National Aeronautics and Space Administration

TECH TRANSFER MAGAZINE IS NOW

THE

SPARK

TECH TRANSFER, PARTNERSHIPS, AND SBIR/STTR AT GODDARD

CATCH THE BREEZE

Science Soars with Aeropods and Kites

VOLUME 18 | NUMBER 2 | SPRING 2020

CONTENTS

ABOUT THE COVER

Aeropods consist of a tail boom and fin that steady data-collecting instruments, providing a stable platform from high in the sky. Instruments including cameras, spectrometers, and other kinds of sensors attach to the Aeropod, and once aloft, they can gather data while flying attached to a kite. In this image, Neil Winn of the National Park Service and Chris Cornett, a University of Maryland Eastern Shore aviation student, fly an Aeropod in the marshes of Assateague Island, Maryland.

Photo credit: NASA/Geoff Bland

OFFICE OF THE CHIEF

Here at the Strategic Partnerships Office (SPO), we like to think of ourselves as a bridge between NASA's domain of technology development for space-related scientific discovery and the private sector's commercial sphere. Though NASA's Goddard Space Flight Center is a government-owned, government-operated federal laboratory, that doesn't mean the entrepreneurial spirit is absent in the Goddard community.

In fact, at SPO, we actively encourage inventors to step outside their comfort zone occasionally and consider the potential impact of their work from a business perspective. The term "public entrepreneurship" refers to the application of the entrepreneurial approach to fostering innovation within the traditionally rigid structure and processes of public institutions.

How can we innovate and explore risky new approaches within the structure of the federal government? At Goddard, SPO fosters the spirit of public entrepreneurship through the establishment of networks and collaborative opportunities with non-traditional partner organizations, along with the exploration of innovative approaches to leveraging resources. These external collaboration opportunities can provide a venue for our scientists and engineers to explore riskier technology development paths in parallel to their Agency project support.

Having that safe venue to "fail quickly, fail fast, and fail cheaply" can provide valuable learning opportunities that can ultimately promote technology breakthroughs. I believe everyone could benefit from adopting the entrepreneurial mindset from time to time.

In this issue of *The Spark*, we share a new method for transferring the nanomaterial graphene. The method was invented by Goddard engineer Mahmooda Sultana, who demonstrates the power of the entrepreneurial spirit in her work. She's received numerous funding awards for her technology proposals, and in 2017, she was named Goddard's Innovator of the Year. We also catch up with Geoff Bland, another brilliant NASA engineer who co-invented the Aeropod, a passive remote sensing technology that leverages kites to collect data. Finally, we talk to Technology Manager Dennis Small about his work with professional athletes, and we take a look at Goddard's history with a story about prolific inventor James Kerley.

Public entrepreneurship is all about trying new approaches and taking challenges head-on. I hope these stories of innovation and ingenuity inspire you to spend more time thinking like an entrepreneur.

Daryl Mitchell

Darryl R. Mitchell, Chief

Strategic Partnerships Office
NASA's Goddard Space Flight Center

NEWS

GODDARD INNOVATORS FEATURED IN NASA TECHNOLOGY TRANSFER PROGRAM INVENTOR HALL OF FAME

NASA celebrates legendary innovators through the Inventors Hall of Fame, an initiative headed by the NASA Technology Transfer Program. Without the brilliant minds who envision and design NASA technologies, commercialization wouldn't be possible.

The newly relaunched Inventors Hall of Fame website features several prominent Goddard innovators, including Frank Cepollina, George Alcorn, Mike Hinchey, and John Vranish.

George Alcorn joined Goddard in 1978 and invented a smaller, more sensitive X-ray spectrometer that improved the way scientists gather data on faraway solar systems. As an African American physicist, engineer, and educator, Alcorn encouraged Goddard to hire more women and minorities, earning him the NASA Equal Opportunity Medal, among other prestigious awards.

Frank Cepollina, better known by his nickname "Cepi," worked at Goddard on engineering solutions for spacecraft and satellites. Known as "the father of on-orbit servicing," Cepollina led a team that designed and built custom instruments that corrected the Hubble Space Telescope's flawed optics.

Mike Hinchey worked at NASA for decades to develop reliable, verifiable software that can be changed and adapted as needed. He served as director of the NASA Software Engineering Laboratory, focusing on self-adaptive software suitable for exploration missions.

John Vranish holds 37 U.S. patents and won Goddard Inventor of the Year six times. His "capaciflector" alone has eight patents with multiple commercial licenses. His inventions span many technology categories, from electronics to mechanics, and his "3D sprag" technology was demonstrated on the John Glenn Shuttle Flight mission in 1998.

Learn about these inventors and more here: *https://technology.nasa.gov/ihof/*

Photo Credit: NASA/Bill Hrybyk

Photo: Frank Cepollina and Kathryn Sullivan discuss robotic refueling at the 2012 Goddard Memorial Symposium.

ON THE MOVE

Goddard engineer invents new graphene transfer method

Mahmooda Sultana has worked with graphene and other nanomaterials for nine years at Goddard.

Photo Credit: NASA/Bill Hrybyk

Carbon is an element known for its versatility. Carbon atoms bond with hydrogen, oxygen, nitrogen, and other atoms to stitch together the fabric of the human body. Strong, carbon-based bonds bring structure to every organic component necessary for life, including muscle cells, neurons, proteins, and hormones. Thanks to carbon, your eyes can read this article and your brain can process the information.

While carbon is abundant in organic compounds, it's also found in the realm of inorganic materials. When carbon atoms bond with each other in a specific way, they can form diamonds. With a different arrangement, the atoms can configure into graphite, the "lead" of modern pencils.

Researchers at NASA's Goddard Space Flight Center are studying a different form of carbon called graphene, a one-atom-layer-thick structure with remarkable properties that make it well-suited for space applications. Graphene also has commercial applications in circuits, solar cells, medical devices, and other fields.

Goddard engineer Mahmooda Sultana, who has worked extensively with graphene and other nanomaterials during her nine years at NASA, has invented a new way to transfer an atom-thin sheet of graphene from a growth substrate to its intended destination. With this new method, graphene transfer is faster, less error-prone, and scalable for larger production.

GRAPHENE ADVANTAGE

"When I first came to Goddard, I was fascinated by all the space missions happening here," Sultana says. "I wanted to work on flight missions, but at the same time, I also wanted to look for new technologies that could open the door to entirely new kinds of missions that had never been done before."

Sultana worked with nanomaterials while pursuing her Ph.D., so when she came across graphene, it piqued her interest. With a strong background in thermodynamics and kinetics, Sultana leads NASA's efforts to research and produce graphene. She's succeeded at making high-quality, large-area graphene in her lab at Goddard.

Graphene continues to attract interest around the world. A 2019 article in the journal Nature Nanotechnology describes a "wealth of graphene research, patents, and applications" published over the past decade. Already, graphene can be found in commercial products, with early examples including automotive coatings and touch screens.

Graphene's carbon atoms bond with each other to form a lattice of hexagons. This 2D structure outcompetes other commonly used materials on several measures – it's harder than diamonds, stronger than steel, and more conductive than copper. Since carbon is everywhere, it's an easy resource to obtain.

Transparent to the human eye and one million times thinner than a human hair, graphene is one of the most promising nanotechnologies currently being studied. Sultana has received funding from Goddard's Internal Research and Development (IRAD) program to develop graphene-based detectors and other instruments for spacecraft.

FORMING A BOND

While making devices from 2D materials, Sultana says she deals with two main challenges. To create 2D materials such as graphene, an engineer must grow the 2D material on a metal substrate, typically made of copper foil. Once a layer of graphene has formed on both sides of the foil, the engineer must transfer the graphene from its original growth platform to its final substrate as part of a device.

"This transfer process is just as critical as the growth process, if not more," Sultana says.

When she first started growing graphene, Sultana completed most of the steps by hand. She added a coating of acrylic to the graphene and then used an acid solution to dissolve or "etch" the copper foil away from the graphene, leaving the graphene to float free-standing in liquid. At this point, she manually picked up the graphene with a glass slide and placed the entire slide in a water solution that removed the residual acid and copper.

"You have to repeat this step many times to remove the acid and copper residues completely," Sultana explains.

In the final step, Sultana had to place the graphene on its final substrate, removing the acrylic layer and allowing the graphene to bond to its new surface. The whole process took days and involved intensive attention, with human intervention required at multiple points during the process.

Repeated handling of the graphene also resulted in a greater amount of defects – instead of lying perfectly flat, the graphene developed folds and holes, reducing its quality and effectiveness.

"Because this process was so labor-intensive and time-consuming, I was motivated to think about a better approach," Sultana says.

FAST AND SCALABLE

Sultana's graphene transfer method removes a degree of human error from the equation. With her new approach, she floats the graphene in a series of liquids that flow into a container and then drain from it. These liquids etch the various substrates and residues until only the graphene remains, ready to bond with its final surface. The entire process can be automated, leading to fewer defects by eliminating the need to move the graphene by hand.

In order to stick tightly to its final transfer substrate, the graphene must lie completely flat. That's because it attaches to substrates through a phenomenon in molecular physics called van der Waals forces. On a molecular level, graphene interacts with the atoms of a substrate's surface, conforming tightly to the surface topology. Folds can keep the material from adhering properly, preventing the graphene from bonding to its substrate.

When the graphene grows with no defects, "it's incredibly stable," Sultana says. "It's not going to come off." The new method also reduces the amount of time it takes to transfer graphene. Through automation, the process can take place without a technician physically present to complete the necessary steps.

Sultana's method has one additional benefit – it's scalable.

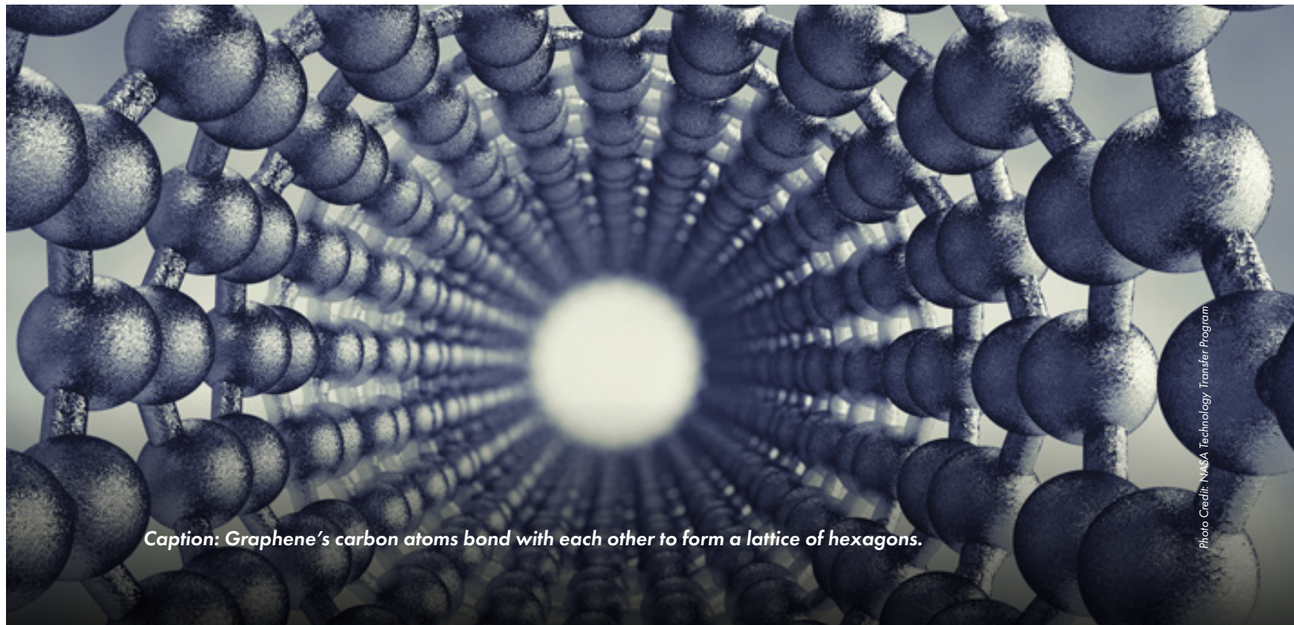
"When I manually take the graphene piece out using a glass slide, I can typically only handle a 1-centimeter-by-1-centimeter sample," Sultana says. "With this new system, you can transfer much larger pieces with significantly fewer defects."

PROMISE OF NANOMATERIALS

Sultana says she's excited about the future use of graphene and other nanomaterials for space instruments, though she acknowledges that leaps in technology development take time to unfold. As graphene use accelerates in the private sector, Sultana says that her patent-pending graphene transfer method has applications for companies interested in manufacturing and supplying large-area graphene.

The transfer method also fits well with businesses focused on applications for 2D materials, including companies that produce solar cells, sensors, or water purification systems.

For those interested in licensing or learning more about Sultana's graphene transfer method, please



Caption: Graphene's carbon atoms bond with each other to form a lattice of hexagons.

Photo Credit: NASA Technology Transfer Program

INNOVATOR HIGHLIGHT

Growing up in Cheverly, Maryland with a NASA inventor for a father, the five Kerley kids learned to expect the unexpected. A normal activity like fixing a broken car could turn into an engineering experiment when it involved James J. Kerley, Jr., who was an engineer at NASA's Goddard Space Flight Center for nearly 30 years.

His eldest daughter, Catherine Kerley Castellan, recalls asking her dad for help with her 1964 Plymouth Barracuda, which was experiencing a strange vibration issue. Jim Kerley specialized in minimizing vibration throughout his career, applying his techniques to both sedans and spacecraft. Always favoring the hands-on approach, Jim Kerley was not the kind of person to call a mechanic or wait to see if the problem worsened.

Instead, he brought an oscilloscope home from his Goddard office one day and had Catherine drive the car while he sat in the back seat. As she drove, he threw open the car door and held the instrument outside to measure the car's vibration patterns. Though unconventional, his solution worked. After fixing the problem, the car continued on its merry way, vibration free.

"He would always tell us, 'You have to feel it,'" says Bernadette Maertens, Jim Kerley's youngest daughter. "With him, it was always hands-on. He knew that was the best way to identify issues and come up with different ideas."

As an inventor, husband, father, and involved member of his community and church, Jim Kerley infused innovation into everything he did. It didn't matter if he was building an elaborate set for a theater production or designing a scaffold for a rocket. Problems existed to be solved in creative and unusual ways. Ideas sprouted from his mind one after the other in quick succession. His inventiveness resulted in 25 U.S. patents and four Canadian patents to his name, spread out between the early years of running his own business, Kerley Engineering, and the decades that followed at NASA.

Despite his robust portfolio of inventions, Jim Kerley never sought the spotlight. Instead, he reflected the light on others by teaching them and inspiring them to seek patents for their own work.

"The hallmark of engineering has always been creative, inventive design," Jim Kerley wrote in course materials for one of his NASA classes, published the year he passed away at age 73. True to his words, he embraced creativity and encouraged others along the way.

EARLY DAYS

Born in 1920, Jim Kerley grew up in Pennsylvania, where his father, James. J. Kerley, Sr., worked on bridges and post offices as an engineer. Jim Kerley's mother, a teacher, helped him with his schoolwork and church memorization. Full of pent-up energy, young Jim Kerley found it challenging to sit still in a chair until he finished his homework.

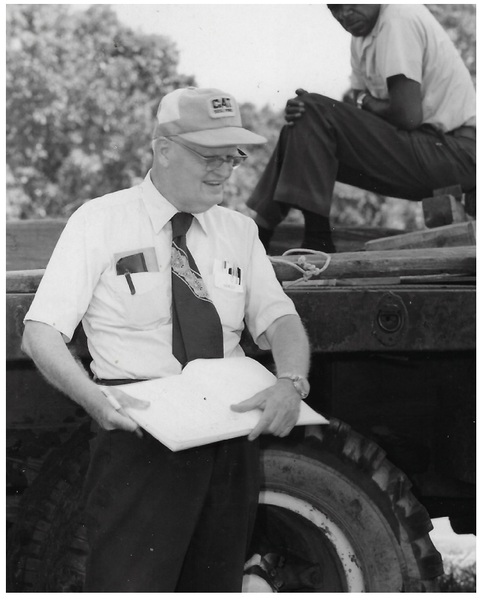
Catherine Castellan remembers her father commiserating with her when she worked on her own assignments. "He said that he technically sat in that chair, but he was up over the chair, under the chair, around the chair, and through the chair," she laughs.

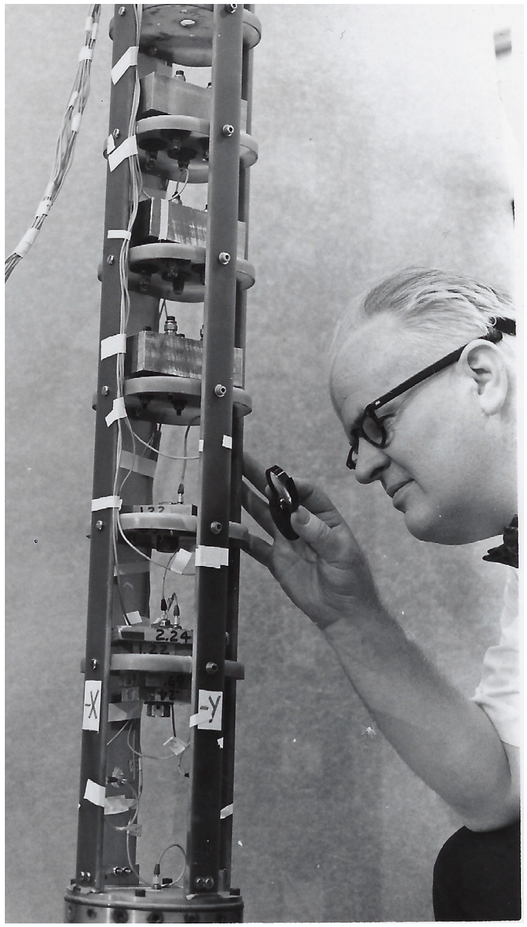
Jim Kerley and his brother, Tom, moved around Pennsylvania for their dad's engineering work. They spent their free time roaming through the woods and climbing trees. The brothers' frequent moves across the state meant that by the time they graduated high school, they had perfected the art of making new friends, a skill Jim carried with him for the rest of his life.

Jim Kerley followed in his father's footsteps by attending Dartmouth College and graduating with an engineering degree. Jim and his brother Tom both served in World War II, Jim in the Navy and Tom as a fighter pilot with the Army Air Forces. After the war, Jim Kerley held several engineering jobs, first with Lockheed in California, then with two other firms in the Washington, D.C. metro area.

In the late 1940s, Jim Kerley met Mary Bier as part of a theater group at Sacred Heart Church in Washington, D.C. Initially bonding over their love of theater, they married within a few years of meeting.

Jim opened Kerley Engineering in the mid-1950s, coinciding with a flurry of patent applications. From 1959 to 1968, the United States Patent and





Jim Kerley has 25 U.S. patents and four Canadian patents to his name, spread out between the early years of running his business and the decades that followed at NASA. Photos courtesy of the Kerley family.

Trademark Office issued 16 patents with Jim Kerley's name on them.

GOOD VIBRATIONS

A glance at his many patent titles reveals one key word: vibration. Much of Jim Kerley's work focused on the concept of vibration and how to stop it from interfering with a machine's function. In a car, too much vibration can break delicate instrumentation or cause discomfort to the driver. In a spacecraft, unwanted vibration can shake nuts and bolts loose, causing parts to come unfastened.

Jim Kerley designed different kinds of isolators, built to protect fragile components from vibration damage. The cable isolator was one of his signature designs that he adapted and updated throughout his career.

"He always told me that you can get strength and flexibility from cables," says Bernadette Maertens, an engineer like her father. "Those tend to be two contradictory properties. These days, it's very common in engineering to use cables in isolator designs, but back then it was groundbreaking."

The Kerley kids say that Jim built prototypes of his designs in the family basement. It wasn't unusual to hear him drilling through the concrete floor with a prototype jackhammer as he perfected the efficacy of his isolation mechanism.

"There'd be 20 to 30 holes in the basement floor where he tested his final solution," says Vincent Kerley, Jim's eldest son.

As the Kerley family grew – Vincent was soon joined by siblings Mary (who recently passed away), Catherine, Joe, and Bernadette – Jim questioned his decision to open his own business. His true passion dwelled in the grand process of invention, and the mundane aspects of running a business lacked the same appeal.

"He was an inventor, not a businessman," says Joe Kerley, Jim Kerley's youngest son. "He went through some struggling years and got to the point where he said, 'I can't do this anymore.'"

The private sector lost a business, but as a result, NASA gained a prolific inventor.

'IF YOU'VE GOT A JOB TO DO, DO IT'

Jim Kerley joined the Goddard community in the mid-1960s, and his timing couldn't have been better. In 1969, Apollo 11 landed on the Moon, and the space program continued to push exploration boundaries in the decades to follow.

Now free from the business world, Jim Kerley applied his disciplined work ethic to NASA's biggest engineering problems. His expertise in vibration meshed well with NASA's needs – rocket launches violently shake spacecraft bound for orbit, risking damage to the complicated instruments inside. All NASA instruments and spacecraft undergo rigorous testing before launch, including vibration tests to verify the structure's stability.

Jim Kerley lived by the motto, "If you've got a job to do, do it," and he brought that ethos to NASA.

"The government had never seen the likes of him," Joe Kerley laughs. "He didn't know what a regular schedule was. If things needed extra attention, he was just there." Jim Kerley sported a distinctive look in the office that featured several kinds of plaid and a big bow tie. When solving a problem at work or at home, he would jump into projects head-first, even if it meant getting plaster or photography dye on his clothes.

Instead of keeping up with the latest fashion, he focused on his engineering prowess. From test chambers to rocket scaffolding and bolted joints, Jim Kerley seemed interested in everything going on at NASA. He jumped into the fray wherever he could make a difference. During the testing of the Hubble Space Telescope, Jim Kerley found a cost-effective way to build an addition to Goddard's test chamber, allowing it to accommodate the giant spacecraft.

When Jim was asked to produce a report on the mechanism by which nuts and bolts shake loose during vibration, Peter Zemanick with the American Society of Mechanical Engineers praised Jim's expertise and experience. "The work to date shows strong evidence of Mr. Kerley's background as a dynamicist and a careful experimentalist," Zemanick wrote.

INVENTIVE DESIGN

Ever modest, Jim believed that inventiveness could be taught. He developed his own theories on education from studying the teachings of Aristotle and Socrates, an intellectual journey he took when teaching his daughter Catherine reading and math after she struggled with the subjects in school.

"It was because of his legacy that I earned my Ph.D. in education," Catherine Castellan says. "Not only did he teach me how to read and do math, but he taught me how to teach."

In the later years of his life, he taught a course at NASA that focused on mastering the process of innovative thinking. In the course materials for his class, he wrote at length about the thinking process, applying his educational theories to inspire better science and engineering outcomes. In his view, American thinking had lost some of its ingenuity, and he was determined to reverse the trend.

"Modern education does not prepare the students for the real world because it trains the students to be deductive with convergent thinking, but it does not train them to be creative with inductive or innovative thinking," Jim wrote. He challenged the idea that invention is a process "left to chance or happenstance," and his course introduced a methodical approach to invention that harnessed the human mind's ability to think.

"In other words," he wrote, "anyone can do it – if they can think and understand how they think! That's a tremendous concept!"

TECHNOLOGY TRANSFER

Jim Kerley's final decade at NASA focused on exploring the full range of applications for his innovations. Starting in 1988, Jim Kerley filed seven patent applications with diverse titles, including "Robot Cable-Compliant Devices" and a "Page Turning System." Some of these inventions aimed to assist people with disabilities, including a "Compliant Walker" consisting of a harness and cable system that could provide support to patients during physical therapy.

According to an article in the 2003 edition of NASA's Spinoff publication, Jim Kerley worked with Goddard engineers Wayne Ecklund and Allen Crane to adapt the design from his work on cable-compliant mechanisms for sounding rocket assemblies and robotics.

"Suffering from severe arthritis himself, Kerley knew that alleviating the weight on the legs was an important part of pain management," the article says. "The technology allowed the harness to control the pelvis, providing support and stability with compliance that mimicked the movement of the hip joint."

In 2002, Enduro Medical Technology licensed the design and created the Secure Ambulation Module for commercial use. Five years later, the company adapted the design for veterinary medicine. Their device for horses supports the animal's weight and gives it time to recover in an upright position post-surgery.

Even though Jim Kerley didn't love running his own business, he saw immense value in NASA's technology transfer program.

"He wanted people to realize that the technologies developed to build the space program and land a man on the Moon directly benefit citizens today," Bernadette Maertens says. "He was always so enthusiastic about the whole program and he shared all of that with us kids." Jim Kerley passed away in 1994. A pamphlet from his memorial service at NASA includes a favorite quote of his: "The inventor never quits."

Goddard has celebrated Jim's legacy each year since his passing with the James Kerley Award, given annually to Goddard inventors who demonstrate extraordinary commitment to technology development and commercialization. His passion for invention lives on in the minds of NASA's most innovative thinkers.

"NASA allowed Jim Kerley to be Jim Kerley," Catherine Castellan says. "That was a gift to us as his children, because we had a dad who got to do what he loved."

Thank you to Vincent Kerley, Catherine Castellan, Joe Kerley, and Bernadette Maertens, whose generous contributions of their time and memories made this story possible. Quotes have been edited for clarity.

> "THE INVENTOR NEVER QUITS."

Q&A w/TECH MANAGER

NASA is full of passionate people, and though everyone at NASA loves space, there's plenty of room for other interests. "I've always loved sports," says Dennis Small, a technology manager with the Strategic Partnerships Office (SPO) at NASA's Goddard Space Flight Center. "Since I began playing organized ball in Baltimore City, the love of the game has never changed." Small found a way to merge his love for space and sports by leading the NASA Commercialization Training Camp, an agency-wide initiative started by Goddard to introduce professional athletes to technology transfer and commercialization. The program is in its second year, with multiple cohorts of athletes completing the training. As a technology manager at Goddard, Small facilitates technology licensing and partnerships, and through workshops like the NASA Commercialization Training Camp, he finds creative ways to achieve these goals. *The Spark* magazine recently caught up with Small to ask him about his work at NASA.

WHAT DID YOU DO AT NASA BEFORE BECOMING A TECHNOLOGY MANAGER AT GODDARD?

Before becoming a technology manager, I worked in the area of ground systems development. I was the government lead working with teams that develop mission control centers for Goddard-led missions. I served as Mission Operation Implementation Manager for the Fermi Gamma-ray Space Telescope mission. Once that mission was in maintenance, I served as the Earth Observing System Mission Operations System (EMOS) Manager. I was responsible for maintenance and enhancement of the highly complex telemetry and command (T&C) ground system, as well as online and analysis subsystems needed for planning, analysis, and real-time operational support for the Aqua, Aura, Terra, and TRMM missions.

WHY IS IT IMPORTANT FOR NASA TO PARTICIPATE IN TECHNOLOGY TRANSFER?

Technology transfer is the process by which existing knowledge, facilities, or capabilities developed under federal research and development (R&D) funding are utilized to fulfill public and private needs. NASA's participation in technology transfer helps the nation's economy. At Goddard, there are close to 200 new technologies reported every year created by the brightest scientists and engineers in the world. In some cases with further R&D of spacecraft, instruments, and software could lead to the development of new technologies called spinoffs, which create new businesses that lead to new jobs. Technology transfer also helps NASA establish partnerships with industry and universities in areas of mutual technology interests.

WHAT DO YOU ENJOY MOST ABOUT BEING A TECHNOLOGY MANAGER AT GODDARD?

What I enjoy about this job is it incorporates all that I love to do. I get the opportunity to learn about new technologies. I get the opportunity to meet and work with some of the greatest minds in the world. Finally yet importantly, I have the opportunity to reach out to industry, colleges, high schools, grade schools, students, and the community to talk about what I do and how the Strategic Partnerships Office is beneficial to them and NASA.

DENNIS SMALL

WHAT IS THE NASA COMMERCIALIZATION TRAINING CAMP AND HOW DID YOU GET INVOLVED?

The NASA Commercialization Training Camp is a three-day workshop at a NASA center where professional athletes learn about NASA programs that are available to entrepreneurs interested in utilizing NASA technology to create businesses. At the camp, they learn about our programs such as technology transfer, Small Business Innovation Research/Small Business Technology Transfer (SBIR/STTR), licensing of NASA technology, and other programs, such as Startup NASA. They also gain the opportunity to speak with former athletes who began their own startup businesses using NASA technologies.

I got involved through former SPO Chief Nona Cheeks, who had a conversation with Dave Naves, a former Harlem Globetrotter and board member of National Basketball Retired Players Association (NBRPA). Dave also worked in our office years ago. Nona and Dave discussed how a collaboration between NASA and NBRPA would be beneficial to both parties. NASA would license its technologies, and the NBRPA would have technology startup companies founded by its members. Since Nona knew of my love for sports, she asked me to draft the Space Act Agreement. And as they say, "the rest is history." Following this success, we now have agreements with the National Football League Players Association (NFLPA), the National Basketball Players Association (NBPA), and the Women's National Basketball Players Association (WNBPA).

Photo Credit: NASA/Johnson Space Center/Bill Stafford

Caption: Attendees of the NASA Commercialization Training Camp celebrate with Dennis Small (back row, third from the right) in February 2020 at NASA's Johnson Space Center in Houston, Texas.

HOW DOES THE TRAINING CAMP SUPPORT ATHLETES WHO ARE SEEKING A SECOND CAREER IN ENTREPRENEURSHIP?
Athletes get a great deal of support from the training camp. Besides learning about NASA programs available to entrepreneurs for licensing technologies, NASA will work with them through the licensing process if they select a technology from NASA's portfolio. At camp, they receive instruction from business professionals on business decision-making. They hear from venture capitalists and economic development professionals on startup business opportunities in their areas. They also talk with athletes that have gone through the training camp and have started businesses using NASA technologies. The camp participants gain access to a business development program run by our partner FedTech, and they receive detailed instruction on further developing their startup business ideas.

The training camp athletes become members of a cohort of professional athletes that have participated in the training. As part of this cohort, they can discuss business ideas and talk about life after the game, which we like to call "The Fifth Quarter."

WHAT RESULTS HAVE YOU SEEN AS A RESULT OF THE NASA COMMERCIALIZATION TRAINING CAMP?
We've had great results from the program. We have two athletes working with NASA centers to license technologies. We have an NBA player working on a prototype basketball shoe utilizing a NASA material technology. We have two members of the cohort that want to return to the training camp with business partners.

I'll also mention that we had a waiting list of NFL athletes wanting to take part in NASA's February 2020 training camp, which is great news for the program! The good word of the program is spreading. As the word spreads, there is more opportunity to get more NASA technology to market to boost the economy. NASA's Johnson Space Center hosted the February 2020 NASA Commercialization Training Camp, and they did a spectacular job.

In addition, the NFLPA thinks so highly of the program that they want to extend the partnership five years, which is a huge win for both parties.

WHICH NASA SPINOFF IS YOUR FAVORITE, AND WHY?
I know this may seem like a copout, but I don't have a favorite, and that's because year after year, there are outstanding technologies developed at NASA. The technologies that are spinoffs help society as a whole. I am just whole-heartedly blessed that I am on the frontline, making it happen.

HOW CAN PEOPLE LEARN MORE ABOUT TECHNOLOGY TRANSFER OR GET INVOLVED?
I would first recommend that they visit the *NASA Home and City website* so they will see how NASA technology affects their everyday lives. I'm sure they will be amazed by all the products that started out as NASA technology. Once they get a taste of innovation, I would direct them to the *NASA Technology Transfer Program's website*, where they will learn about the licensing process that can lead to the creation of new businesses. I would also suggest visiting the *Federal Laboratory Consortium for Technology Transfer's website*, which has information on what other federal labs are doing in tech transfer.

UP WHERE THE AIR IS CLEAR

NASA technology helps gather data from the skies

Riding aloft in a tethered hot air balloon floating over Paris, French photographer Gaspard-Félix Tournachon must have rejoiced when he first saw the towering Notre Dame Cathedral and glittering Seine River from above. In 1858, he snapped the first aerial photograph ever taken, according to a 2014 article in *The New Yorker*.

Brave souls such as Tournachon had to drag their clunky photography equipment into a hot air balloon basket and stage carefully orchestrated photoshoots from thousands of feet in the air. As camera technology improved, these early forays into remote sensing evolved to rely on kites, allowing photographers to stay safely on the ground. In 1912, French inventor Pierre Picavet designed the Picavet suspension method, which employed pulleys and two bars in the shape of a cross to hang a camera from a flying kite.

Nearly 100 years later, NASA engineers Geoff Bland and Ted Miles decided Picavet's design was ready for an update. They invented the *Aeropod*, a lightweight, inexpensive structure that stabilizes science instruments. Aeropods easily attach to kites, making the whole operation low-cost and relatively simple to execute. Patented in 2012, Aeropods have been used in a number of scientific studies, with research topics spanning diverse fields such as volcanology and air pollution. On top of that, Aeropods are part of a robust education program that makes remote sensing and in-situ measurements accessible to students.

Step aside, satellites and drones – with the right modifications, kites can be valuable tools for science.

GO FLY A KITE
The beauty of the Aeropod lies in its streamlined simplicity. The device consists of a tail boom and fin that steady data-collecting instruments, providing a stable platform from high in the sky. Instruments including cameras, spectrometers, and other kinds of sensors attach to the Aeropod, and once aloft, they can gather data while flying with the kite. The original Aeropod design featured balsa fins, plywood and spruce construction, but 3D-printed plastic parts and foam-core fins are important components. Spruce is still the choice for most tail structural booms due to its reliable combination of strength, stiffness, and lightness, but other materials can be used as well.

When the kite takes to the air, the Aeropod follows, flying about 15 feet from the kite line and typically 100 feet below the kite. Though it only takes about 10 minutes to put the Aeropod in flight, it takes around 45 minutes to get it back down. The whole process can be completed in a few hours, including pre- and post-flight briefings in which team members plan and review the missions to provide suggestions for improvements.

Photo below: An Aeropod takes flight over Chincoteague Bay.

Photo Credit: NASA/Geoff Bland

"It's the iterative process of engineering on full display," Bland says.

Bland, Aeropod's co-inventor, has immersed himself in the world of unmanned aircraft technologies for decades at Goddard Space Flight Center's *Wallops Flight Facility* in Wallops Island, Virginia. He explores new ways to collect remote sensing data without the expense and complexity of putting a satellite into orbit.

"I've worked with tethered balloons, kites – basically anything that will allow us to get quick access to our observations," Bland says.

Bland and Miles invented the Aeropod to improve on the old Picavet suspension system and to create a new platform that takes advantage of aerodynamic principles. The older technology was "cantankerous and heavy, in our experience," Bland says, leading them to try out new designs that could achieve their objectives.

IN THE FIELD

Work on the Aeropod design began in 2008, and the "Aerodynamically Stabilized Instrument Platform" received a patent in 2012. Since then, hundreds of Aeropods have taken flight.

"One thing I appreciate about the Aeropod is that it's really versatile," says Kay Rufty, an associate scientist who has led education-related efforts with the technology. "Our only real restriction is weight, so if you have an instrument that weighs less than a pound, we can make a 3D mount and fly it. You can gather so many types of data on this one platform."

Aerial photography is one example. Just like Tournachon in his hot air balloon, scientists can mount a compact action camera onto an Aeropod and send it soaring with the help of a kite. The camera takes video or still images from high above, which scientists can use to track changes in topography and landscape through multiple flights.

A typical Aeropod mission can unfold over the course of an afternoon. Missions require at least two people, but teams of four are ideal, Bland says. As with any NASA mission, safety is the top priority. Wearing appropriate personal protective equipment (PPE) such as gloves and closed-toe shoes is mandatory.

Contrary to popular film depictions of kite-flying, "the number one rule is 'No Running,'" Bland shares. "You need one person to fly the kite by hand and a payload operator to control the instrument and run all necessary checks."

Aeropod operators need favorable weather to conduct a mission. Rufty says they look for sunny, slightly windy conditions, with wind speeds somewhere between 6-14 miles per hour.

"If it's too low we can't fly, and if it's too high, it becomes dangerous because the strings can cut your hands," Rufty explains.

Wide open fields make ideal flight locations, typically a park or sports field that doesn't have any power lines nearby. Bland and Rufty have conducted missions at Wallops, which has vast quantities of open area as a restricted airspace. The University of Maryland Eastern Shore, which features Aeropods in its engineering and aviation classes, has provided a dependable venue.

Rufty says they've flown Aeropods on the pier of the *Chesapeake Bay Environmental Center*, which is a partner of the Aeropods program. The coastal area in Grasonville, Maryland offers a gusty sea breeze and lacks trees that can get in the way of kite-flying.

"As long as you don't accidentally step off the pier, it's a really great flying site!" she laughs.

VOLCANOES AND LANDFILLS

Bland has helped collect data for researchers in a variety of scientific fields, but some of his favorite examples involve challenging or unusual circumstances. On a trip to Turrialba in Costa Rica, Bland and Miles worked with volcanic plume researchers David Pieri of NASA's Jet Propulsion Lab (JPL) and Jorge Andres Diaz of the University of Costa Rica to measure sulfur dioxide emissions from volcanic activity. The team tested their instruments on kites, using Aeropods to develop their payload systems. The instruments ultimately flew on drones, but the kites allowed the team to troubleshoot and streamline their approach.

"We learn a lot from experiments like this," Bland says.

"Even though kites have been around for thousands of years, using them in this way is still pretty fresh territory."

Another study leveraged Aeropods to fly a compact and lightweight methane sensor over a landfill in Sacramento, California. Though the wind was very light on the day of the flight, Bland and Miles briefly flew the packaged prototype instrument built by Lance Christensen of NASA's JPL. The instrument was originally tested and flown under normal conditions prior to the missions, highlighting the Aeropod and kite technique as a quick response test method.

Rufty says a commercial hand held weather station works well for Aeropod flights – it can measure data points such as wind direction and crosswind. It's useful for capturing temperature differentials near the ocean, where the top of the sea breeze has different characteristics than lower altitudes.

"The sea breeze that comes off the ocean is different than your normal regional wind, so you're able to see these localized phenomena," Rufty says.

For newbies to the Aeropod game, a simple action camera can capture more than enough data to keep a budding scientist busy. By walking the kite in a straight line and using a camera that takes pictures every two seconds, Aeropod fliers can create a long transect of images using a panoramic software program.

The National Park Service has plans to employ this technique at *Assateague Island National Seashore* in Maryland by flying a kite and Aeropod off the back of an all-terrain vehicle (ATV). With repeated studies, park officials could capture fluctuating dynamics of the island.

"If there's a storm event, or if you wanted to see the seasonal shifts from year to year, you could take this map of the beach and look at how the shoreline has changed over time," Rufty points out.

LEARNING TOOL

In her time working on Aeropods, Rufty has assembled hundreds of kits for teachers around the country who participate in Aeropod-related education programs. Bland founded the Advancing Earth Research Observations with Kites and Atmospheric/Terrestrial Sensors (*AEROKATS*) program, which is now rolled into the AEROKATS and ROVER Education Network (*AREN*) with Principal Investigator Andy Henry of the Wayne County Regional Educational Service Agency (Wayne RESA). AREN is part of NASA's Science Activation (SciAct) Program, a collective of teams providing science activities for learners of all ages, led by Kristen Erickson of NASA Headquarters with Lin Chambers of NASA's Langley Research Center in Hampton, Virginia.

Aeropods make ideal educational tools because they open the door to remote sensing with the relative accessibility of kite-flying. Bland's first education-based collaboration with the Aeropod took place 10 years ago, when Andy Henry of Wayne RESA in Detroit, Michigan reached out to Bland about remote sensing opportunities.

Now, partners include the University of Maryland Eastern Shore, Chesapeake Bay Environmental Center, Montana State University, University of South Florida, the Public Laboratory for Open Technology and Science Washington College, University of Alaska Fairbanks, Drexel University, Oklahoma State University, the American Kitefliers Association, Black Swift Technologies, LLC, and more.

Caption: Ocean winds pushed this Aeropod aloft at the 2019 American Kitefliers Association Annual Convention in Seaside, Oregon. Photo credit: NASA/Geoff Bland

AREN uses a website called *Mission Mapper* to track Aeropod missions happening across the country.

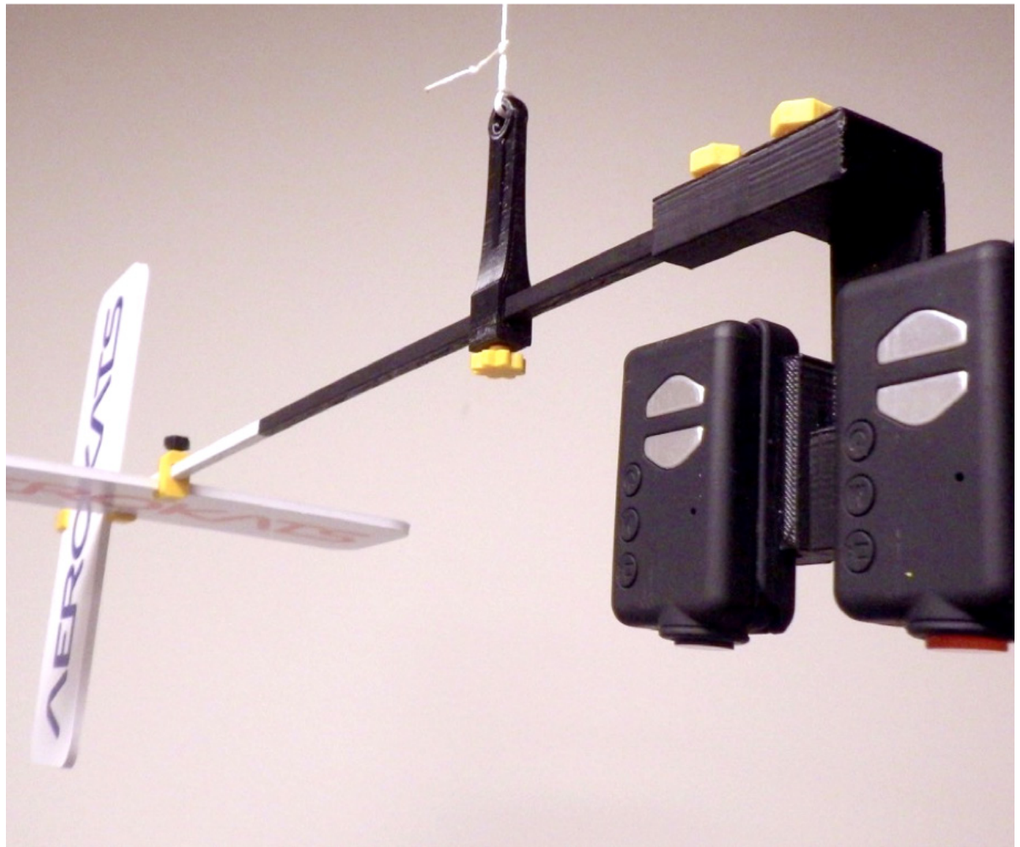
The AREN team has conducted dozens of trainings with groups of teachers to explain the technology and show them how to gather data safely.

"We go through all the risks and talk them through the instruments and how to use them when they're in the field," Rufty explains. "It may sound silly to some people that we have a specific procedure for flying kites, but there are risks involved, so we want to make sure everyone's communicating when they're doing a flying session."

Bland says that Aeropods provide a great model for NASA's flight operations, giving students a peek into the world of mandatory procedures that all NASA personnel follow in the lead-up to a satellite launch or aircraft mission. By putting students on teams, they each fall into roles that interest them, whether it be artistry or engineering.

"Once you start getting three or four people on a team, it encourages communication by identifying roles and responsibilities," Bland says. "In this way, we're introducing the same elements used in a control room for Mars missions. That's the really cool part."

Goddard has granted nine licenses for Aeropods to educational institutions, and since the licenses are non-exclusive and educational, the technology is available for others to license. Those interested can visit *https://technology.nasa.gov* to start a license application, or reach out to the Strategic Partnerships Office by emailing *techtransfer@gsfc.nasa.gov*.



Caption: With modifications, an Aeropod can carry two cameras for data collection. Photo credit: Andy Henry

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THE SPARK

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