature data that are recorded on-board every three seconds. TerraROVER also has a camera to provide imagery.

Bland and the team created the TerraROVER with an electric propulsion system that would make any vehicle designed for planetary exploration on the Artemis mission jealous. TerraROVER is suitable for operations outdoors on surfaces such as pavement, grass, or soil, and is equipped with suitable traction for ice or snow. It is also designed for pre-programmed or autonomous control.

"What we are trying to do with TerraROVER is turn young people on to the concept of observing their environment," explained Bland. "NASA's Landsat satellite program helps

The AEROKATS and ROVER Education Network (AREN) team from left to right, Sallie Smith (NASA Goddard Space Flight Center), Josh Jones (University Alaska, Fairbanks) Rich Cairncross (Drexel University), Andy Henry (Wayne Regional Educational Service Agency), Chris Hartman (University Maryland Eastern Shore), Lisa Ogiemwonyi (Wayne Regional Educational Service Agency), Mike Jabot (State University of New York, Fredonia), Suzi Taylor (Montana State University), Eric Banilower (Horizon Research Inc), Sarah Safley (Horizon Research Inc), James Moon-Dupree (Wayne Regional Educational Service Agency), Geoff Bland (NASA Goddard Space Flight Center). Photo Credit: NASA

give us important Earth science data, but what TerraROVER does is allows students to engage in that very same data-collection process that we do with all our space and airborne missions. Students can do it right from their classroom. In fact, only recently, we tested the TerraROVER with a group of 7th graders. To answer their own science questions, students were able to take TerraROVER out into the field and do a mission themselves."

Bland said the TerraROVER was intentionally designed to be easy to use and built and operated at minimal cost. "You don't need a receiver or a cell phone to operate this. You don't need anything but the radio transmitter to control it," he said. "Everything is stored onboard. And when your science mission is done, back in the classroom, you take out the SD Card where all the data is stored, open it, and then you can begin to analyze the information."

As part of the AREN project, for the past two years, Bland and members of the development team have tested the vehicle with selected educators in TerraROVER workshop programs at locations across the U.S. About 30 teachers are invited to each workshop. Before each workshop, teachers receives a TerraROVER in the mail and with the

Testing the TerraROVER in a live environment, Photo Credit: NASA

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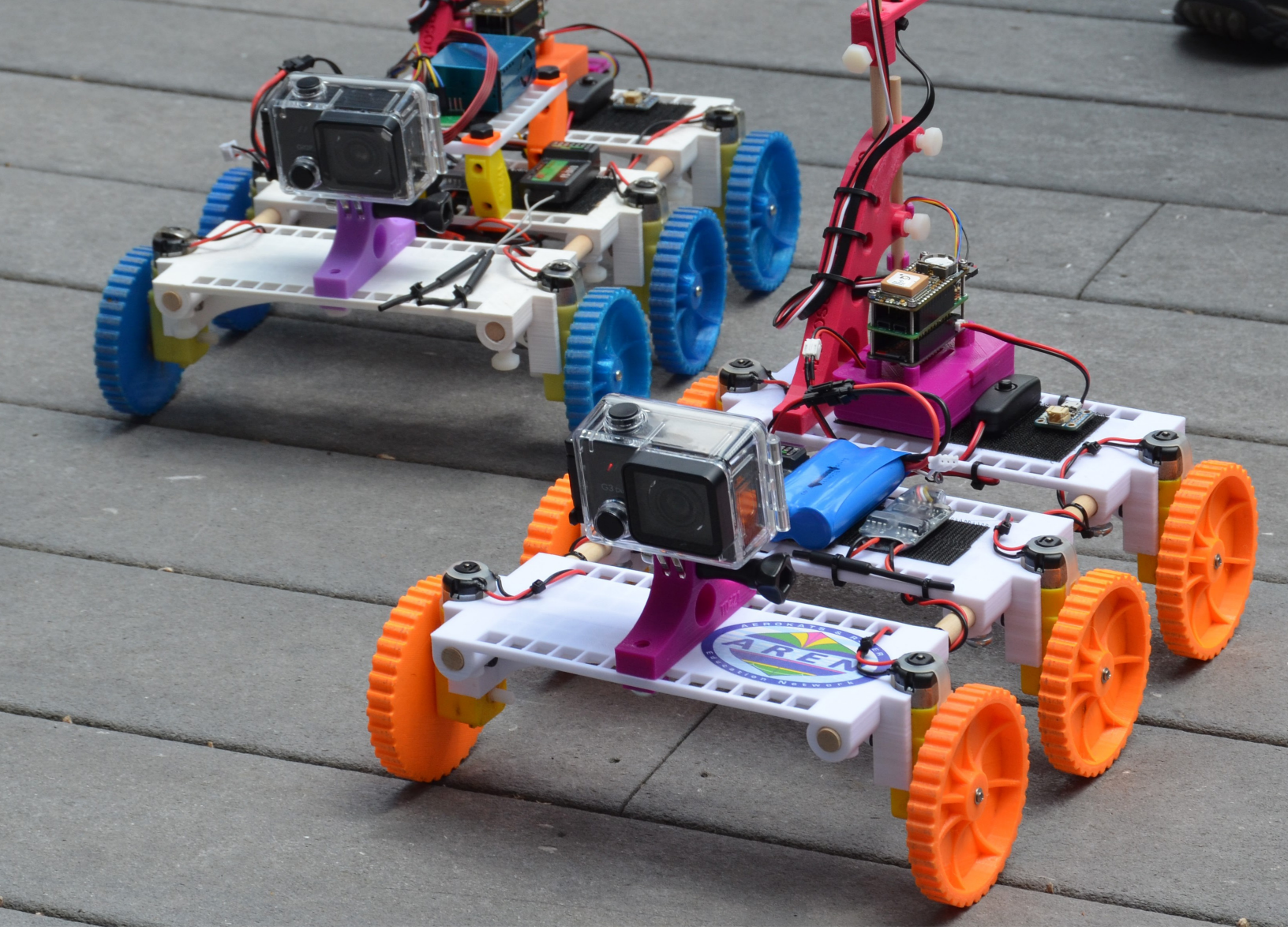

Two TerraROVER models with onboard cameras and battery packs, Photo Credit: NASA

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assistance of development team members, they are given the opportunity to drive it around on surface areas and learn how to use its functions. "We are always trying to understand how our educators would be implementing these vehicles," Bland said.

Working with the technology managers at the Strategic Partnership Office, Bland believes that there is a commercial market at schools and universities to license TerraROVER. Bland believes there may be interest in TerraROVER from the National Science Teachers Association, among other organizations. "I think we have absolutely proven in a relevant environment that TerraROVER is mature enough that somebody can either commercialize or manufacture it," said Bland. "We are very interested in finding commercial partners."

Bland has been working on various kites, rovers, and drones for educational purposes for approximately 30 years. For several decades, he was not getting anywhere with the concept of a land rover. He credits the development of TerraROVER to its predecessor, AquaROVER, a radio-controlled boat, that uses similar technology to collect data on rivers and lakes.

"AquaROVER was developed for in-water measurements and proved the concept of remotely operated vehicles," recalled Bland. "The University of Maryland Eastern Shore (UMES) was a key partner in this development. Knowing water quality makes sense if you are worried about the Chesapeake Bay but if you are in the middle of Nebraska, you are more worried about the impact of roads versus other vegetation. With TerraROVER, I wanted to have something that would meet the needs of those people, too. So, after about two decades worth of effort, it has finally come together and is now ready to be shared with the general public. That is very encouraging."

Technology Transfer University

Bringing NASA Technology into the Classroom

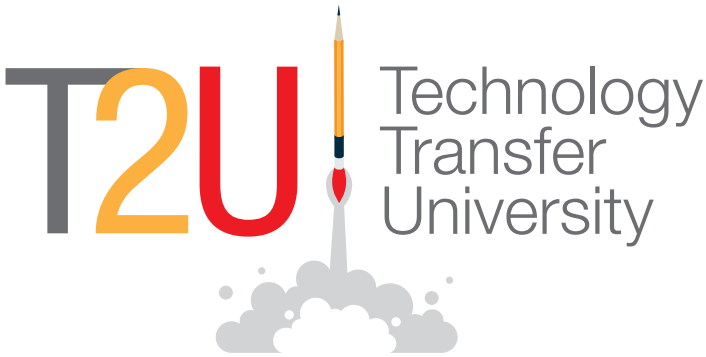
At Technology Transfer University (T2U), we are bringing real-world, NASA-proven technologies into the classroom.

NASA's T2U program connects universities with NASA-developed technology to give students the opportunity to work with federal government research and technology.

Student entrepreneurs build case studies with NASA's patent portfolio while learning about commercialization and licensing opportunities.

NASA T2U has generated a number of successful licenses and new startup companies.

To learn more about T2U or to initiate a program at your school, contact us at hq-t2u@mail.nasa.gov.



Brains of the Operation

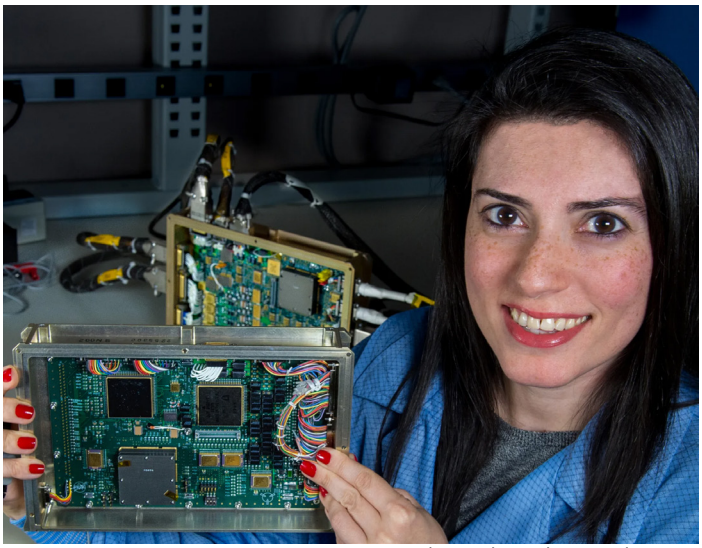
Goddard Team Develops an Avionics System for Commercial Use

In the 1939 classic movie, *The Wizard of Oz*, the scarecrow played by Ray Bolger memorably sang, "If I Only Had a Brain." Every modern satellite, spacecraft, or aircraft built and flown today does not have to worry, they all have a brain. This brain, better known as the avionics installed on a spacecraft or aircraft, can control many or all the flight mission management tasks. Among those are the flight control systems, engine controls, navigation, communications, flight recorders, lighting systems, threat detection, fuel systems, electro-optic (EO/IR) systems, weather radar, and performance monitors.

Commercial airliners, helicopters, military fighter jets, unmanned aerial vehicles (UAV), business jets, and spacecraft all use avionics to provide services, conduct missions, make new discoveries, track and report performance measures, and operate within established safety parameters. The most advanced avionics systems also integrate multiple functions to improve performance, simplify maintenance, and contain costs. Generally, the more complex the craft or mission is the more complicated the electronic system that they employ. That translates into the need both for the commercial world and at NASA for a more ubiquitous avionics systems that be used for all these crafts and missions, big and small.

Noosha Haghani, a systems engineer in Mission Engineering and Systems Analysis (Code 590) at NASA Goddard led a team to develop the Modular Unified Space Technology Avionics for Next Generation missions (MUSTANG). Other Goddard engineers and designers on the MUSTANG team include Amri Hernandez-Pellerano and Robert Gheen.

There is nothing new about an avionics system in principle. It has been used on every satellite since Explorer 1 was launched on February 1, 1958. MUSTANG is unique in using mix-and-match avionics electronic



Noosha Haghani, Photo Credit: NASA

cards. By integrating a hardware and software design built with off-the-shelf parts to reduce costs, it can also be customized for use on virtually any size mission or craft.

In the past, mission planners would build their own avionics system, which was expensive. The goal of MUSTANG, which is a patent-pending technology, was to create an avionics system that mission planners would not have to completely redesign for each mission. MUSTANG is essentially an a la carte avionics system, where an engineer can pick and choose among different avionics applications to meet their specific mission needs. With MUSTANG, mission planners can now focus their time and resources on their mission and instruments instead of the electronics running them.

"At Goddard we've built and designed avionics systems, but over the years we kept reinventing the wheel on the avionics. We made changes and tweaks, and the avionics systems got larger and more expensive," explained Haghani, original chief architect of MUSTANG who now serves as the MUSTANG team lead. "This quickly led to being sized-out of the smaller explorer missions that we used to fly in the

past. We then realized that the designs that we made on each of these avionics systems are 90 percent the same and 10 percent different, but we always started the design from scratch, which is silly. We just asked ourselves, why don't we just make something built with an architecture that includes the lessons learned from all of the missions that we have done in the last two decades. As such, with MUSTANG, we have developed a reusable product line, where we don't have to spend money trying to build a custom avionics system from scratch every time for each mission."

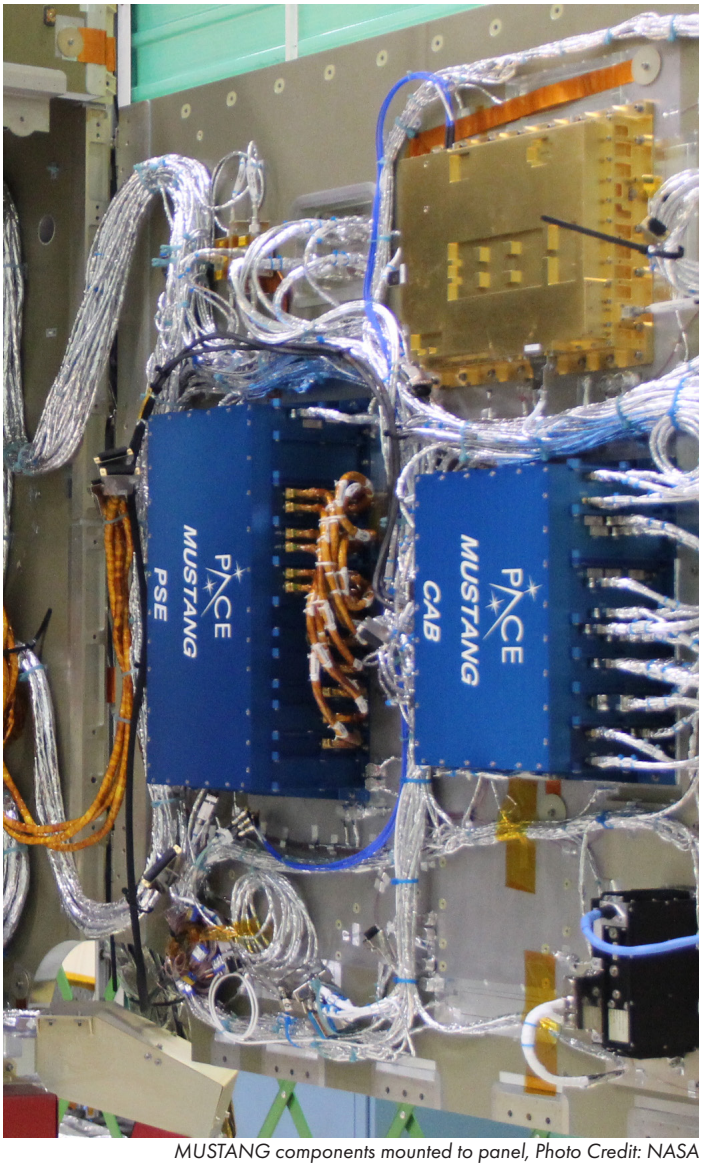
In 2018, MUSTANG was first successfully tested in a live operation by running the avionics operations on the Global Ecosystem Dynamics Investigation (GEDI) satellite. GEDI was a joint mission of NASA Goddard and the University of Maryland, designed to measure how deforestation has contributed to atmospheric CO_2 concentrations.

Looking ahead, MUSTANG has already been tapped to run the avionics operations on NASA's Plankton, Aerosol, Cloud, ocean Ecosystem (PACE) mission, which is scheduled to be launched in January 2024. PACE is an Earth-observing satellite mission that will advance observations of global ocean color, biogeochemistry, and ecology, as well as the carbon cycle, aerosols, and clouds.

"MUSTANG is not necessarily better than the avionics systems that we were using before, it is just a more structured avionics system where we have taken all the expertise that we have learned and put them all into one reusable, customizable product line," said Haghani. "The number of avionics applications that we have included on MUSTANG over the years have been growing so large, we can't keep up with how many we actually have. Every project manager wants their mission to be risk adverse and wants to save money. So far, users have found MUSTANG to be a good avionics tool because it uses low power, has low mass, and those kinds of things cut down the cost of the program."

NASA's technology transfer goal has been to develop technologies for a specific space application, and then patent and license them to private industry for their own use. Haghani said that she and the MUSTANG team have been working with the technology managers at the Strategic Partnership Office (SPO) to find commercial partners for MUSTANG. In August 2023, SPO executed a licensing agreement with a small commercial space company that is planning to offer MUSTANG for sale by 2026.

"This experience with the team developing and commercializing MUSTANG has been humbling but at the same time very gratifying," said Haghani, who has been working on developing MUSTANG since 2014. "It was a very long road to get to where we are now. We have accomplished and achieved something as a team that not many people have been able to do on Center in the past and I am very proud of that."



MUSTANG components mounted to panel, Photo Credit: NASA

It's a Breeze

Goddard Inventors Are Developing a Technology to Measure Air Pressure from Space

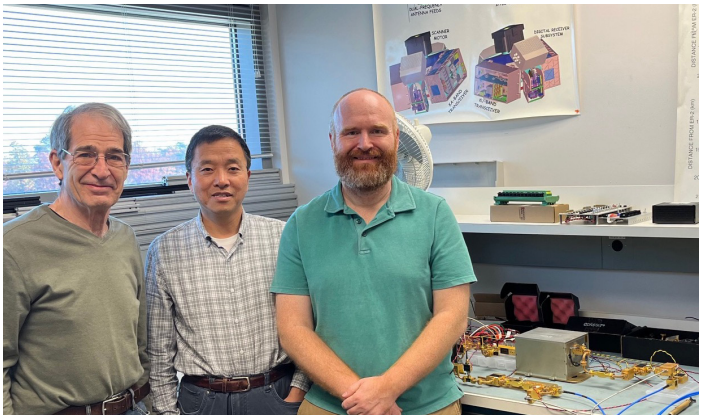
When you go up in an airplane, you may notice that your ears pop. The reason is that the atmospheric pressure— the force and weight of the air at any given point—becomes lower than the pressure of the air inside your ears. Your ears pop to equalize, or match, the pressure. The same thing happens when the plane is on its way down and your ears have to adjust to a higher atmospheric pressure. This also explains why an aircraft creates artificial pressure in the cabin, so its passengers will remain comfortable while flying.

Simply put, atmospheric pressure is the force and weight of the air at any given point. Atmospheric pressure is also one of the best ways a meteorologist can forecast the weather. For example, when a low-pressure system moves into an area, it usually means cloudiness, wind, and precipitation. High-pressure areas usually lead to fair, calm weather.

To capture marine weather conditions over the ocean, the National Oceanic and Atmospheric Administration's National Buoy Center has stationed approximately 3,000 drifting or moored in-situ buoys throughout the globe. Using sensors, these buoys are constantly collecting air pressure data. However, due to the harsh conditions of the ocean, most of these buoys are located near the coast. As a result, there are thousands of miles of ocean where there is little or no air pressure data being collected for forecasting atmospheric models.

With funding support from NASA's Earth Science Technology Office (ESTO), a team of engineers and scientists from Goddard, the Langley Research Center (LaRC), and academia are developing the Microwave BArometric Radar and Sounder (MBARS). MBARS is a unique patented technology that uses a multi-frequency differential absorption radar (DAR) combined with a passive radiometer on a scanning platform to provide a swath of air pressure and temperature data in areas of the ocean where buoys are not located. MBARS is meant to be used either aboard an aircraft or satellite.

Matthew Walker McLinden, a microwave engineer in Goddard's Microwave Instruments and Technology Branch (Code 555), Gerald Heymsfield, a research meteorologist in the Mesoscale Atmospheric Processes Laboratory (Code 612), and Lihua Li, also microwave engineer in the Instrument Systems and Technology Division (Code 550) are developing MBARS. To develop this technology, they have partnered with a team of engineers and scientists from LaRC, including scientist Bing Lin and



Gerald Heymsfield (left), Lihua Li (center), Matthew Walker McLinden (right), Photo Credit: NASA

engineer Steven Harrah, who had also been working on the concept.

"One of the reasons we think a scanning platform is important on MBARS technology is because a single point measurement of air pressure does not actually provide all the information a meteorologist needs," said Walker McLinden. "Utilizing a scanning instrument enables us to observe alterations in surface pressure across two dimensions. With the incorporation of temperature data, our goal is to expand this into a comprehensive three-dimensional perspective on pressure variations," added McLinden.

"A hurricane's intensity is very often given by its pressure," he added. "The lower the pressure at the center of the storm, the stronger the winds will be. As a storm is working its way across the Atlantic, the future tropical storm might not go over a single buoy the entire time, or if it does go over the buoy, maybe it just grazed it on the side. Without high resolution pressure information, we know little about its intensity. With the MBARS instrument in space or on an aircraft, we can provide high-resolution pressure information that is useful for tracking tropical storms or in other forecasting applications."

"This concept has been around for decades but has never been demonstrated with anywhere near the precision that is required for meteorology," added Li. "But we found this innovation would probably work best in space or on a very high-altitude aircraft. So, we are building an aircraft protype to demonstrate that the pressure retrievals work."

MBARS is patented with a Technology Readiness Level (TRL) of 3 that is fast approaching TRL 5. MBARS has been tested for proof-of-concept in the laboratory and is now getting ready for demonstrations aboard an aircraft. Two flight campaign demonstrations over the Pacific Ocean are planned in the summer and fall of 2024.

One area the MBARS team is exploring to use MBARS is on a Distributed Systems Mission (DSM). A DSM is a mission that involves multiple spacecraft to achieve one or more common goals. Some DSM development includes constellations, formation flying missions, or fractionated missions. A key component and advantage of DSM is the idea that this is an open architecture where anyone can join and contribute to the network.

"There are some studies that simulate using multiple satellites that fly in a constellation and could potentially provide meteorologists with the kinds of measurements needed for global weather modeling," said Heymsfield. "I would say what we are looking at in the future is to mature the technology and use these instruments on SmallSat constellation missions."

Presently, there are companies in the U.S. and around the world that manufacture or use atmospheric radar for space-based or airborne-based weather-related applications. Working with the technology managers in the Strategic Partnership Office (SPO), the inventors believe once MBARS is fully tested and developed there will be a commercial market for it.

"Twenty or 30 years ago the space business was NASA's domain," Li said. "Today, there are private companies that use satellites for different applications of Earth science. So, we believe that there is a market for MBARS."

"If you give a forecaster a map of atmospheric pressure, they can tell you a lot about the weather," McLinden said. "They can tell you where its windy, where there will be precipitation and where is it sunny. Unlike other key atmospheric measurables like temperature and water vapor, there is not remote sensing technology in the market today that has been demonstrated to retrieve atmospheric pressure. With MBARS, we are building the first instrument to go up in an airplane to show that it can be done."

Q&A

with Goddard Deputy Director
for Technology and Research
CHRISTYL JOHNSON

Photo Credit: NASA

> *"One of the benefits of Goddard being in the lead is that we have cross division science capabilities."*

Dr. Christyl Johnson is Goddard's deputy director for technology and research investments. She manages the center's research and development portfolio and is responsible for formulating Goddard's future science mission and technology goals and objectives. She also leads an integrated program of investments aligned to meet those goals. This summer, NASA headquarters tasked Dr. Johnson with "the leadership role" for the technology elements of the NASA 2040 exercise.

Dr. Johnson came to NASA Goddard from the White House Office of Science and Technology Policy, where she served under the President's Science Advisor as the Executive Director of the National Science and Technology Council (NSTC). Serving under both President's George W. Bush and Barack Obama, she was responsible for ensuring the establishment of clear national goals for Federal science and technology investments in a broad array of areas across the executive branch. Those include basic science, technology, energy, environment, natural resources and homeland and national security.

Prior to joining the White House staff, Dr. Johnson served as the assistant associate administrator in NASA's Office of the Administrator. She along with the associate administrator provided oversight of the agency's technical mission areas and field center operations. Dr. Johnson is dedicated to inspiring women and girls to pursue careers in Science, Technology, Engineering, and Mathematics (STEM), and

has established several programs to accomplish this. In 2018, she established STEM Girls Night In, a STEM-themed sleepover for young women to meet female engineers and scientists and to discover opportunities for women in STEM-related professions.

Last year, the Library of Virginia and Dominion Energy bestowed Dr. Johnson as an honoree of the Strong Men & Women in Virginia History Award. This award honors distinguished and prominent African Americans, past and present, who made "noteworthy contributions to the Commonwealth of Virginia, the nation, and their profession."

The Spark magazine caught up with Dr. Johnson to learn more about her vision for Goddard's research and development investments, NASA 2040, Artemis, the importance of technology transfer and partnerships with private industry, and SmallSat development. She also discussed Goddard's focus on Distributed Systems Missions and how and why this could be used in conjunction with NASA missions.

To the readers of The Spark who may not know you, I would like to begin by offering you the opportunity to introduce yourself.

People should know my background is in engineering. I began my career at NASA designing and building laser systems for remote sensing of the atmosphere in the Remote Sensing Technology Branch at the Langley Research Center. From there I became program manager and lead engineer [of the Diode-Pumped Cr:LiSAF Technology Development Program, whose ultimate goal was to assess the capability of the laser to meet spaceborne water vapor Differential Absorption Lidar transmitter requirements]. Later, I managed the Electro Optics and Controls Branch, focusing more broadly on flight electro-optical sensors and systems. Later, as associate director for Exploratory Missions at NASA Headquarters, I was responsible for managing the formation and development for all of NASA's Earth exploratory missions and went on to become the Agency's deputy chief engineer for program implementation.

After working as assistant administrator in NASA's Office of the Administrator, I went to work at the White House with the responsibility as executive director of the National Science and Technology Council. My job with the White House was only supposed to last for one year, but President Obama asked me to stay on board an extra year to help make sure our science and technology strategies properly aligned with the budget. I worked closely with OMB [Office of Management and Budget] to achieve that. It was a really incredible set of insights that shaped who I am today. Now, in my role as deputy director for technology, research, and investments, I am in charge of directing the future directions of astrophysics, Earth science, heliophysics, and planetary science missions. I am also responsible for ensuring that we have a strong technology portfolio of investments that will support those incredible science missions in the future.

In the recent Center Director Town Hall, Dr. Makenzie Lystrup posed a critical questions: How can NASA amplify the impact and extend the scope of its science? Looking towards NASA 2040, what are Goddard's planned science missions, technological objectives, and the required science and engineering investments to meet these goals?

We want to be the preeminent science organization, period. To achieve that, we are positioning Goddard to be an Earth science information hub and a climate information center. We have the expertise right here at Goddard that can really help pull the different data sets together to aid scientists in making informed decisions about our planet. So, getting to a place where NASA Goddard is providing data-based and data-driven earth science and climate data is going to be critical, not just for the future of our country but for the future of the world. So, as we look at the future science and engineering investments at Goddard, we must be very strategic about how we deploy our limited resources.

Also, as we envision the Artemis mission, which is one of the top priorities of our agency, there is a significant role for science to play. For example, if NASA is going to have humans living on another planetary body, we really have to understand the environment in which astronauts are going to be living. So, we develop instruments and missions that help us to understand the atmosphere and other parameters that will affect their ability to not only survive but thrive there.

If you read about the history of the Apollo program,

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you would have learned that on July 20, 1969, if we had gone to the Moon one week later, there might have been a totally different outcome. There was a solar event that occurred, which humans might not have survived. So here at Goddard, we are playing a major role in the heliophysics aspects of planetary exploration. Our engineers and scientists at NASA Goddard are monitoring solar events, determining potential impacts from those events, and providing warnings to the global community so that they can protect satellites and assets in space and on the ground here on Earth. They will also provide warning on hand-held devices (or heads-up visors) to the astronauts on the surface of the Moon so that they can quickly get to the safest location to survive the event.

When discussing heliophysics and Goddard's role, the focus extends beyond exploration; it encompasses understanding the Sun's influence on life on Earth, right?

Absolutely. The electromagnetic radiation that comes from solar flares can disrupt radio communications and electric power grids on Earth like we saw on the entire East Coast of North America back in 1989. NASA needs to do all that we can to understand the mechanisms that cause these solar events, because you certainly can't predict something that you don't understand. Goddard is the hub for the entire agency's efforts in heliophysics. NASA has entrusted Goddard with its new Heliophysics Strategic Technology Office (HESTO). So, we have the role of coordinating and overseeing the development of technologies and capabilities for all of the science mission directorate heliophysics missions.

What is NASA 2040 and what role does Goddard have in it?

Our NASA 2040 initiative is intended to drive a better integrated, coordinated NASA that outlines clear roles for decision-making. It outlines our budgets with our priorities. It attracts and retains the best and the brightest people. And it invests in the infrastructure and the technology that we need to move NASA forward.

When thinking about NASA 2040 and how that relates to the Artemis mission, we plan to have humans living sustainably on the Moon with planned excursions and explorations of Mars. In order for NASA to have humans living sustainably on another planetary body, we need to change the way we think about so many things. We have to create things that do not exist today, and we have to get our people ready not only to have access to those technologies and approaches but accept them. There is a difference between having access to something and fulling integrating it into your everyday life.

For example, how do you grow food sustainably on another planet, and how can you ensure that you will have clean drinking water? We also have to address health and medical practices. With the Artemis mission, we are not going to be able to take an MRI machine to Mars, so you are going to need special sensors on your body to assess what is going on inside it. We may be exposed to bacteria and viruses that we have never come in contact with before and there is no analog for them. We will need to develop AI [Artificial Intelligence] capabilities tied to special sensors that can quickly come up with the best mitigation and then use machine learning to determine the best delivery mechanism. We also need to have ways of building the habitats on other planetary bodies, and maybe that means using robots and 3-D printing.

With NASA 2040, we are not just focused on the missions of NASA today but developing the technology, infrastructure, people, budgets, and processes we will need to get us there. It means transitioning our way of thinking and being open to doing things differently today so that we can actually be in a position to realize the amazing vision later.

Regarding your leadership in NASA's Technology 2040 Vision, could you detail what this vision entails and the strategies planned to realize the ambitious goals you've outlined?

As part of NASA 2040, there are seven different work streams or visions. There is the engine, which is looking overall across of all of NASA 2040. There is the mission that is going to look at all the elements of the NASA missions that are going to be undertaken by 2040. There is the structure, that is going to look at the roles, responsibilities, and functions of everyone involved. Also, you have the infrastructure that looks at the facilities, the people involved and the budget. Finally, there is the technology, and I am its workstream leader. This workstream will focus on working digitally: seamlessly integrating new approaches and technologies to

significantly improve effectiveness, strengthen data and system security, and enable a greatly improved NASA work experience. The goal is to create a NASA of the future that embraces digital ways of working by prioritizing and accelerating transformation, integrating cutting-edge technology and advanced cybersecurity to drive missions forward, developing our people to harness these capabilities, and adopting new and more responsive tools and processes.

We will be focused on digital modernization; utilization of model-based [a mathematical, visual, and cost-effective method of designing complex systems] design approaches; artificial intelligence enhancements to institutional management and mission design and execution; integrated cybersecurity methods that protect NASA data while not impeding collaboration; and more. At Goddard we are also investing in technologies that may bring about revolutionary changes like quantum [sensors, communications, computing, and more.] It is very important for us to continue to invest in technologies today so that we can enable the advanced capabilities of tomorrow.

How does the first annual NASA Heliophysics Technology Symposium, showcasing heliophysics-related technologies and research, align with Goddard's science and engineering investment goals?

As I said earlier, one of the most important things for NASA to do is to really get to a place where we understand the mechanisms behind what is happening with the Sun. That is the only way we can get to a place where we can predict space weather, and we are still a long way from that. To do that, we need to formulate missions and invest in technologies that can help us answer the questions that have not yet been answered.

On behalf of NASA's Science Mission Directorate, Goddard is the preeminent leader of the heliophysics community. With that, we are hosting these workshops so that we can bring that community together. We are very open and interested in hearing from all those organizations out there that are developing technologies that can be applied to heliophysics missions. One of the benefits of Goddard being in the lead is that we have cross-division science capabilities. What I mean by that is, there is a lot of synergy between heliophysics and Earth science. Being able to bring those communities together gives us a more complete understanding of the interconnected nature between the Sun and the Earth. Goddard is in a very unique position to be able to inform and to do something about the challenges that we are facing in heliophysics.

Since you came on board in 2010 as deputy center director for technology and research investments, the Strategic Partnership Office and tech transfer appear to have taken on more importance and meaning at Goddard. Why is tech transfer important and how does that help meet the center's future science missions and technology goals and objectives?

Tech transfer is an area that is not fully understood or appreciated by many. We are developing technologies for our specific mission objectives, but they can also be transferred to private industry to be commercialized and used to make significant improvements in a totally different field. Sometimes these improvements can be revolutionary, improving the quality of life, for example, or providing for significant reductions in cost.

NASA intends for us to develop technologies for our missions, but also intends for us to fuel the U.S. economy. We take deliberate steps to highlight and report those technologies Goddard has developed and connect them to those people outside of NASA who have a vision and may want to commercialize it. We can work with them to determine the feasibility for commercialization, and once that is successful, they can license that technology and actually improve the quality of life for lots of people, while improving the economy.

How does Goddard plan to foster 'partnerships that really matter' with private industry, as emphasized by both you and Center Director Dr. Lystrup, to enhance its groundbreaking work?

First of all, we don't have enough resources to do all the kinds of missions that we need to do to answer the kinds of scientific questions that need to be answered. So, the only way we can do more with less is to bring other resources to the table. And so, finding people who have a common strategic objective, and who want to make the same kinds of investments that we are making

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in terms of climate, Earth science, heliophysics, planetary, astrophysics, and so many other areas is key. If we can co-invest in those kinds of missions with private industry, that is the way we get a whole lot more done for less. And when I say less, I mean each entity investing less.

I am really excited that Makenzie has encouraged us to lean forward when it comes to strategic partnerships. That includes things like potentially moving the fence line [on the Greenbelt Campus] so that we can have commercial entities that can take advantage of the land that we have to build facilities and Goddard being able to share those facilities. That means we would have very close access [to private facilities] and be able work on joint missions. That is a very different approach to the way that we have done things here at the Greenbelt Campus in the past. At Wallops, we have some experience with what you might call "research parks." Other centers like Kennedy [Space Center] and Johnson [Space Center] also have experience with these. It is about utilizing unused land and some of our facilities and providing the opportunity for private industry to take them over or lease them.

So, it sounds like partnerships are a big part of NASA 2040.

Yes, they are. NASA 2024 is looking at non-conventional ways of partnering and looking at the kinds of policies that we have in place as it relates to partnering and the procurement processes. All of that has to be looked at because the objective is to get to a place where we can be the innovative agency of the future. And we cannot do that alone. We will do that with not only our domestic partners but also our international partners.

How can private industries take advantage of what Goddard has to offer?

There are many companies making investments in space technologies and capabilities on a bet that they will be able to be infused into a NASA mission. Sometimes they will invest millions of dollars in a technology or a capability, and it will do nothing but sit on a shelf. It makes a lot more sense for us to communicate with each other and share our visions going forward, so their investments align with our investments. Goddard can invest and develop the early stage of a particular technology when private industry does not have a business case for it. But, once we get to a place where the technology is demonstrated and people can see its application, then those companies can pick it up and run with it.

Goddard is on the forefront of developing architectures to support the Distributed Systems Mission (DSM) concept relying on SmallSats. Given that multiple organizations outside of Goddard are already developing and executing DSM missions, how and why is Goddard positioned to be one of the leaders in DSM?

Our workforce at Goddard has very solid engineering experience on a full range of missions, whether it be on very small CubeSats to very large flagship missions. We understand what is necessary to make a mission successful and what exact measurements that we need to make. In the future, the agency may not have as much funding for these big flagship missions, but we have the science and engineering expertise to develop reconfigurable constellation missions, using a swarm of these smaller satellites to fly in formation to achieve many of the same objectives. The other aspect and advantage to using a swarm of satellites is that they are designed to communicate with each other and see things from a different vantagepoint as they fly past a given point. All of these intricacies require the kind of expertise that only comes from flying very complex missions, and that is where Goddard has a unique capability.

Any final thoughts?

Yes, I just think that DSM is an example of one area of technology where we at Goddard can really inspire and get people thinking outside of the box. I believe if we can give people a vision for the future, they can find ways that technology can be brought to bear to realize that vision. This will not only motivate NASA employees and the community at large but also the next generation of engineers and scientists. To me, that is very important, making sure that we have a pipeline of engineers and scientists in the future, including administrative and support staff, who help get our missions done. With the Artemis missions on the horizon and the NASA 2040 exercise underway, this is a very exciting time to be at NASA Goddard.

Five Ways to Work with Goddard's Strategic Partnership Office

Helen Keller once said, "Alone we can do so little; together we can do so much." There are many ways industry can work with Goddard's Strategic Partnership Office (SPO) and take advantage of the technology resources available to accomplish your goals. The following list of options is a great place to start:

1 **License Goddard technology.** If you think patented or patent-pending SmallSat technologies found in this magazine or on our website, *http://partnerships.gsfc.nasa.gov*, may meet your technology needs, contact SPO to learn more and begin the licensing process. First, get in touch with a Goddard technology manager to troubleshoot your requirements and agree on a suitable technology to fit your requirements. Then, fill out an application through NASA's Automated Technology Licensing Application System (ATLAS). After submitting your application in ATLAS, a staff member from Goddard's SPO will get in touch for next steps.

2 **Apply for Startup NASA.** Startup companies can take advantage of additional benefits by participating in our Startup NASA initiative. NASA waives licensing fees for participants, removing some of the barriers encountered by tech entrepreneurs looking to secure intellectual property rights. Learn more about this opportunity by contacting the SPO office at *techtransfer@gsfc.nasa.gov*.

3 **Check out our online software catalog.** Goddard has 143 programs available online to fulfill your software needs, free of charge. Categories include business systems and project management, environmental science, and data and image processing. To request NASA software, go to *https://software.nasa.gov/* and select the "Software Catalog" button. Some codes and mobile apps offer direct download, while others require a completed request form for processing through Goddard's Software Release Authority.

4 **Explore Space Act Agreements.** Established in 1958, the National Aeronautics and Space Act allows NASA to form Space Act Agreements (SAAs) with various partners to make progress on shared goals. SAAs facilitate advancements in numerous industries—for example, in 2016, Virginia Electric and Power Company signed an SAA with Goddard to allow researchers to study the effect of Geomagnetically Induced Currents (GICs) on the U.S. power grid. SAAs can play a role in license agreements by allowing Goddard scientists to support technology transfer as long as it doesn't interfere with their job responsibilities. This arrangement also permits partners to reimburse Goddard for its time.

5 **Leverage your Small Business Innovation Research or Small Business Technology Transfer (SBIR/ STTR) award.** Companies with SBIR/STTR awards or government contracts can utilize Goddard technology to enhance their research objectives. Your contracting officer or contracting officer representative can assist you in adding new technology to your list of Government Supplied Equipment.

To learn more about the **Strategic Partnerships Office**, please visit *https://partnerships.gsfc.nasa.gov*.

To connect with a technology manager, send an email to *techtransfer@gsfc.nasa.gov*.

Enhanced Mirror Coatings Will Enable Future NASA and Commercial Observatory Missions in Space

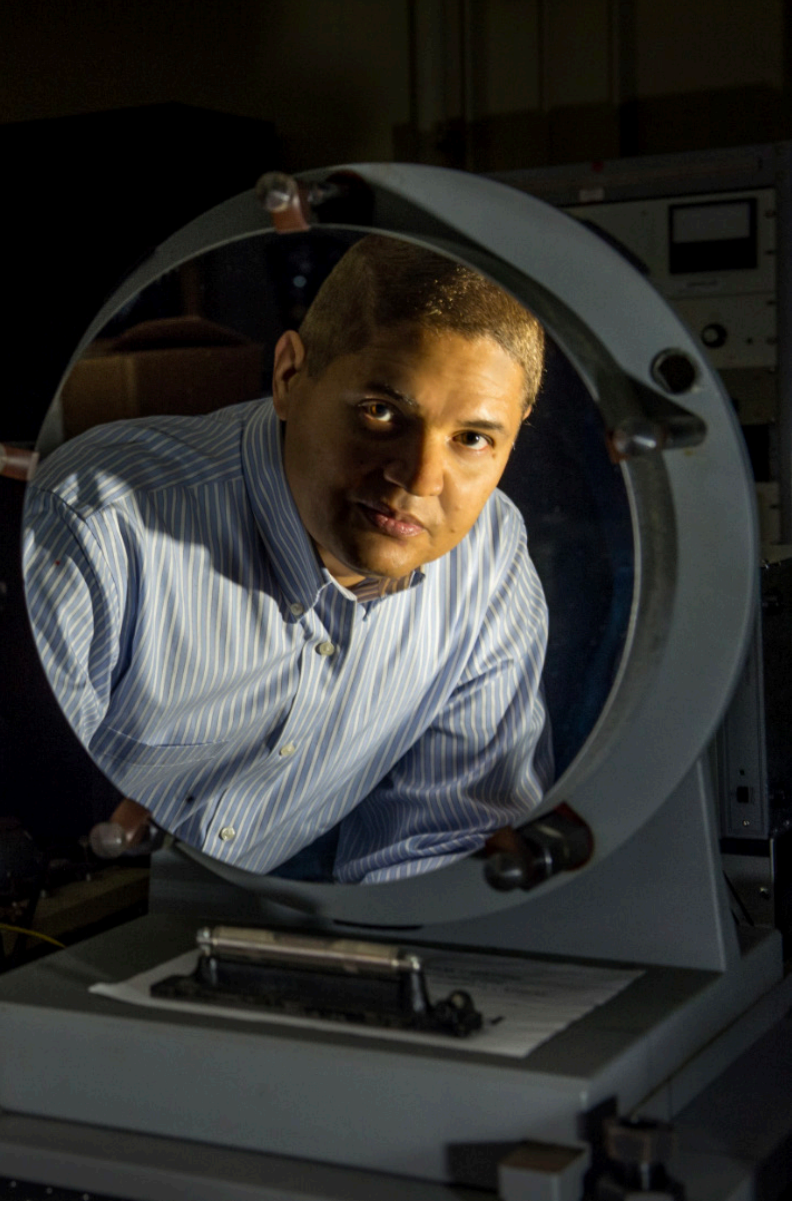
Astronomy, or the science of celestial objects, space, and the physical universe, is more easily conducted in space than on the ground. For one, there's never daytime or any light pollution to contend with; it's always night from space when you point away from the Sun. You don't have to worry about clouds, weather, or atmospheric turbulence from space.

By sending a telescope up on a satellite in space, you can observe anywhere or anything you want, all across the electromagnetic spectrum, and there's no atmosphere blocking your view. You can get an incomparably large, wide, precise field-of-view without any directional biases. In particular, due to its high density of emission lines, ultraviolet (UV) wavelengths provide unique access to some of the of the richest portions of the spectrum for astronomy. These lines provide a "fingerprint" of the material making up astrophysical objects. But there are downsides, too. For instance, performing measurements on a space telescope at far-ultraviolet (FUV) wavelength range has historically been quite difficult for several technical reasons, including poor mirror reflectance. The mirrors on a space telescope are a critical subset of the optical components essential for the success of current and future space missions.

Most space telescopes – like NASA's Chandra X-ray Observatory, the Hubble Space Telescope, and the James Webb Space Telescope – operate in diverse and harsh environments that range from low-earth orbit to interplanetary orbits and deep space. The more stable and reflective a telescope mirror is at FUV wavelengths, the better the images it can collect. In fact, the viability of the next generation of FUV-sensitive instruments heavily relies on efficient mirror surfaces and optical coatings. In practice, mirror efficiency ultimately drives the throughput and defines the achievable science return of current and future missions. Throughput is fundamental for complex space telescopes in which several reflections are required.

Unlike gold and silver coatings – which are currently used - aluminum is considered the metal with the broadest spectral coverage. In fact, pure aluminum mirrors are highly reflective to collect FUV. But aluminum is highly susceptible to oxidation. When this occurs, the telescope's optics performance degrades, resulting in a huge drop in the instrument throughput, which in turn affects the scientific return.

Therefore, to be used in space telescopes, aluminum needs to be protected from naturally occurring oxides with some thin coating of transparent material. Unfortunately, no one has been able to develop a coating that effec-



Research physicist Manuel Quijada, Photo Credit: NASA

tively protects and maintains a mirror's reflectivity in the desired 90- to 130-nanometer range, also known as the Lyman Ultraviolet. This is a spectral regime that is rich in astronomical targets, including potentially habitable planets beyond our solar system.

Luis Rodriguez (left), Edward Wollack (right), Photo Credit: NASA

A team of engineers and scientists at NASA Goddard in the Science and Exploration Directorate (Code 600) and the Engineering and Technology Directorate (Code 500) have developed a patented protective coating technique for aluminum mirrors that will significantly improve and maintain the reflectance at optical, infrared, and FUV wavelengths for space-based telescopes. The team consists of Manuel Quijada, a research physicist, Javier del Hoyo, an optical engineer, Luis Rodriguez de Marcos a research scientist and Edward Wollack, a research astrophysicist. What makes this innovation unique is that it uses a new ingredient, XeF_2 (xenon difluoride) along with the more standard LiF (lithium fluoride) to prevent oxidation.

"This coating technique that we are using was first developed in the 60s and early 70s," explained Rodriguez de Marcos. "And since then, only a few improvements in this technology have been made. But this new deposition method is different because, for the first time, a technological advancement has been made in this field by introducing a new element, in this case the XeF_2 gas. This gas has been a well-known element to process silicon-based devices, but what we have done is think out of the box and try this element in a completely different application....and it worked!"

The Goddard team believes this technique will produce more durable and less hygroscopic aluminum mirrors than the ones produced from the conventional techniques. "We have been studying the process of protecting aluminum for some time," said Quijada. "With our innovation, we have found a way to not only reduce the oxidation, but in fact to stop it from happening to begin with."

The coating technique has already been successfully used on two NASA sounding rocket programs. It is being used on the FORTIS (Far-UV Off Roland-circle Telescope for Imaging and Spectroscopy), a telescope equipped with a next-generation micro shutter array capable of imaging individual stars while simultaneously obtaining their far-UV spectra. The goal of the joint NASA-Johns Hopkins University science mission is to study massive star clusters in the star-forming Galaxy M33. It is also being used on one of the diffraction gratings of the INFUSE (INtegral Field Ultra-

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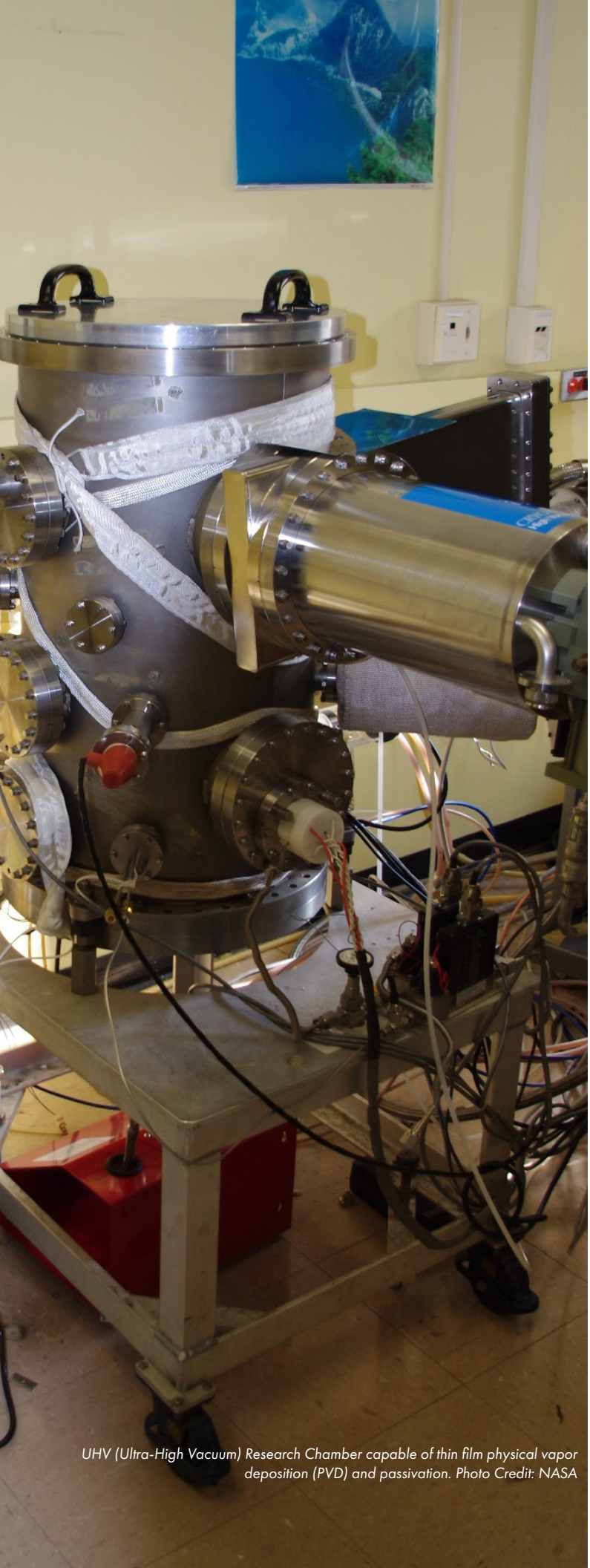
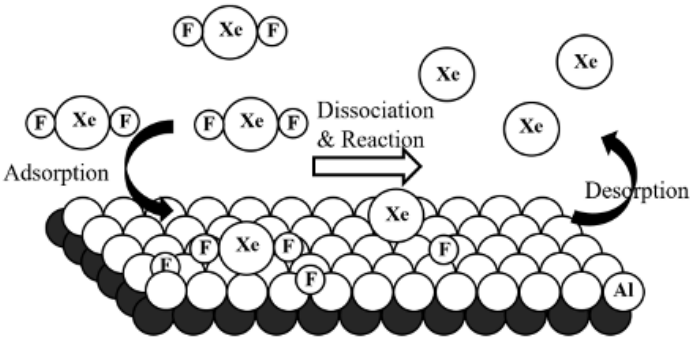


UHV (Ultra-High Vacuum) Research Chamber capable of thin film physical vapor deposition (PVD) and passivation. Photo Credit: NASA



Cartoon of coating process. Photo Credit: NASA

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violet Spectroscopic Experiment) mission, whose goal is to provide the first spectral maps of "shock velocity" remnants of the Cygnus Loop supernova.

This innovation is also being studied for use on NASA's Habitable Worlds Observatory (HWO). "HWO is going to be an observatory that searches for life in other worlds outside of our solar system," Quijada said, "There is some instrumentation onboard HWO that will also do observations of FUV wavelengths, and that is why HWO may want to use our aluminum-based coating for their optics."

Goddard's Strategic Partnership Office (SPO) sees commercial potential with this patented innovation. SPO has secured a licensing agreement with a private company that provides coating design to the astronomy community.

"NASA has made an investment in our coating innovation. It is nice see how a technology like ours can find a home in other possible applications. That is what the technology transfer process is about for me." said Wollack, who was not only one of the three 2022-2023 inductees into the NASA Technology Transfer Program's Inventors Hall of Fame, but also this year, received SPO's James Kerley Award for going above and beyond to facilitate the technology transfer process.

"Typically, when someone develops a new application or technology, users don't immediately want it because of the risk; they want it to be fully tested until they are satisfied everything is perfectly fine," said Rodriguez de Marcos. "What we found to be really remarkable is the fact that astronomers are willing to utilize this really new coating innovation, which is less than one year old, because they see the potential."

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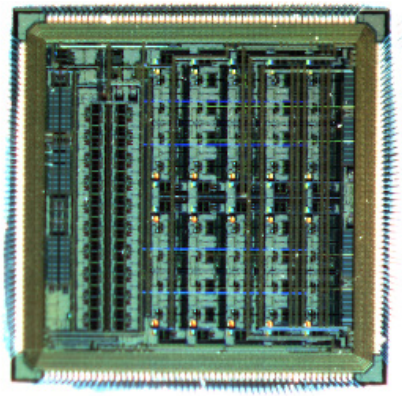


Goddard Innovators Develop Innovation to Protect Crystal Oscillators from Radiation in Space

Quartz crystal oscillators, pivotal in a wide array of devices like smartphones, GPS systems, and communication satellites, are crucial for generating precise frequencies essential for the transmission, reception, and processing of digital data. In spaceflight instrument electronics, these oscillators play a vital role in accurately sampling, digitizing, storing, and reconstructing analog signals.

A crystal oscillator is an electronic circuit that relies on the mechanical resonance of a vibrating crystal of piezoelectric material to generate an electrical signal with a precise frequency. The use of crystal oscillators to provide stable and accurate reference signals dates to the early part of the 20th century. Regardless of its application, frequency stability with time, temperature, and other environmental effects such as radiation are a critical performance metric for crystal-based oscillators.

To gain both short- and long-term frequency stability in instrumentation, a crystal oscillator is used to provide a clock signal source. The clock is a critical electronic function as it is used in digital systems to synchronize other components such as microprocessors, instrumentation, and memory chips. Over the long term – years or decades – the clock frequency must remain stable. For example, if a digital system's clock runs too slow, the processing takes longer. Conversely, if the clock runs too fast, there may not be enough time to complete the required operations before the next set begins. Even small variations in clock speed could have unpredictable consequences for internal microcontroller operations. Timing accuracy is critical not only in instruments, but also for spacecraft operation.

As spacecraft from NASA and private industry venture out farther and longer into space, they are exposed to harmful radiation effects which have both immediate and long-term deleterious implications. According to NASA, "radiation is a form of energy that is emitted in the form of rays, electromagnetic waves, and/or particles." Effects from radiation can degrade an electronics system and the clock functions on a satellite.

Two proposed NASA instrument projects targeting Europa, a moon of Jupiter – TIMERS and SEASHELS – faced challenges in sourcing commercially available, radiation-hardened crystal stabilized clock sources for their designs. 'Radiation-hardened' refers to components specifically engineered to resist the high levels of radiation in space, ensuring reliable performance in these harsh conditions. Back when these proposals were developed, there were no commercially available radiation hard by design (RHBD) clock sources that could protect crystal oscillators from radiation exposure. Designers relied instead on enclosing the electronics in lead,

titanium, and aluminum vaults or spot shielding, which increases an instrument's mass, volume, and cost.

Gerry Quilligan (left) and Terry Hurford (right). Photo Credit: NASA

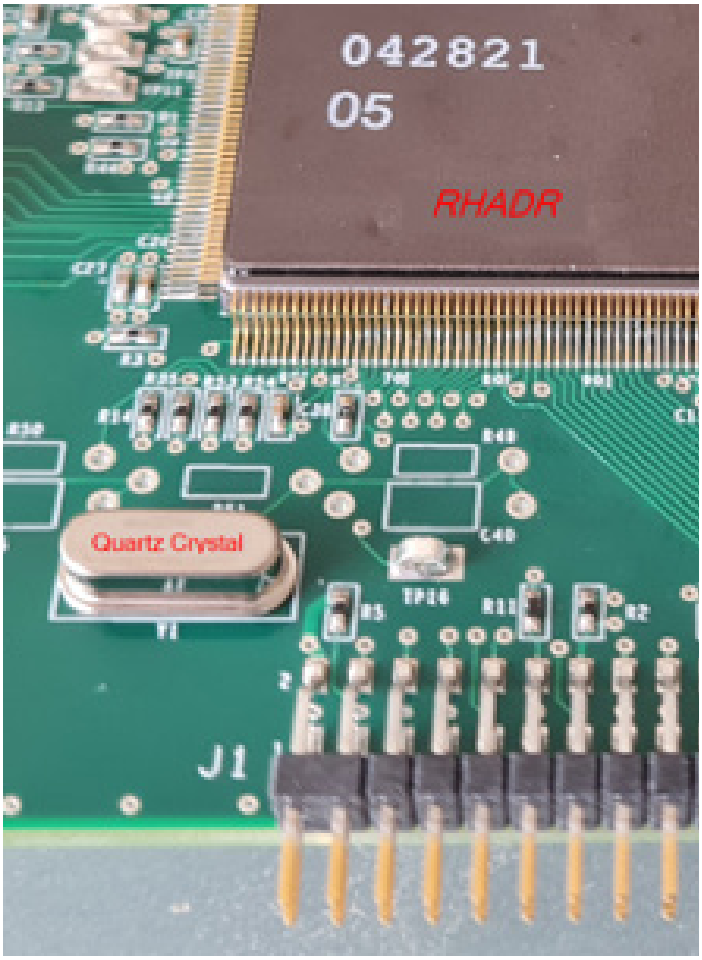
Two Goddard designers have come up with several patented solutions that work in unison to protect a crystal oscillator from radiation while keeping the clock running accurately. Gerry Quilligan, an analog mixed signal designer in the Instrument Electronics Development Branch (Code 564) and Terry Hurford, a planetary scientist in the Geology, Geophysics and Geochemistry Laboratory (Code 698) first developed the Radiation Hard Autonomous Digital Readout (RHADR) chip which includes low noise amplifiers, filters, and digitizers. The RHADR chip is an electronics component that has been tested to resist different types of radiation damage. This RHADR chip design has five separate patents associated with it.

Additionally, using RHBD design techniques, Quilligan and Hurford crafted a Complementary Metal Oxide Semiconductor (CMOS) oscillator called RHXO (radiation hard crystal oscillator), which, along with clock timing and digitizer functions, can survive a dose of at least 300,000 rad (units of radiation absorbed). Any unhardened CMOS circuit that accumulates this level of radiation will usually end its reliable lifespan. CMOS is the semiconductor technology used in most of today's integrated circuits as a foundation for computers and other electronic devices.

"We took some building blocks from earlier designs, which we already tested several years ago for radiation hardness, and we reused those blocks to build a radiation hard crystal oscillator design," explained Quilligan. "Combining the RHADR's high speed amplifier and buffer circuits with an external quartz crystal, we realized an RHBD oscillator that functions with precise frequency generation."

One key topic at the recent SmallSat Conference at Utah State University in August centered on the expansion of small satellite missions beyond low Earth orbit. The Strategic Partnership Office (SPO) sees a lot of potential commercial applications for both the RHXO and RHADR chip for NASA and private companies that are seeking to send spacecraft farther out in space.

"RHXO is a valuable function," said Quilligan. "There are a lot of new companies that are coming into the space industry today and starting to build spacecraft for missions in space. Eventually, chips using the RHXO will likely be in high demand."



RHADR with Quartz Crystal Photo Credit: NASA


GONE
IN THE
ATMOSPHERIC
WINDS

Goddard Inventors Develop Technology to Discover NO_2 in the Air

Clean air is one of the basic requirements of human heath and well-being. However, according to the World Health Organization (WHO), due to the "process of economic development," air pollution has been and continues to be a significant health hazard worldwide.

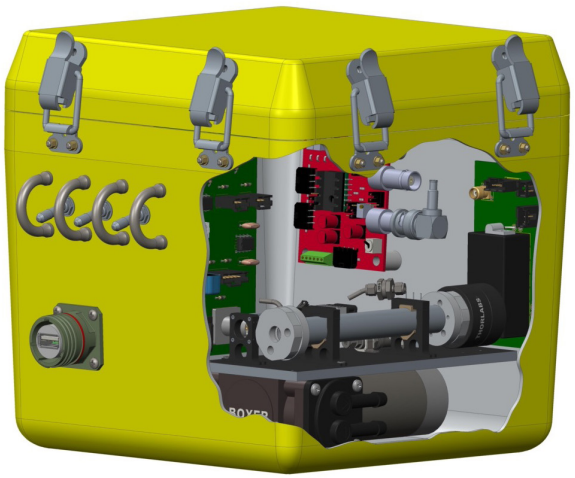
"Urban air pollution continues to rise at an alarming rate, wreaking havoc on human health," said Dr. Maria Neira, director of the Department of Public Health, Environmental and Social Determinants of Health at WHO. "At the same time, awareness is rising, and more cities are monitoring their air quality. When air quality improves, global respiratory and cardiovascular-related illnesses decrease."

There are numerous ambient air pollutants encountered in our daily life. According to the U.S. Environmental Protection Agency (EPA), one of the worst pollutants is nitrogen dioxide (NO_2). According to the EPA, "Breathing air with a high concentration of NO_2 can irritate airways in the human respiratory system. Such exposures over short periods can aggravate respiratory diseases, particularly asthma, leading to respiratory symptoms, hospital admissions, and visits to emergency rooms." NO_2 primarily gets in the air from the burning of fuel. It comes from emissions from cars, trucks and buses, power plants, and off-road equipment.

Today, there is a growing market in both the commercial private sector and the federal government for tools to accurately measure the NO_2 pollution in the air, especially in urban, industrial areas. NO_2 levels are observed from space from various existing satellites, including the Ozone Monitoring Instrument (OMI), the TROPOspheric Monitoring Instrument (TROPOMI) and the Geostationary Environment Monitoring Spectrometer (GEMS). However, these space-based measurements rely on a prior knowledge obtained from models, which vary depending on atmospheric height, leading to imprecise NO_2 measurements.

Chemiluminescence, a widely utilized technique for measuring NO_2 directly in its environment, works by detecting light emitted from a chemical reaction. When NO_2 interacts with a specific reagent, it produces a glow, the intensity of which is proportional to the NO_2 concentration, allowing for accurate measurement. This technique is especially crucial in devices such as balloon sondes and satellite probes.

Balloon sondes are instruments attached to weather balloons that ascend through the atmosphere, collecting data on various atmospheric components. Similarly, satellite probes, equipped with chemiluminescence detectors, orbit Earth and gather vital information about the composition of the atmosphere. The emitted light in the chemiluminescent reaction, induced when NO_2 reacts with specific reagents, provides a precise measure of NO_2 levels. This chemically based technique has several shortcomings. It is not very accurate, it is hard to calibrate, and the chemical mixtures are not always consistent from batch-to-batch.



Package rendering of internal components, Photo Credit: NASA

A team of engineers and scientists at NASA Goddard have come up with a solution to solve both of these problems. Steven Bailey, a computer engineer in the

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Instrument Systems and Technology Division (Code 550) and Thomas Hanisco, a research physical scientist in the Atmospheric Chemistry and Dynamics branch (Code 614) have developed the "Miniature Cavity-Enhanced Nitrogen Dioxide Sensor." This patented technology uses Cavity Enhanced Absorption Spectroscopy (CEAS) to measure the absorption of NO_2 into the atmosphere.

CEAS is a simple absorption technique that uses commercial-off-the-shelf (COTS) components and highly reflective mirrors to trap light emitting diode (LED) ultraviolet (UV) light from exiting an optical absorption cell. Once trapped, the UV light then bounces back and forth many times increasing the probability of it being absorbed by NO_2. Once the remaining light exits the cell, its intensity is measured with a photo detector. The lower the intensity, the higher the concentration of NO_2 in the cell. The higher the intensity, the lower the concentration of NO_2 in the cell.

"Our technique uses no chemicals, just optics, and a particular wavelength of light," said Bailey. "The novelty of this innovation, aside from its small size and weight, is the combination of CEAS with a simple and inexpensive optical and electrical design to achieve a high quality NO_2 measurement. This CEAS technology is much more sensitive, up to 100 times more sensitive, than those using chemiluminescence to measure NO_2. Our design is easier to calibrate and is extremely stable. We will not only get more accurate NO_2 data, but at a faster rate than current NO_2 sonde instruments."

The other novelty of the sonde CEAS technology is that it is primarily designed to be used on a scientific balloon and not a satellite or aircraft. Bailey highlighted the advantage of using balloon sondes for in situ NO_2 measurements, noting that this method would yield more precise data, thereby refining the atmospheric models utilized by satellites.

"As the balloon is rising, the CEAS technology is taking NO_2 measurement of the atmosphere, every second," explained Bailey. "That is important if you are trying to get what is called the profile of the atmosphere. An aircraft is different in that you can't go straight up to take that measurement. It can only go back and forth as it rises."

The sonde CEAS technology is presently in a Technology Readiness Level 6. A prototype has been made, demonstrated, and flown on a balloon on three test flights from the Goddard area. "We hope to fly ten of these things in the next year," said Bailey, who noted the biggest problem they have had so far is the balloon getting caught in trees as it descends.

There are three distinct methods for collecting, storing, and transmitting NO_2 data from their technology to engineers and scientists on the ground. The data can be written to an onboard secure digital (SD) card, transmitted to an external computer, or sent to an attached commercial radio sonde that then transmits the data to a ground station in real-time.

Working with the technology managers in SPO, this technology is being licensed to the SciGlob Corporation, which plans to manufacture the technology and sell it to interested air quality companies. The Columbia, Maryland headquartered science and engineering company designs air, ground, and space platforms for air quality monitoring and satellite validation.

"This sonde CEAS technology did not just happen. It took a lot of work to make it operate and work," said Bailey. "It is very encouraging and satisfying that commercial industry is interested in licensing and manufacturing it. We are still working on the CEAS sonde to make it even better."

The CEAS technology is going up in a balloon, Photo Credit: NASA

Careers and Internships at NASA Goddard

NASA's Goddard Space Flight Center (GSFC) in Greenbelt, Maryland, leads the world in scientific discovery and understanding. Goddard is the home of innovative Earth science, astrophysics, heliophysics, and planetary science. The center's diverse and talented team is responsible for each breakthrough emerging from Goddard laboratories. From high school interns to accomplished Nobel Prize winners, each member of the Goddard team plays a vital role in mission success. If you are interested in applying for employment with NASA's Goddard Space Flight Center and need special assistance or an accommodation to apply for a posted position, contact our Human Resources department at 301-286-7918.

Civil Servant Career Opportunities

NASA's Goddard Space Flight Center has a variety of opportunities for scientists, engineers, technicians, and other professionals that range from student to senior career levels. Follow the links below for more information.

- External applicants: https://www.nasa.gov/careers
- Current NASA employees: https://hr.nasa.gov/
- Current NASA Goddard employees: https://ohcm.gsfc.nasa.gov/

Student Career Opportunities

The NASA Pathways Intern Employment Program (IEP) is open to students that are currently enrolled or accepted for enrollment in a qualifying educational program. The Pathways IEP provides opportunities to work and explore careers while still in school. Pathways IEP appointments may be for indefinite periods without not-to-exceed (NTE) dates or appointments with NTE dates of up to one year. If you successfully complete an appointment without an NTE date at NASA, you may be converted to permanent employment or term employment of up to six years. For more information, please visit https://www.nasa.gov/careers/pathways.

To be eligible for NASA's IEP, you must:

- Be a U.S. citizen
- Be at least 16 years of age
- Be enrolled or accepted for enrollment on at least a half-time basis
- Be pursuing a degree or certificate
- Currently have and maintain a 2.9 grade point average
- Be able to complete at least 640 hours of work prior to completing your degree/certificate requirements
- Meet any other requirements described in the announcement (some IEP positions require you to be pursuing specific majors)

To find opportunities:

- Federal agencies must post Intern opportunities on https://www.usajobs.gov/. You may go directly to https://www.usajobs.gov/ to begin your search.
- You may review current NASA IEP vacancies at https://www.nasa.gov/careers/pathways
- You may also create an account on https://www.usajobs.gov/ and sign up to be automatically notified about vacancies meeting your interests.

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