

National Aeronautics and Space Administration



spinoffs



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Keeping astronauts healthy often requires innovations that advance medicine on Earth too—but that’s not the only way NASA’s work benefits human health. Whether collecting rocks from Mars or attempting to unravel the mysteries of deep space, NASA pioneers new materials and tools that end up in operating rooms and doctor’s bags around the world. This section highlights sutures used in heart surgery, “paints” that highlight DNA damage, and a unique polymer that’s been used on hundreds of thousands of pacemakers—all tracing their roots to a need or expertise stemming from NASA missions.

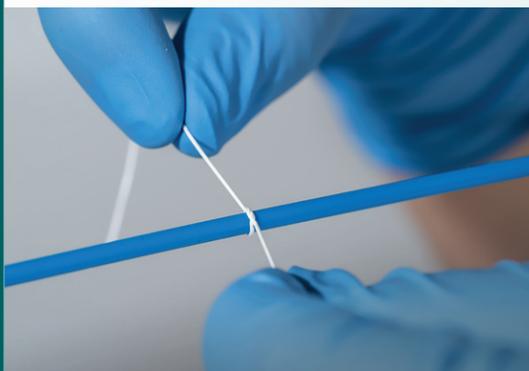
1 Unique Polymer Finds Widespread Use in Heart Devices

A material that a Langley Research Center scientist stumbled on in the early 1990s has helped to keep hundreds of thousands of patients’ hearts beating properly all over the world. Since 2009, medical technology giant Medtronic, based in Minneapolis, has been using the substance now known as LaRC-SI to get a relatively new type of pacemaker implanted into more patients more easily. As a result, many patients who might otherwise have continued to suffer symptoms of congestive heart failure were able to be treated.



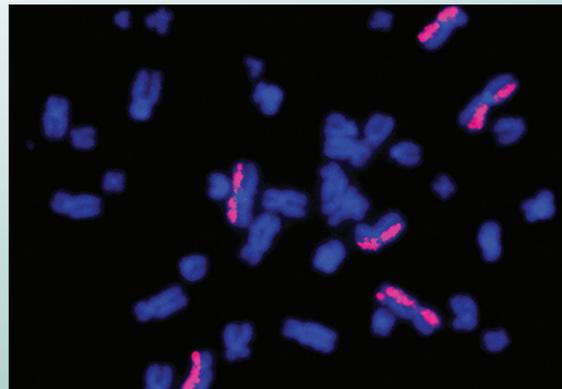
2 Material for Mars Makes Life-Saving Sutures

NASA aims to bring samples back from Mars, but challenges abound: for example, simulated Martian dirt interfered with a clean seal. Techno Planet Inc., building a canister with SBIR funding from the Jet Propulsion Laboratory, turned to Orangeburg, South Carolina-based Zeus Inc. to make a barrier to wipe dirt off the canister edge, which resulted in a new process to get the required properties. Since then, the company has found numerous uses for the extruded material, including as soft, flexible, strong sutures.



3 Fluorescent Paints Spot DNA Damage from Radiation, Gene Editing

A cutting-edge technique for detecting chromosome damage developed for space medicine has major implications on the ground. In space, astronauts are exposed to radiation that causes damage to DNA. But some mutations are easier to see than others. KromaTiD Inc., based in Fort Collins, Colorado, developed a technique with SBIR funding from Johnson Space Center that uses chromatid paints to highlight previously undetectable abnormalities. Applications include helping doctors select cancer treatments based on identifying mutations, diagnosing genetic conditions, and, potentially, spotting unintended damage from gene editing.



4 Image-Analysis Software Sees Cancer in 3D

NASA studies the physical effects of space travel, and that research benefits ground-based medical research as well. For a 2011 study on vascular changes in microgravity funded by Ames Research Center, lead researcher Ron Midura called on Image IQ, now owned by Philadelphia-based ERT, which developed software that helped count and identify the edges of stained blood vessels. The software has since been used for many clinical studies, and it may one day help doctors better diagnose—and remove—tumors.



5 Miniature Positioner Focuses Lenses with Precision

An instrument designed to study dark matter and dark energy for the ground-based Subaru Telescope in Japan required thousands of miniature positioners powered with tiny piezoelectric motors. Engineers from the California Institute of Technology and the Jet Propulsion Laboratory worked with Victor, New York-based New Scale Technologies to perfect the rotary motors, and these low-voltage modules are now being used in a variety of contexts, including medical instruments.



6 Biometric Sensor Tracks Vital Signs for Health

Technology developed to help monitor astronauts in orbit has pushed forward wearable technology here on Earth too, leading to devices that could provide clues to heart disease and more. Funded by SBIR contracts from Johnson Space Center, researcher Lino Velo developed a tiny sensor that tracks heart rate variability, a measure of the spaces between beats that can indicate stress level. Now Newark, California-based Salutron sells the sensor to wearable-makers and directly to consumers.





Not many humans ride in rocket ships, but all of us have benefited from the technology created to get the lucky few into orbit and beyond. We see space innovations in everything from sensors created for the Space Shuttle that alert drivers to flat tires to battery innovations that could power all-electric aircraft. Also in this section is software that helps design airplanes—and lawnmowers—and new developments in aerogel technology that could soon serve as a lighter-weight substitute for plastic in cars and planes.

7 Battery Innovations Power All-Electric Aircraft

One major challenge to developing all-electric aircraft—safely delivering enough power to the motors—got a boost from Industry, California-based Electric Power Systems. The company used funding from Armstrong Flight Research Center to develop a new technique to safely package thousands of off-the-shelf lithium-ion cells into one lightweight, powerful battery. The company is now supplying similar batteries to power an all-electric training airplane and has contracts with companies interested in designing electric vehicles for travel between small airports and within urban areas.



8 Shuttle Tire Sensors Warn Drivers of Flat Tires

A flat tire can take drivers by surprise. This was something the Space Shuttle engineers at Kennedy Space Center worried about too. In the 1990s, NASA commissioned a miniature pressure sensor on a silicon chip, powered by a small battery, that alerted pilots if the pressure was low. St. Marys, Pennsylvania-based Amphenol Advanced Sensors adapted the sensor for car tires and sold many millions, most of which ended up on U.S. passenger vehicles.



9 Space-Age Insulator Evolves to Replace Plastic and Save Weight

When aerogels, the world's lightest solids, were first invented, they were incredibly brittle and nobody had much use for them. Nearly a century later, the material could become as ubiquitous as plastic, says the founder of Boston-based Aerogel Technologies. NASA has discovered ways to make different aerogels stronger, flexible, and able to withstand high heat, among a range of other properties. Now, after in-house R&D and licensing patents from Glenn Research Center, Aerogel Technologies is selling the material to a variety of industries, including airplane and car manufacturers.



10 Software Helps Design Artery Stents, Lawn Mowers, Airplanes

Lockheed Martin developed the Structural Analysis of General Shells (STAGS) code under contract to Langley Research Center in the 1980s. It was a finite element analysis (FEA) program, meaning it broke down models of structures into tiny elements to model a structure's behavior as a whole. In 2005, French company Dassault Systèmes acquired Abaqus Inc. of Johnston, Rhode Island, which had developed the Abaqus FEA program. The company regularly consulted with users, including Langley's STAGS developers, and many of STAGS' capabilities were added to the program.



11 Super-Accurate Atomic Clocks Could Aid in Navigation, Communication

Measuring time accurately is crucial for advanced scientific research, but it could also be key for what comes next after GPS, as well as for synchronizing communications satellites. Sunnyvale, California-based AOSense Inc. is working on a portable, world-class atomic clock. Thanks to several SBIR contracts, mostly from Goddard Space Flight Center, the company has built components, including a laser-cooled atomic source, that are already selling to researchers, helping fund other advances needed to complete the clocks.



12 Probes Characterize Air and Water Flows over Aircraft, Yachts

A new approach to characterizing high-speed turbulence in wind and fluid flows is on track to become the new standard for wind tunnel measurements. Devices for measuring fluid speed are known as anemometers, and Hampton, Virginia-based Tao Systems Inc. first pioneered the constant voltage anemometer under two SBIR contracts with Langley Research Center in 1992, releasing it as a commercial product not long after. Today, the device is finally catching on in the aircraft-design industry and even among yacht builders.





Staying safe in space, which means dealing with a total lack of air and dangerous radiation, among other things, is no easy feat. In this section, you will read about technology designed for astronauts, like the breathing regulator that provided safe oxygen to John Glenn, which has been adapted for pilots, oil workers, and everyday people. You'll also see how even seemingly unrelated scientific missions can end up saving lives on the ground—like corrected GPS that helps first responders find accident scenes and robots that can step in for humans in dangerous settings.



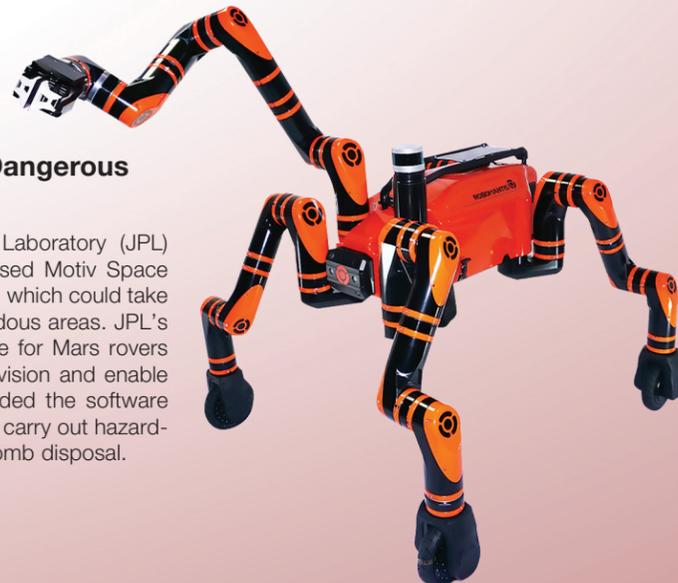
14 Gas Regulators Keep Pilots Breathing

Since John Glenn's first orbit in 1962, all U.S. astronauts have used a derivation of his oxygen regulator. For the original project, Cobham Mission Systems (then operating as Carleton Controls) needed to make a gas regulator smaller and lighter than ever before. Now the Orchard Park, New York-based business uses the innovative spring design it created for Johnson Space Center and its oxygen safety expertise in oxygen systems for pilots, as well as for applications like wastewater treatment and offshore drilling.



15 RoboMantis Offers to Take Over Dangerous Missions

A rugged robot built at the Jet Propulsion Laboratory (JPL) has been adapted by Pasadena, California-based Motiv Space Systems into the five- or six-limbed RoboMantis, which could take over dangerous jobs in disaster zones or hazardous areas. JPL's version built on decades of robotics experience for Mars rovers and more to give the modular robot accurate vision and enable semi-autonomous navigation. Motiv has upgraded the software and tweaked the design and says the robot can carry out hazardous jobs like cleaning chemical containers or bomb disposal.



13 NASA Brings Accuracy to World's Global Positioning Systems

GPS is an Air Force program, but NASA algorithms are largely to thank for the system being useful for secure, precision applications like airplane guidance, self-driving farm equipment, and directing first responders. Raw GPS data can be off by 30 feet or more, so the Jet Propulsion Laboratory developed software to correct for these errors, enabling real-time precision GPS. An early adopter, Long Island-based Comtech Telecommunications Corporation, remains a major provider of location-based services, including for cell phone companies, helping 911 operators pinpoint the location of a caller.

16 Wrapped Tanks Cut Weight on Everything from Buses to Paintball Guns

What do infant incubators, a Mars lander, and paintball guns have in common? All employ an invention developed at Glenn Research Center to cut weight from the Space Shuttles. Composite overwrapped pressure vessels, made of a liner tightly wrapped in high-strength filament, weigh half as much as all-metal pressure tanks by safely storing gases and liquids at higher pressures than was previously possible. Today, Worthington Industries, with production facilities in Pomona, California, sells them for, among many applications, fuel tanks for buses and breathing systems for firefighters.



17 Membranes Mimic Kidneys to Filter Water

Aquaporin A/S, based in Copenhagen, Denmark, approached Ames Research Center in 2007 with a proposal to create filters by infusing membranes with aquaporins, the proteins that let water in and out of living cells. With Ames funding and testing and eight years of development, the company released under-sink reverse-osmosis filters that clean water twice as fast as existing technology, with twice the recovery rate. Aquaporin sees a bigger future market for filtering industrial wastewater using highly efficient forward osmosis.



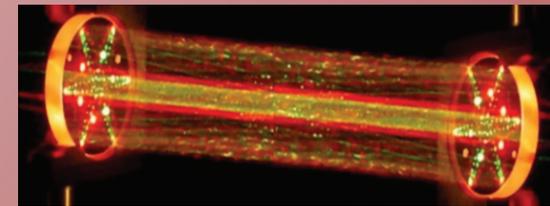
18 Detailed Spectrometry Makes Dangerous-Materials Testing Safer

Mars rovers carry an instrument that can zap a sample with a laser and read its composition in the resulting flash. But this process can only identify molecules, not their isotopes, which would reveal more about a sample's age, formation, and radioactivity. An Ames Research Center scientist set out to build a laser spectrometer that uses the same technique to identify these subtle differences. After joining Fremont, California-based Applied Spectra, and with the help of Ames SBIR contracts, he accomplished what no one thought was possible.



19 Methane Detector Sniffs Out Leaks

Methane is the main ingredient in the natural gas that powers heating, cooking, and electricity—and a potent greenhouse gas. Methane can also be a sign of bacterial life, which is why NASA installed a methane detector on the Curiosity rover, designing a brand-new tunable laser spectrometer for the task. A different team at the Jet Propulsion Laboratory made it even smaller and faster for methane sniffing on Earth, and Pasadena, California-based SeekOps licensed the technology to detect gas leaks at oil and natural gas wells and more.



20 Biofeedback Loops Aim to Enhance Combat, Sports Training

Steadying a computer cursor with your brain might sound far-fetched, but NASA has had the technology for years. In the late 1990s, researchers at Langley Research Center observed different brainwave outputs to measure attention levels. The team found showing subjects their engagement level, as determined by brainwaves, enabled them to control it and stay more focused. They invented games cued to brainwaves, and now J&F Alliance Group of Hampton, Virginia has licensed the technology and is refining it for consumers and the military.





When you look around your home, do you see NASA spinoffs? This section highlights some well-known products, like the Bowflex Revolution, that you may not have known traced their origins to space. You'll also find familiar favorites, like memory foam, turning up in new places, and some more recent releases, like an air-filtering pot for houseplants that relies on decades-old research.



21 **Bowflex System Spurs Revolution in Home Fitness**

The Bowflex Revolution home gym was a phenomenon of the 2000s and to this day sells well—but it might not exist without NASA. Inventor Paul Francis took his idea for a weightless weight-trainer, using elastic resistance, to Johnson Space Center, which was looking for ways to help astronauts retain muscle mass and bone density in microgravity. The end product launched to the space station in 2000, and Francis began approaching fitness companies. Nautilus Group, now based in Vancouver, Washington, licensed the technology and released the Bowflex Revolution in 2005.

22 **Spacesuit Air Filters Eliminate Household Pet Odors**

NASA-backed research on spacesuit technology could improve air quality in the homes of pet owners, keep cars smelling fresh, and keep the air pure in microchip manufacturing facilities. Serionix Inc., based in Champaign, Illinois, developed an air-filtering technology involving polymers that carry a permanent electrical charge. Three SBIR contracts from Johnson Space Center funded the company's development of systems to filter out ammonia and formaldehyde in spacesuits and purify air in spacecraft, improving the Colorfil technology it now applies to air purifiers and filters for cars and HVAC systems.



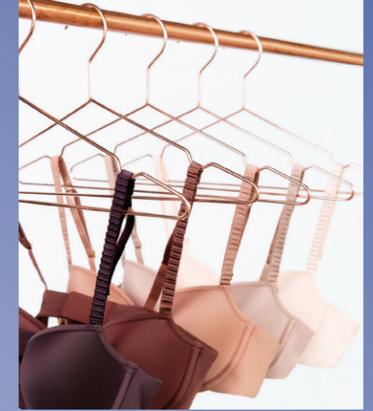
23 **NASA Research Sends Video Game Players on a Journey to Mars**

What would it be like to build a shelter on Mars? To plant a garden or explore its lava tubes? Now anyone can experience it like never before, in an immersive virtual reality "experience" developed by Miami-based Fusion Media Group Labs. Mars 2030, available for download and free for educators, is the result of years of consultations with researchers at Langley Research Center and across NASA. Its Editor tool is also free to the public, so others can build new simulations.



24 **Memory Foam Supports and Shapes in Women's Apparel**

The famous, and famously cushy, memory foam was invented for a 1960s Ames Research Center project to improve airline seating safety. A new foam cushion, made out of "temper foam," did a remarkable job of absorbing impact. Today, the material, more commonly known as memory foam, is used in many commercial products, including San Francisco-based start-up ThirdLove's high-end bras, which take advantage of the foam's ability to soften with body heat and conform to the body for a comfortable, supportive fit.



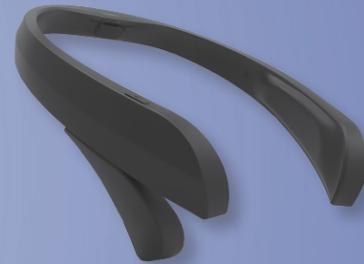
25 **Rocket Design Leads to Turbo-Charged Air Purifier**

The founders of Wynd didn't particularly have space exploration on the brain when they built their personal air purifiers. But experience calibrating sensors for launch pads at Kennedy Space Center and designing turbines for rockets at Marshall Space Flight Center proved crucial when designing the smart, portable device. Now the Redwood City, California-based company sells a device that is extremely powerful and efficient, but lightweight and small, and which comes with an instant air quality sensor.



26 **Brainwaves Reveal Student Engagement, Operate Household Objects**

In the mid-1990s, a team at Langley Research Center studying pilots' mental states created an "engagement index" to gauge subjects' attention levels based on their brainwaves. The team then demonstrated that subjects who were shown their engagement score could learn to control it. Decades later, the founders of BrainCo in Cambridge, Massachusetts, came across the work and incorporated it into a system for monitoring students' engagement and teaching kids with ADHD to control their attention by controlling video games or even objects around them.



27 **NASA Plant Research Offers a Breath of Fresh Air**

In the 1980s, Stennis Space Center researcher W.C. Wolverton studied how to maximize the air-scrubbing potential of houseplants. He found that, perhaps counter-intuitively, plant roots and associated microorganisms in the soil did the bulk of the work, not plant leaves. AIRY GreenTech, a Hamburg, Germany-based company has designed plant pots based on this research, maximizing airflow through the soil and roots to increase air filtering and improve plant health. The products are available in some 50 countries around the world.



28 **Light Research Aids Slumber**

When astronauts only spent a few hours or days in orbit, sleep was not the biggest concern. As stays stretched longer, however, Johnson Space Center and partner nonprofit National Space Biomedical Research Institute began studying rest and alertness in microgravity. The work showed different light wavelengths help govern sleep and wake cycles. Using these results, Headwaters Research and Development Inc., with U.S. headquarters in Marblehead, Massachusetts, has developed the Illummy sleep mask with light cues to help wearers fall asleep faster and improve alertness on waking.





Many of the challenges of space missions—from keeping healthy to making the best use of scarce resources—apply here on Earth as well. In this section, read about electricity-generating bacteria that could power future exploration and are already cleaning wastewater, as well as new ways to mimic sunlight with LEDs that could concentrate nutrients in vegetables grown in space—and on the ground. Other innovations make use of the long view of Earth from orbit to predict crop growth and provide new insights into our changing planet.

29 Electrified Bacteria Clean Wastewater, Generate Power

A group of graduate students used a NASA grant to study ideas for “bioelectric space exploration,” including a fuel cell powered by wastewater and based on bacteria that “breathe” electricity. They later won NASA SBIR funding, including a Johnson Space Center contract for a cell that could turn waste into energy, hydrogen, or methane. Their company, Boston-based Cambrian Innovation, now offers the EcoVolt reactor, which uses exoelectrogenic microbes to clean wastewater while generating methane for energy at 10 breweries and wineries and counting.



30 Building-Monitoring System Provides Insights for Sustainability

When Ames Research Center built Sustainability Base, the “greenest” building in the Federal Government, it counted on producing more energy than it consumed. To monitor energy consumption and production, it turned to Ramon, California-based Integrated Building Solutions Inc., which, with help from Ames, also added fault detection to its existing energy dashboard. Today, that’s a standard component of its Intelligent Building Information System, which has been installed at corporate campuses across Silicon Valley and beyond.



31 Space Station Garden Shines Light on Earth-Based Horticulture

The new Advanced Plant Habitat on the space station has features its predecessors don’t, including the ability to automate “light recipes”—variations in the color, intensity, and time intervals of lighting, which affect how plants grow. The German company OSRAM, whose U.S. headquarters is in Wilmington, Massachusetts, was developing a similar technology when its engineers were introduced to Kennedy Space Center scientists developing experiments for the Advanced Plant Habitat. Kennedy started using OSRAM’s Phytofy platform, essentially beta testing, validating, and providing feedback on it ahead of its commercialization.



32 Carbon Capture Process Makes Sustainable Oil

Palm oil, found in everything from soap to ice cream, is also a key driver of deforestation. Likewise, soybeans provide protein for fish and livestock but only at huge environmental cost. Now, San Francisco Bay Area-based Kiverdi offers a sustainable alternative: proteins and oils produced by bacteria—with a process based on early life-support studies for deep-space missions published by Ames Research Center. As the researchers discovered in the 1960s, the process is not only far more efficient than traditional agriculture but also captures, and transforms, excess carbon dioxide.



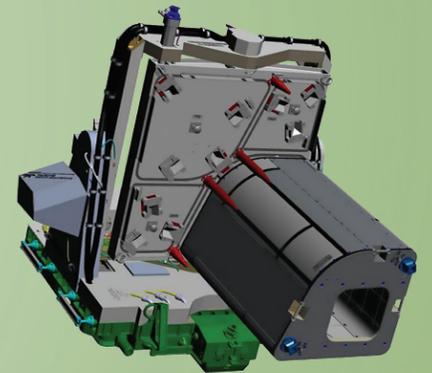
33 Emissive Coatings Cut Industrial Costs, Emissions, Fuel Consumption

A high-heat coating first developed for a planned Reusable Launch Vehicle now helps industrial plants save money and cut way down on harmful emissions. The Protective Coating for Ceramic Materials, created at Ames Research Center in the 1990s, can withstand temperatures up to 3,000 °F. Blacksburg, Virginia-based Emissshield Inc. has licensed the patent and now sells a range of formulations in a variety of industries. The company has recently expanded its product line and made significant inroads into various industrial applications, reducing energy costs and emissions.



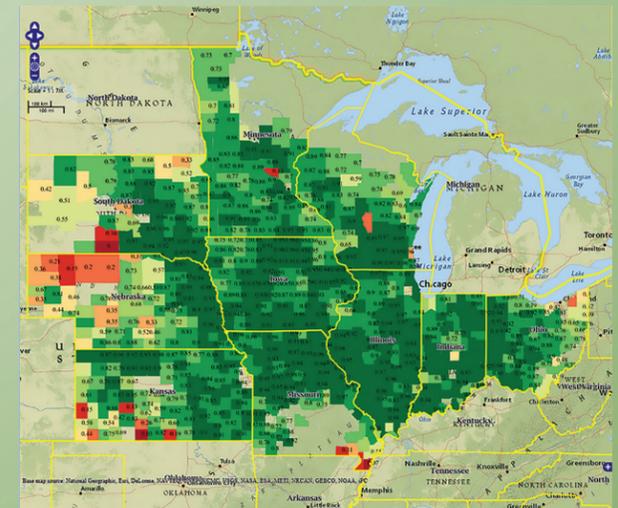
34 Pointing Platform Enables Earth Imaging from Space Station

Although Earth-pointing satellites are increasingly common, the space station offers a more affordable option for orbiting science-grade imagers. ISS’s National Laboratory, overseen at Johnson Space Center, partnered with Huntsville, Alabama-based Teledyne Brown Engineering to outfit the station with the Multi-User System for Earth Sensing, which can house multiple payloads and can point with extreme accuracy. The first customer, the German Aerospace Center, installed a hyperspectral imager that will help inform Germany on issues like climate protection and food security. The images are also available for purchase from Teledyne Brown.



35 Algorithms to Detect Clouds Forecast Global Crop Production

An algorithm originally created to detect clouds is now being used for everything from increasing food security in the developing world to guiding futures trading on Wall Street. Landsat satellites typically looked for clouds with a thermal imager, but when plans for Landsat 8 didn’t include one, Stennis Space Center put out a call for software that could identify cloud cover. State College, Pennsylvania-based Geospatial Data Analysis Corporation won the SBIR contract and developed an algorithm that it later expanded with additional SBIR funding to detect other features, including crops.





Software and information technology are already woven deeply into the fabric of daily life. Engineers use computer software to more quickly design new, and safer, aircraft. Digital communications make it easier for teams of doctors across specialties to care for patients. And even the ads we experience online are placed there through complex algorithms that work unimaginably fast. These advances and more improve our daily lives, and they got their start at NASA.

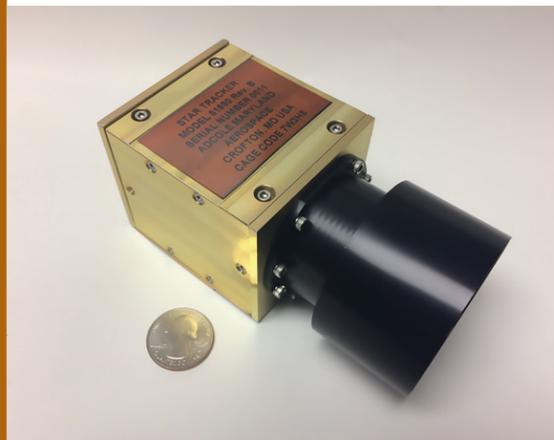


36 Space Mission Planning System Targets Advertising with Precision

Most Internet users may not know that every online ad appears after a near-instant auction for that slot. A leading company driving that process got its start planning NASA missions to the Moon and Mars. A team from the Massachusetts Institute of Technology, one of several funded by NASA Headquarters, developed software to choose the best among some 1,162 possible mission architectures. In 2007, team members founded Boston-based dataxu to adapt the software for commercial purposes, ultimately finding a niche in online ad sales.

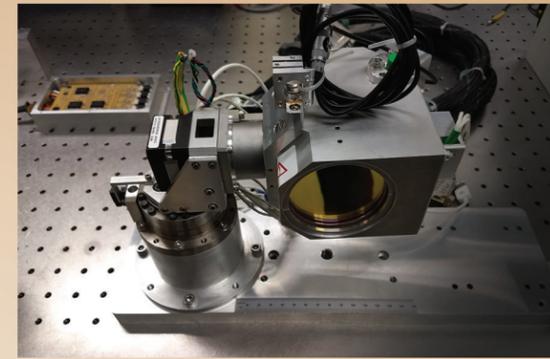
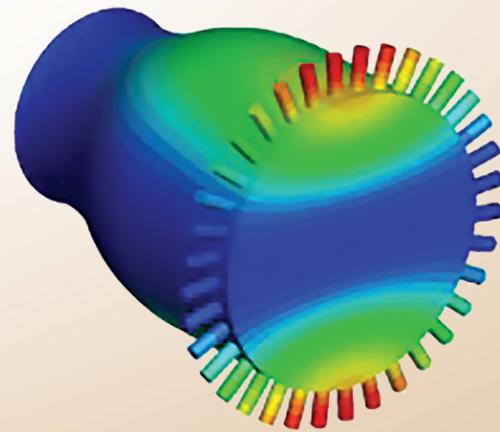
37 Tiny Star Trackers Help Spacecraft Find Their Place

NASA tackles some of the universe's biggest questions, and the tools it needs are often big, in size and cost. But Crofton, Maryland-based Adcole Maryland Aerospace, with SBIR funding from Goddard Space Flight Center, has designed a modern take on an ancient navigation device that is tiny, cheap, and potentially revolutionary. The device, a "space sextant," fits inside a CubeSat but can match the accuracy of much larger instruments. The company now sells it in a variety of configurations, primarily for Earth-observation satellites.



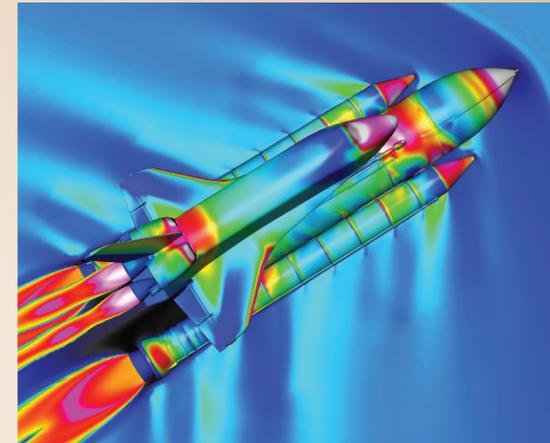
38 Software Toolkit Steadies Rockets

Combustion instability, when oscillations from firing resonate into an explosion, is one of the biggest risks in designing a rocket engine. Tullahoma, Tennessee-based Gloyer-Taylor Laboratories, with several SBIR contracts from Marshall Space Flight Center and others, built its Universal Combustion Device Stability process and toolkit based on an insight that breaks the problem into different layers and can predict how an engine will behave and why, enabling engineers at NASA and beyond to change problematic factors during the early design phase.



39 Low-Cost Transceiver Will Allow First Laser Mass Communication

Since the advent of the laser in the 1960s, engineers have struggled to use light beams in free space to send information the way we use radio waves. A transceiver created at the Jet Propulsion Laboratory, now licensed by Atlanta-based Xenesis, could be a breakthrough. Rather than burying fiber-optic cables, clients can beam secure laser signals above ground across a network of these transceivers. But the more widespread application will come when a satellite constellation and ground network now under construction begin to support mass communications.



40 NASA Code Speeds Nation's Aircraft, Spacecraft Design

In the late 1980s, NASA engineers were working to improve airflow simulation software. The Space Shuttle, with an external fuel tank and solid rocket boosters each generating interacting airflows, posed a distinct challenge. To better model multiple-body problems, a NASA team created the overset-grid method and built OVERFLOW software to run the simulations. Now available through Langley Research Center, OVERFLOW has been widely adopted, including at Seattle-based Boeing Commercial Airplanes, which uses it throughout its operations for development of planes, rotorcraft, advanced concepts, and more.



41 Tiny Springs Improve Electronic Reliability

A connection issue in printed circuit boards led to a tiny solution that could have an outsized impact. Printed circuit boards are layered with copper lines and pads that connect electronic components together. However, the joints can break when things heat up. Marshall Space Flight Center's Mark Strickland and Jim Hester engineered a micro-coil spring connector that is far stronger and longer-lasting. Milledgeville, Georgia-based Topline Corporation now sells the springs and attaches them to components for industry tests and verifications.



42 Collaborative Platform Trains Students in Simulation and Modeling

NASA uses simulations every day to test new ideas and science, saving untold time and money and resulting in improved outcomes. To make it easier to share simulations across centers and teams, engineers at Kennedy Space Center built the Distributed Observer Network, a simulation viewer that works alongside a commercial game engine to make simulations portable. Now the platform is available to university students through the Simulation Exploration Experience, which aims to train the next generation of simulation builders.

To ensure everything goes right in space—and to fix any problems that arise—NASA pioneers cutting-edge technology that then finds uses in every industry, in every phase of manufacturing. These innovations improve the cars we drive, help pioneer new television screens, advance 3D printing, and make Earth-bound telescopes more powerful.



43 Spray Analyzer Turns Up in Cars, Planes, Medicine, Cutting-Edge TVs

A technology an engineer developed with SBIR funding from Glenn Research Center in 1985 continues to find new uses today. With further SBIR funding from NASA and others, Sunnyvale, California-based Artium Technologies Inc. has built on the Phase Doppler Particle Analyzer originally created to analyze fuel spray in rocket and jet engines. Today it's used to design and test products including automobile fuel injectors, aircraft parts, inkjet printers, and systems for printing organic LED displays, among others.

44 Deep-Space Food Science Research Improves 3D-Printing Capabilities

Maintaining astronauts' nutrition becomes harder the farther they go from Earth. Contemplating sending astronauts as far away as Mars, Johnson Space Center took one company up on a proposal to explore 3D-printing foods, awarding SBIR funding. After the company built a prototype, one of its senior engineers adapted it to print pizzas to sell on the ground. He founded BeeHex, based in Columbus, Ohio, altered his Chef 3D device to decorate cookies for customers, and is now working on printing custom breakfast bars based on individuals' nutritional needs.



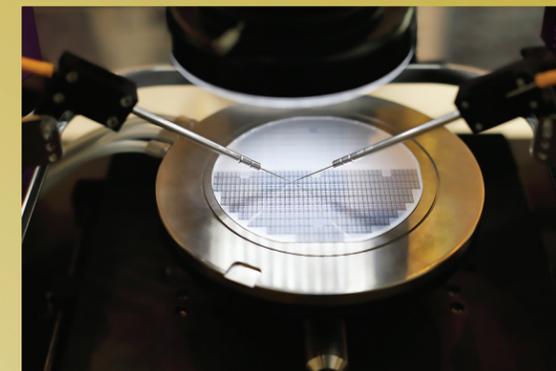
45 Simulated Space Dirt Supports Future Asteroid Mining

Water is "space gold," and Deep Space Industries is working on technology to mine it from asteroids. The San Jose, California-based company answered a call from Kennedy Space Center to develop special mixes of dirt and rocks that mimic the surfaces of asteroids to help test equipment. Now the company sells the simulant to universities, space agencies, and other companies interested in space mining.



46 Vibration Isolator Steadies Optics for Telescopes

For some very sensitive optics, even ordinary ground vibrations throw off the results. A vibration isolator, which creates a very stable platform, can help. Minus K Technology makes vibration isolators based on negative stiffness mechanisms, which, among other benefits, can work extremely well in a vacuum. The Los Angeles-area company improved its vacuum-capable system for the Jet Propulsion Laboratory and now sells it to companies that make semiconductors and optics, as well as the Department of Defense and the National Laboratories.



47 IonCCD Enables Fast, Reliable, Inexpensive Mass Spectrometry

Jet Propulsion Laboratory engineers and a start-up company worked together to create a small, low-voltage mass spectrometer, which identifies isotopes in a material. A key innovation was replacing traditional camera film in the focal plane detector with a charge-coupled device array, a kind of digital imager. Today, College Station, Texas-based OI Analytical, a subsidiary of Xylem, incorporates that digital detector array into its IDS 2030 Charged Particle Detector, which analytical chemists, the pharmaceutical industry, the military, and others use for various mass spectrometry applications.



48 Beryllium Blazes New Trail for Telescopes

For the James Webb Space Telescope's mirrors, Goddard Space Flight Center needed a lightweight, durable material that would maintain a stable shape at frigid temperatures. The answer: beryllium, which is stiff and doesn't change size at temperatures below about -300 °F. Mayfield Heights, Ohio-based Materion Corporation, one of the top beryllium-producing companies in the world, created new tools and adapted its unique processes to make such large components. The work resulted in a new capability and a new industry standard for beryllium for space applications.



49 Phase-Change Coating Absorbs Heat from Rockets, Pipes, Beer

Most people enjoy an icy drink without thinking about the physics of the phase-change reaction inside the glass. In the early 2000s, Marshall Space Flight Center materials scientist Raj Kaul encapsulated phase-change materials in a plastic that could be applied like paint, aiming to better protect the Space Shuttle's solid rocket boosters. A commercial license was quickly snapped up by entrepreneur Chris Bilec, whose Austin-based PrimeBilec company has plans to sell it for aviation, in hospitals, and even in an ice-free cooler.



NASA Spinoff Technology across the Nation

Health and Medicine

1. Unique Polymer Finds Widespread Use in Heart Devices (MN)
2. Material for Mars Makes Life-Saving Sutures (SC)
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4. Image-Analysis Software Sees Cancer in 3D (PA)
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Transportation

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8. Shuttle Tire Sensors Warn Drivers of Flat Tires (PA)
9. Space-Age Insulator Evolves to Replace Plastic and Save Weight (MA)
10. Software Helps Design Artery Stents, Lawn Mowers, Airplanes (RI)
11. Super-Accurate Atomic Clocks Could Aid in Navigation, Communication (CA)
12. Probes Characterize Air and Water Flows over Aircraft, Yachts (VA)

Public Safety

13. NASA Brings Accuracy to World's Global Positioning Systems (NY)
14. Gas Regulators Keep Pilots Breathing (NY)
15. RoboMantis Offers to Take Over Dangerous Missions (CA)
16. Wrapped Tanks Cut Weight on Everything from Buses to Paintball Guns (CA)
17. Membranes Mimic Kidneys to Filter Water (Denmark)
18. Detailed Spectrometry Makes Dangerous-Materials Testing Safer (CA)
19. Methane Detector Sniffs Out Leaks (CA)
20. Biofeedback Loops Aim to Enhance Combat, Sports Training (VA)

Consumer Goods

21. Bowflex System Spurs Revolution in Home Fitness (WA)
22. Spacesuit Air Filters Eliminate Household Pet Odors (IL)
23. NASA Research Sends Video Game Players on a Journey to Mars (FL)
24. Memory Foam Supports and Shapes in Women's Apparel (CA)
25. Rocket Design Leads to Turbo-Charged Air Purifier (CA)
26. Brainwaves Reveal Student Engagement, Operate Household Objects (MA)
27. NASA Plant Research Offers a Breath of Fresh Air (Germany)
28. Light Research Aids Slumber (MA)

Energy and Environment

29. Electrified Bacteria Clean Wastewater, Generate Power (MA)
30. Building-Monitoring System Provides Insights for Sustainability (CA)
31. Space Station Garden Shines Light on Earth-Based Horticulture (MA)
32. Carbon Capture Process Makes Sustainable Oil (CA)
33. Emissive Coatings Cut Industrial Costs, Emissions, Fuel Consumption (VA)
34. Pointing Platform Enables Earth Imaging from Space Station (AL)
35. Algorithms to Detect Clouds Forecast Global Crop Production (PA)

Information Technology

36. Space Mission Planning System Targets Advertising with Precision (MA)
37. Tiny Star Trackers Help Spacecraft Find Their Place (MD)
38. Software Toolkit Steadies Rockets (TN)
39. Low-Cost Transceiver Will Allow First Laser Mass Communication (GA)
40. NASA Code Speeds Nation's Aircraft, Spacecraft Design (WA)
41. Tiny Springs Improve Electronic Reliability (GA)
42. Collaborative Platform Trains Students in Simulation and Modeling (FL)

Industrial Productivity

43. Spray Analyzer Turns Up in Cars, Planes, Medicine, Cutting-Edge TVs (CA)
44. Deep-Space Food Science Research Improves 3D-Printing Capabilities (OH)
45. Simulated Space Dirt Supports Future Asteroid Mining (CA)
46. Vibration Isolator Steadies Optics for Telescopes (CA)
47. IonCCD Enables Fast, Reliable, Inexpensive Mass Spectrometry (TX)
48. Beryllium Blazes New Trail for Telescopes (OH)
49. Phase-Change Coating Absorbs Heat from Rockets, Pipes, Beer (TX)



This map details the geographic locations of the companies that appear in *Spinoff* 2019.

SPINOFFS OF TOMORROW

Spinoff 2019 profiles nearly 50 products and services that are already improving lives, creating jobs, and enhancing the bottom line for businesses. But NASA has thousands more technologies ripe for commercialization. This year's *Spinoff* publication features 20 of NASA's best industry-ready technologies on offer, including:

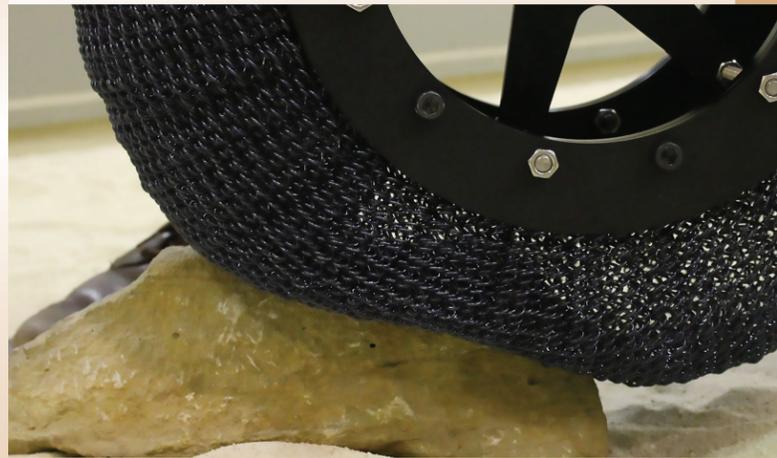
REMOTE SENSING TOOLKIT

The Technology Transfer Program has created an online resource to promote commercial use of NASA's Earth science data. With the Remote Sensing Toolkit, users can find, analyze, and use the most relevant data for their research, business projects, or conservation efforts. The toolkit provides a simple system that quickly identifies relevant data sources based on user input and tools and code to make use of it.



SUPERELASTIC TIRE

The superelastic tire, developed for future Mars missions, is a viable alternative to pneumatic tires here on Earth. This technology represents the latest evolution of the spring tire, which was originally invented by NASA and Goodyear. By using shape-memory alloys, the superelastic tire can undergo significant strain and deformation while retaining its shape.



ANTI-INSECT COATING

NASA has developed epoxies that serve as an effective anti-insect coating. The coating could be useful in a variety of applications, including aircraft, but also in cases where the reduction of insect residue adherence is desirable, such as in the automotive and wind-energy industries.



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