National Aeronautics and Space Administration

SPINOFF

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Health and Medicine

Sometimes it's an innovation to meet the unique health challenges of the space environment. Other times it's a technology for analyzing distant objects or protecting components from the harsh conditions of space that happens to find a medical application on Earth. This section highlights exercise equipment, sterilizers to prevent the spread of infection and disease, and a device to improve cancer and stem cell research, all built on innovations to support space exploration or the deep expertise NASA's missions require.

1 Sterilizing Fogger Cleans Ambulances with a Breeze

When paramedics come racing, the last thing anybody worries about is where the ambulance was that morning. But traces could be lingering—and they could be spreading disease.

An innovative new product, designed with NASA's help, aims to sterilize the rig and gear to make it safer for the patients and the paramedics. The product uses atomic oxygen and oxidation, two things NASA is familiar with, explains Glenn Research Center's Sharon Miller.

High in the atmosphere, atomic oxygen is far more prevalent than here on the ground, and it can become a destructive problem. But atomic oxygen can also be harnessed for good: sterilization. "Atomic oxygen removes any hydrocarbon from a surface," Miller explains.

Kent, Ohio-based Emergency Products + Research (EP+R) planned to make a device that used oxidation to sterilize ambulances—but the team had many questions.

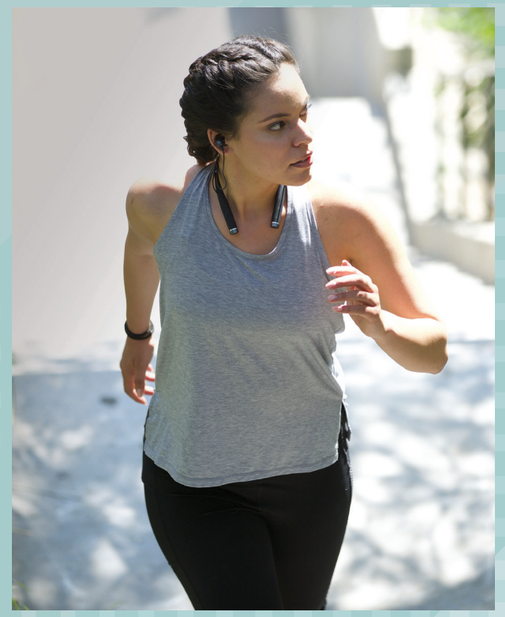
Enter NASA. Through the Regional Economic Development Program, field centers offer consulting. Glenn paired EP+R with Miller. "It was a key turning point," says EP+R Vice President Jason Thompson.

Just a few months later, Thompson says, EP+R was delivering its first units. EP+R has fulfilled orders across the United States, and the interest continues to grow.

"Now we're getting courted by an international aid group for Liberia and Sierra Leone," Thompson says. "I'm really hopeful. Talk about making a difference around the world."

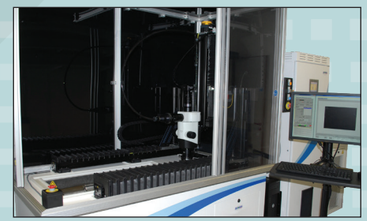
2 Biometric Sensors Optimize Workouts

Biometric sensors could give warnings when astronauts near a blackout while pulling heavy G-forces. LifeBEAM founder Omri Yoffe and his team made a prototype of such a sensor when they won the opportunity to work with NASA personnel as part of a program run by Singularity University, which has a Space Act Agreement with Ames Research Center. Afterwards, New York City-based LifeBEAM used that experience to build a commercial exercise tracker that monitors biometric indicators to help wearers optimize their workout.



3 Optimized Imager Tracks Cancer, Stem Cells in Medical Research

Under the Adopt a City program, Cleveland-based BioInVision was selected for 40 hours of free technical expertise from Glenn Research Center, aimed at developing a smaller version of its CryoViz imaging system. The device maps the location of fluorescent-tagged cancer or stem cells in a specimen, usually a mouse, for medical research. The desktop version is still in the works, but advice on a cheaper, more efficient, more sensitive optical system was immediately incorporated into the original imager.

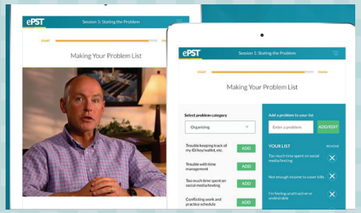


4 Weightless "Weight"-Lifting Builds Muscle on Earth

Loss of bone density and muscle during long stays in zero gravity posed a dilemma without a clear solution: weights are useless in a weightless environment. Paul Francis was working on exercise equipment based on resistance rather than weight, called SpiraFlex, and answered NASA's call for ideas. Francis worked with Johnson Space Center to build SpiraFlex FlexPacks into a system with up to 300 pounds of resistance. He's now founded Kansas City, Missouri-based OYO Fitness to market the SpiraFlex-based DoubleFlex portable gym.

5 Virtual Therapist Offers Out-of-This-World Depression Treatment

Mental health problems could be a real challenge for NASA crewmembers on long-duration missions—and it's not like they can pop out to the therapist. With grants from the Johnson Space Center-funded National Space Biomedical Research Institute, James Cartreine built a computer-based system called Virtual Space Station that would help diagnose and treat a range of mental health issues. In 2012, Cartreine and Claudia Zayfert founded Norwich, Vermont-based everMind to adapt and sell the virtual treatment modules on Earth.



6 Compact Spectrometers Unveil Clues to Diagnose Cancer

Hindsight Imaging Inc. founder Arsen Hajian began working to build a better spectrometer to look for distant planets and stars in the 1990s at the Naval Observatory, where much of his funding came from NASA. Now the Boston-based company's small but mighty devices—Hajian says they pack the resolution of machines nearly 30 times larger and 10 times more expensive—are helping uncover hidden details on this planet, and could be incorporated into future instruments at Goddard Space Flight Center.

Transportation

Technology is never finished confronting the challenges of air and space travel, and weall benefit from these steady improvements to flight technology, from software to ease aircraft design to advanced avionics capabilities that apply to planes, wind turbines, and selfdriving cars. Also in this section is the highperformance rocket engine that's put countless commercial and defense satellites in space and the specially outfitted NASA facility that tested the world's fastest business jet.

7 Innovative Design Propels Small Jet Faster, Farther with Less Fuel

Honda is best known for budget-friendly, fuel-efficient family cars, not high-powered jets. But that's just what its new Honda Aircraft subsidiary sells: high-speed business jets—that are also fuel-efficient and budget-friendly.

The plane body and its breakthrough over-the-wing engine mount were designed on computers, explains Honda Aircraft Company CEO and President Michimasa Fujino. "We found … a sweet spot to reduce wave draft."

But before Honda was ready to invest in building the planes, it needed real-world testing. That's where NASA came in.

"We were searching for a wind tunnel all over the world," Fujino recalls. NASA's National Transonic Facility, or NTF, housed at Langley Research Center, was the clear choice.

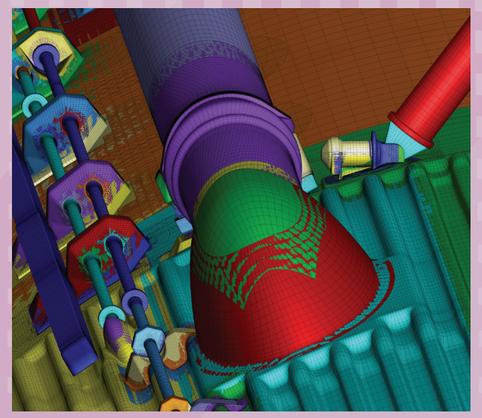
Greensboro, North Carolina-based Honda Aircraft did a week of testing there. The team also worked with NASA wind tunnel experts in advance to ensure they got the most possible from the tests.

"Because I could confirm my concept from test results, I had more confidence to go into the commercial phase," Fujino says.

The HondaJet has the fastest maximum cruising speed in its class and can fly at the highest altitude in its class. It is also less expensive to operate than other light jets because of its higher fuel efficiency.

8 Design Software Transforms How Commercial Jetliners Are Built

Computational fluid dynamics (CFD) software that simulates aerodynamics has been a major boon to aircraft designers. NASA funded the creation of Pegasus 5, a preprocessor that greatly decreases the work necessary to prepare a design for CFD analysis. Ames Research Center took over the program and refined it with Seattle-based Boeing Commercial Airplanes, which has used it to design a number of its airliners. Pegasus 5 opens up CFD preprocessing to less experienced users, speeds it up, and drastically reduces user error.



9 Original Cryogenic Engine Still Powers Exploration, Defense, Industry

The first cryogenic rocket engine, the RL10, remains the most-used upper-stage rocket engine in the country more than 50 years after its creation. The engine, powered by liquid hydrogen and oxygen, was matured under a contract between what are now known as Glenn Research Center and Aerojet Rocketdyne. Built in West Palm Beach, Florida, the RL10 helped launch most commercial satellites for three decades and remains the upper-stage engine of choice for NASA and the military.

10 Time-Triggered Ethernet Slims Down Critical Data Systems

Ethernet traditionally could not be used for critical systems because it couldn't guarantee when or whether signals would reach their destinations. TTTech, whose U.S. headquarters is in Andover, Massachusetts, developed a more reliable system, called Time-Triggered Ethernet, which it honed under a Johnson Space Center subcontract to build avionics for the Orion capsule. The technology, which allows for far simpler data handling on fewer computers, is now applied to launch vehicles, planes, wind turbines, and driver assistance and self-driving cars.

11 Simplified Aircraft Modeling Packs Weeks of Analysis into Minutes

Using software to model how an airplane flies in real-world conditions requires major computing power. Langley Research Center engineer Walter Silva designed software that makes at least one aspect of this modeling much faster, by creating a simplified version of the aircraft structure using a mathematical tool called system identification. The software, called Reduced Order Model, is now available for license, and Huntsville, Alabama-based CFD Research Corporation is using it for current and planned future contracts.

Public Safety

The Space Agency is renowned for its culture of safety and ability to protectastronauts in the harshest environments—but even seemingly unrelated scientific missions can end up keeping us safer here on Earth. Technology used to map gravity is repurposed to find survivors trapped under rubble. Software to direct a robot construction team improves warehouse safety. These and more are featured in the following pages.

12 Radar Device Detects Heartbeats Trapped under Wreckage

NASA often analyzes weak signals to identify slight physical movements, such as alterations in a satellite's path that might indicate gravity fluctuations. In the early 2000s, federal agencies approached the Jet Propulsion Laboratory (JPL), wondering about using this capability to remotely detect human vital signs.

JPL called the prototype it developed FINDER.

By picking out the faint but correlating movements of human breathing and heartbeats, FINDER can detect unseen survivors buried under rubble.

The founders of R4 Inc., based in Edgewood, Maryland, licensed FINDER, and the company spent the next couple of years developing it into a device first responders could use in real-world situations.

A major success came when a 7.8-magnitude earthquake rocked Nepal in April 2015. One of R4's founders arrived with two FINDER prototypes and detected four victims trapped under debris. All four men, who had been buried as deep as 10 feet, survived.

FINDER has since proven capable of detecting humans through 30 feet of dense rubble with 80 percent accuracy. R4 has also designed prototype versions to mount on a remote-controlled octocopter, a truck, and a motorcycle.

13 Surveillance System Captures, Maps Lightning Strikes

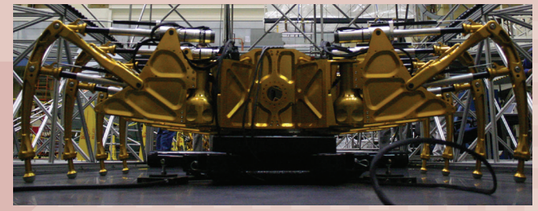
Lightning strikes cause critical damage that can delay a launch, so NASA wanted a better system to detect and monitor them near its launch pads. Carlos Mata, then of Kennedy Space Center, built a highly accurate system using sensors and high-speed cameras, and then founded Titusville, Florida-based Scientific Lightning Solutions to sell it commercially. The Optical Jupiter precision lightning surveillance system could help keep wind farms functioning and help insurance companies investigate claims.

14 Virtual Reality Platform Helps Pilots Land in the Sky

A pilot can practice landing on a virtual runway in the air, thanks to a Fused Reality platform built by Hawthorne, California-based Systems Technology Inc. SBIR contracts from Armstrong Flight Research Center helped the company turn a ground-based system first developed by the Air Force into an in-flight simulator. By superimposing virtual elements over a view of the real world, it allows for safer, more accurate, and cheaper training. The technology will also help plane manufacturers evaluate and design aircraft.

15 Autonomous Robots Take On Dangerous Warehouse Jobs

Engineers at Johnson Space Center worked with programmers at Carnegie Mellon University to create a prototype robot team capable of working autonomously to build a solar array on the moon. The project never flew, but one of the graduate students who worked on it is now a senior research scientist at Cambridge, Massachusetts-based Vecna Technologies, where he used the experience to design software that turns any collection of standard warehouse vehicles into an autonomous team.

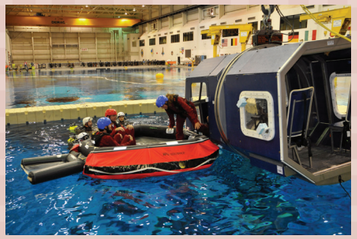


16 Drone Traffic Forecasts Show Commercial Skies of the Future

As Ames Research Center worked with the Federal Aviation Administration to craft regulations for future drone traffic, the team ran into a problem: it needed data on drone flights that wouldn't exist until regulations were already in place. Under Ames SBIR contracts, Rockville, Maryland-based Intelligent Automation Inc. created a drone traffic forecast by contacting scores of companies and agencies which, they were surprised to learn, already had drone operations planned. The enormous dataset is now commercially available to anyone planning drone operations.

17 Offshore Oil Workers Learn Survival Skills in Astronaut Training Pool

At Johnson Space Center's Neutral Buoyancy Lab, astronauts practice spacewalks underwater to simulate weightlessness. To offset the cost of maintaining the enormous and well-equipped pool, the center charges outside groups to use the facility under a Space Act Agreement. The biggest customer is Houston-based Bastion Technologies, which provides offshore survival and fire training to oil and gas workers. The facility provides the company with a proven safety system, comfort, heavy equipment, and an ample staging area.



Consumer Goods

Many of NASA's most memorable spinoffs have been consumer goods, such as memory foam and the Dustbuster. This year's issue of Spinoff adds to that list advanced LED lighting for greenhouses, art made with magnetic fluid, a system for retraining sleep cycles, a long line of air purifiers, and more.

18 Apollo 11 History Archive Helps Virtual Reality Program Come to Life

Imagine yourself in the cockpit of the Apollo spacecraft heading to the moon. Look around to see Earth out one window and stars from another. Reach out to the control panel. This is Apollo 11 VR, a virtual reality experience that lets users relive the Apollo 11 mission and take some of the first steps on the moon.

The project required extensive study, and the company behind it, Waterford, Ireland-based Immersive VR Education, says it wouldn't have been possible without vast amounts of information NASA posts on public websites.

NASA is tasked not only with exploring aeronautics and space but also with the "widest practicable and appropriate dissemination of information concerning its activities." That phrase guides the work of NASA Headquarters' History Division, which maintains the agency's historical websites. These offer information on many projects, and the Apollo mission pages are among the most popular.

These repositories provided the company with design plans for the interiors of the spacecraft, the lander, and the command module, as well as original audio from the mission. The developers found a photo mosaic of the landing site and drew their virtual world on top of that image.

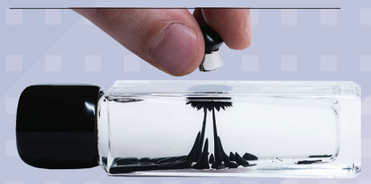
Though popular as a paid app, the program is free for teachers to show to students. In its first year, it was purchased more than 40,000 times.

19 Light-Induced Oxidation Cleans Air, Surfaces, Clothes

Under a Marshall Space Flight Center research partnership in the 1990s, scientists at the Wisconsin Center for Space Automation and Robotics discovered photocatalytic oxidation, a process that creates charged hydroxyl radicals that oxidize airborne organic contaminants, turning them into carbon dioxide and water. Dallas-based Aerus Holdings acquired and improved an active form of the technology that emits hydroxyls to purify air and surfaces and has incorporated it into several product lines, even including detergent-free clothes washing.

20 Ferrofluid Technology Becomes a Magnet for Pioneering Artists

Magnetized ferrofluid was developed in the 1960s at what is now Glenn Research Center and has since found a number of industrial uses. More recently, artists have begun experimenting with it. When Nikola Ilic developed a liquid in which ferrofluid could be suspended without staining its container, he founded Hamburg, New Jersey-based Concept Zero, which sells a line of glass displays that let the user manipulate the ferrofluid inside. The company also supplies and collaborates with other artists working with ferrofluid.

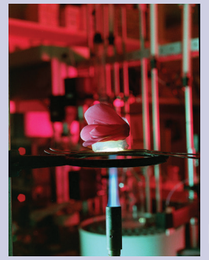


21 The Martian Garden Recreates Red Planet's Surface

In 2006, the Jet Propulsion Laboratory tested dust and rocks from a basalt quarry in the Mojave Desert and found it mineralogically and chemically similar to the surface of Mars. The center now uses the resulting Mars Mojave Simulant (MMS) to test rovers bound for the Red Planet. The Martian Garden, based in Austin, sells kits that use MMS to simulate the challenge of gardening on Mars and is also now the only remaining supplier of Mars surface simulant.

22 Aerogel Insulation Makes Thinner, Warmer Outerwear

After a bundled-up trip up a Swiss mountain, Oros co-founder Michael Markesbery wanted to make thinner, more lightweight outerwear. He came across aerogel insulation—first made practical when Aspen Technologies, under SBIR contracts from Kennedy Space Center, infused the brittle material into flexible, durable composite blankets—when he won a scholarship from the Astronaut Scholarship Foundation. Markesbery took the $10,000 award and additional seed money and started making jackets with Aspen Aerogel insulation. The Cincinnati-based company continues to improve aerogel technology in its ever-expanding product line.



23 Space-Grade Insulation Keeps Beer Colder on Earth

NASA didn't invent reflective insulation, but the Space Agency mastered it in the form of layered metalized polyester thin films first made for Marshall Space Flight Center in the mid-1960s. Known as radiant barrier technology, this durable, lightweight "superinsulation" is used in all spacecraft and spacesuits and a host of applications on Earth. JUNTO LLC, based in Philadelphia, now uses the technology to make KegSheets, which, coupled with ice, can a keep beer keg cold all through a hot day.

24 High-Efficiency LEDs Grow Crops, Stimulate Alertness

Two former Kennedy Space Center contractors are using expertise gained from NASA work in LED lighting to benefit agriculture and human health. The two engineers are now vice presidents at BIOS Lighting, based in Melbourne, Florida. The company produces agricultural LED lighting that maximizes efficiency by emitting light only in the wavelengths that drive photosynthesis, as well as human lighting with peak output in wavelengths in the blue-green region, which suppresses melatonin production, inducing wakefulness.

25 Paired Sleep Tracker, Light Therapy Tools Retrain Circadian Rhythms

Since around 2000, the Johnson Space Center-funded National Space Biomedical Research Institute (NSBRI) has supported research on the use of blue light wavelengths to regulate circadian rhythms. Based on this research, London- and San Francisco-based Circadia developed a light therapy system to train the user's sleep cycle. A cell phone app based on software partially funded by the NSBRI uses data from a sleep tracker to program each day's light therapy, via a portable lighting device, inducing daytime wakefulness to facilitate nighttime sleepiness.

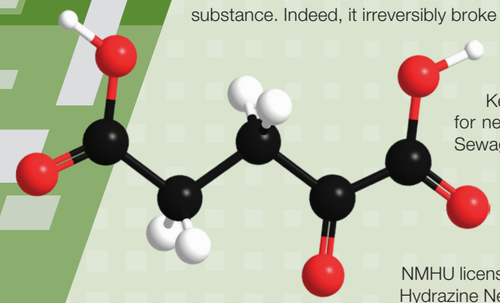
Energy and Environment

Many of the challenges of space missions—from keeping healthy to making the best use of scarce resources— apply here on Earth as well. NASA research into fields like agriculture and energy-efficient electronics is tailored for the long-duration missions to Mars and beyond that the Space Agency envisions, but it is already making life better here for us. The research has led to precision fertilizer, a solution that helps plants make better use of it, LED lighting that is safer and uses a fraction of the power of traditional lighting, and much more.

26 Organic Compound Turns Toxic Waste into Harmless Byproducts

In 2004, researchers at New Mexico Highlands University (NMHU) were trying to develop a substance that would glow in the presence of hydrazine, a toxic, flammable compound often used as rocket fuel. But their first attempt didn't just react with hydrazine—it neutralized it.

A chemist on the team had identified alpha-ketoglutaric acid (AKGA), a common metabolite, as a likely reactant with the substance. Indeed, it irreversibly broke hydrazine down into harmless byproducts.



The university contacted Kennedy Space Center, which generates about 15,000 gallons of hydrazine waste each year and spends heavily to dispose of it.

Kennedy funded experiments to determine the effectiveness and ideal procedures for neutralizing hydrazine with AKGA. Shortly, the Cape Canaveral Air Force Station Sewage Treatment Plant partnered with Kennedy and the University of Central Florida to evaluate the impacts of disposing of the byproducts through the sewer system.

Following those tests and Kennedy's creation of disposal procedures, the Air Force obtained permits to treat hydrazine with AKGA and dump the end product down the drain.

NMHU licensed its invention to Millennium Enterprises, which created Marietta, Georgia-based Hydrazine Neutralizing Solutions Inc. to market it under the name of ZeenKleen.

The company has found customers in the nuclear power industry and could find more in plastic, pesticide, and pharmaceutical manufacturing, all of which use hydrazine.

27 LED Lighting Improves Efficiency, Imaging, Cuts Maintenance

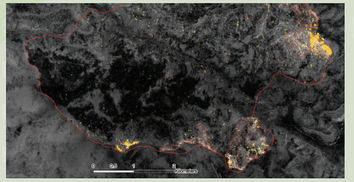
In an effort to improve energy efficiency, Stennis Space Center issued two STTR contracts in 2009 to Solon, Ohio-based Energy Focus to develop LED-based replacements for lighting in two rocket engine test stands. While crafting floodlights and general area lights, all for use in hazardous areas, the company developed heat-management and beam-focusing techniques that have improved efficiency and lifespan in its other LED lighting, and the work also led to commercial lighting for hazardous areas.

28 Plant Food for Space Grows Crops on Earth

Florikan's controlled-release fertilizers had already benefited from a NASA partnership that generated a more robust polymer coating when NASA again approached the Sarasota, Florida-based company looking for a fertilizer to grow tomatoes in space. Flowering plants required a different ratio of nutrients than Florikan's existing products, so the company developed and packaged a new formula in its signature coating. Here on Earth, it's the first controlled-release fertilizer to work in vertical hydroponic farming, replacing liquid feed and the need for multiple fertilizer applications.

29 Remote Sensing Technology Fights Forest Fires Smarter

A long-standing partnership between NASA and the U.S. Forest Service aims to help firefighting agencies make good use of advanced technology to better fight forest fires. One recent collaboration with researchers at Ames Research Center led to installing a digital downlink connection on the Forest Service's instrumented aircraft, to make it easier to send the latest fire updates to people on the ground.



30 Earth Images Enable Near-Perfect Crop Predictions

NASA has been enabling and producing constant imaging of Earth's surface since the 1970s. One of TellusLabs' cofounders has worked extensively—and often with NASA's involvement or funding—with this image archive as a Boston University scientist.The Boston-based startup developed a crop prediction model that combines Earth-imaging data from satellites built at Goddard Space Flight Center with historical data, weather models, and other information. Its first product, Kernel, predicted 2016 U.S. soy crop yields with 99 percent accuracy. After a year, Telluslabs has more than 600 subscribers.

31 Micronutrient Formula Strengthens Plants, Increasing Yields

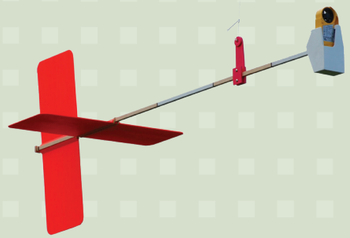
Keeping astronauts healthy on long-duration space missions will require packing maximum nutrition into small packages. Boca Raton, Florida-based Zero Gravity Solutions Inc. developed one solution under Space Act Agreements including one with Ames Research Center, infusing extra micronutrients into plants as they grow. Multiple studies have shown that the formula adds nutritional value and helps increase yield—both of which could be powerful tools on Earth, especially in developing countries. The company now sells it as BAM-FX around the world.

32 Chemical Simulation Software Predicts Climate Change, Air Quality

Climate scientists use physical measurements coupled with computer models to observe what is happening across the entire planet over time. This requires supercomputers and can be very slow, especially for modeling chemical reactions. Baltimore-based ParaTools Inc., with SBIR funding through Ames Research Center, built faster and easier-to-use software for advanced computer processors to analyze chemical kinetics. Now it is being used around the world, including by the air quality research division of Environment and Climate Change Canada.

33 NASA Kite Invention Spurs Ever-Growing Educational Program

When leaders at Wayne Regional Educational Service Agency (RESA) of Wayne County, Michigan, contacted NASA about aerial monitoring of ponds and streams, they learned of AeroPods, invented at Goddard Space Flight Center's Wallops Flight Facility. The devices stabilize imagers suspended from kite string. With funding through a NASA Cooperative Agreement Notice award, Wayne RESA and Wallops personnel created the Investigating Climate Change and Remote Sensing Project around the AeroPod, including 60 lesson plans now used at numerous middle and high schools.



Information Technology

When NASA wants to design a selflearning Mars robot, predict how a rocket will react to pressure, or pick up fainter clues in images of deep space, it relies on high-powered software and information technology. But these innovations don't just appear—to meet these needs, NASA partners with industry and tasks its own computer scientists to build them. That benefits all of us, because the same codes end up with wideranging applications, including helping cars avoid collisions and image analysis that can map storms and detect inflamed cells.

34 Planet-Navigating AI "Brain" Helps Drones and Cars Avoid Collisions

Once you've designed a robot that can autonomously explore planetary terrains, putting that technology in cars, toys, and drones seems easy. That's why NASA-funded development of deep-space computing was a natural fit for Boston startup Neurala.

The company's core technology is artificial intelligence (AI) software modeled on the human brain. It doesn't require a cloud-based supercomputer like other AI systems, an important capability for a robot on Mars, where communication with Earth is delayed.

The company has long worked on programs that operate like brains, computing large amounts of information in parallel, rather than rapidly processing bits of information one after another.

A Langley Research Center engineer learned of the work and reached out. Under two Small Business Technology Transfer contracts, Neurala worked on unsupervised learning and navigation capabilities and developed visual processors based on passive sensors. A Center Innovation Fund award let the team create collision aversion capabilities.

Neurala soon built apps for consumer robots and drones, and the company now has contracts with drone companies, industrial robot manufacturers, and a major automaker looking toward self-driving cars.

Its main product, the Brains for Bots software development kit, lets developers incorporate the Neurala Brain—which can identify, find, and track objects—into programs for drones, self-driving cars, industrial robots, and more. Later iterations will incorporate navigation and advanced collision avoidance.

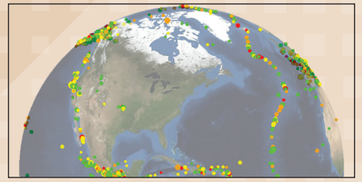
35 Early NASA "Dream Computer Program" Still Optimizes Designs

Half a century after it was created at Goddard Space Flight Center, NASTRAN remains at the cutting edge of computer-aided engineering as perhaps NASA's most successful software spinoff. It has helped design everything from cars and turbines to buildings and roller coasters. Its code is also incorporated into many commercial programs, including Newport Beach, California-based MSC Software's Apex platform, which makes modeling and simulation up to 10 times faster and allows computer-aided engineering to be introduced earlier in the design process.

36 2D Analysis Software Clarifies Medical, Weather, Intelligence Images

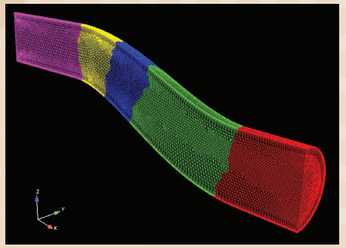
In the 1990s, a Goddard Space Flight Center oceanographer developed a mathematical formula to analyze ocean and atmospheric data, now called the Hilbert-Huang Transform (HHT), but it only worked on a one-dimensional signal. Another Goddard scientist later created software that could apply the transform across two dimensions. Arlington, Virginia-based Syneren Technologies Corporation licensed the HHT2 software and developed its own program, which can tease information out of images for medical, defense, and meteorological applications, among countless others.

37 Quake Hunter Maps a Century of Quakes Worldwide



Government agencies, companies, and individuals use the NASA-created World Wind software development kit, based on a virtual model of Earth developed at Ames Research Center, for many different purposes. In 2016, interns at Ames used it to create Quake Hunter, which charts every earthquake of the last century, offering an unprecedented visualization of seismological data. The team also used World Wind to build SpaceBirds, which tracks about 15,000 satellites in Earth's orbit, and WorldWeather, which maps weather for the entire globe.

38 Free Aerodynamic Simulation Code Supports Industry, Education



In the 1990s, what is now Glenn Research Center, the Air Force, and McDonnell Douglas cooperated to produce the versatile, publicly available Wind-US program for computational fluid dynamics, which predicts how aircraft surfaces will interact with air. Alan Cain, who worked on a precursor software at McDonnell Douglas, founded Chesterfield, Missouri-based Innovative Technology Applications Company (ITAC) based largely on his knowledge of the program and the problems it can solve. ITAC and others use Wind-US for free through software usage agreements.

39 Software Models Atmosphere for Spacecraft

When the Curiosity rover made its spectacular landing on Mars, most of the attention was focused on the revolutionary "sky-crane maneuver" that helped slow the spacecraft down. But behind the scenes, atmospheric modeling software developed at Marshall Space Flight Center helped with another make-or-break factor: choosing the landing site. Boeing, whose aerospace business is based in Berkeley, Missouri, is now one of many companies that license this software to ensure spacecraft can fly—and land—safely.

40 Software Takes Cost Estimating to the Stars

When imagining what it takes to design a spacecraft, few people think about the engineering that goes into getting an accurate cost estimate before the building begins. And yet software designed at Marshall Space Flight Center to do just that, called Project Cost-Estimating Code, has become one of the center's most-downloaded codes. Bethesda, Maryland-based Lockheed Martin is one of dozens of companies, universities, Government agencies, and international organizations that use the software.

41 Communication Devices Ease Contact with Commercial Spacecraft

As part of an overhaul of the ISS communications system, Johnson Space Center contracted Colorado Springs-based AMERGINT Technologies to build a new data processor for Mission Control to receive data from the space station. The company was developing its reconfigurable SOFTLINK architecture of software devices, each of which carries out a specific function. Now AMERGINT's commercial offering benefits from rigorous testing, security requirements, and the many new software devices it had to create to carry out the work.

42 Mission Control Software Manages Commercial Satellite Fleets

Saber Astronautics—based in Sydney, Australia with offices in Denver—used data from Goddard Space Flight Center's Advanced Composition Explorer to validate data-mining software that models and predicts the behavior of spacecraft components. Upon validation, the company started building its Predictive Interactive Groundstation Interface (PIGI) mission control software. The company uses PIGI, which can predict and track component performance for dozens of satellites simultaneously, in its mission control service, and it will soon enable a commercial software package.

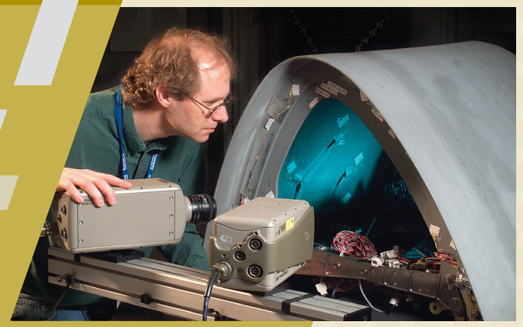
Industrial Productivity

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 make our lives safer and even enable research that will power future medical advances, including a tuneable light filter designed to facilitate remote sensing that now enables biologists to manipulate microscopic genetic material. They also turn up in unexpected places, like a gold-plating technique improved for space that puts the shine on the Oscars.

43 High-Speed Cameras Test Material Performances on Impact

After Space Shuttle Columbia suffered a catastrophic failure, NASA spent months investigating what went wrong and how to prevent it ever happening again.

One of the tools it needed, a high-speed stereo photogrammetry system, didn't exist yet. High-speed photogrammetry uses two synchronized cameras to film an impact, and then software to analyze how the materials deform during the event.



"It's like using your two eyes to know where something is in 3D space," explains John Tyson, president of Philadelphia-based Trilion Quality Systems.

But ARAMIS, the photogrammetry software NASA uses, "didn't have the ability to work at 30,000 frames per second," explains Matthew Melis, a ballistics expert at Glenn Research Center.

So Glenn worked closely with Trilion to adapt it to work with high-speed cameras. The resulting product helped complete the Columbia investigation and get the Shuttles back to flight—and now helps make cars and airplanes safer, and much more.

Boeing used Trilion's systems to confirm its Dreamliner 787 was structurally sound. Ford used it to test aluminum for its F-150 truck bodies to ensure it wouldn't compromise the toughness. Adidas used it to design an advanced running shoe based on the gait of Olympic marathoners.

Tyson says the high-speed ARAMIS system also saves money over traditional sensor measurements over time: 10 times cheaper, according to an estimate from Boeing.

44 External Platform Enables Space Research

Many ISS investigations test how materials perform outside our atmosphere or use the vantage point for Earth, sun, and star observations. Houston-based Airbus DS Space Systems has built external platforms for NASA, working with Johnson Space Center, to enable that kind of research, and most recently used that expertise to build a commercial platform, which will allow private companies to test materials and mount sensors in space.

45 All-in-One Lab Device Gets New Instruments via Software Update

Researchers at Australian National University who worked on the Jet Propulsion Laboratory's (JPL) Gravity Recovery and Climate Experiment under an agreement with the Australian government, some of whom had also worked on the Laser Interferometer Space Antenna for JPL, used their expertise in signal processing and chip programming to build a device that can reconfigure itself into eight common electronics test and measurement instruments. Configurations for new instruments are available via download to the Moku:Lab as Canberra, Australia-based Liquid Instruments develops them.

46 Gold Coating Keeps Oscars Bright

The Academy Awards is not a place most people look for NASA technology, but it's there: the coveted Oscar trophy is coated in the same gold that helps telescopes glimpse distant galaxies. In the 1990s, Brooklyn-based Epner Technologies, a longtime NASA partner, improved its process to make the gold more durable while retaining its high shine for a Mars Orbiter instrument. Now that process is used for art, medical instruments, the James Webb Space Telescope constructed at Goddard Space Flight Center—and the Oscars.

47 3D Printer Aims to Accelerate Materials Development

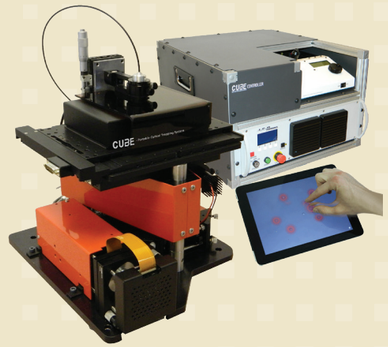
PrintSpace 3D founder Mark Jaster built the expertise he needed to design the Altair 3D printer in part during his years at Glenn Research Center, where he learned about cutting-edge materials, thermal management, and more. His printers now sell to universities, businesses, and research labs across the United States and overseas, and his Rexburg, Idaho-based PrintSpace 3D is working on adding metals and advanced materials to the more than 25 materials its printers can already use.

48 Silicon Diode Sensor Tracks Extreme Temperatures

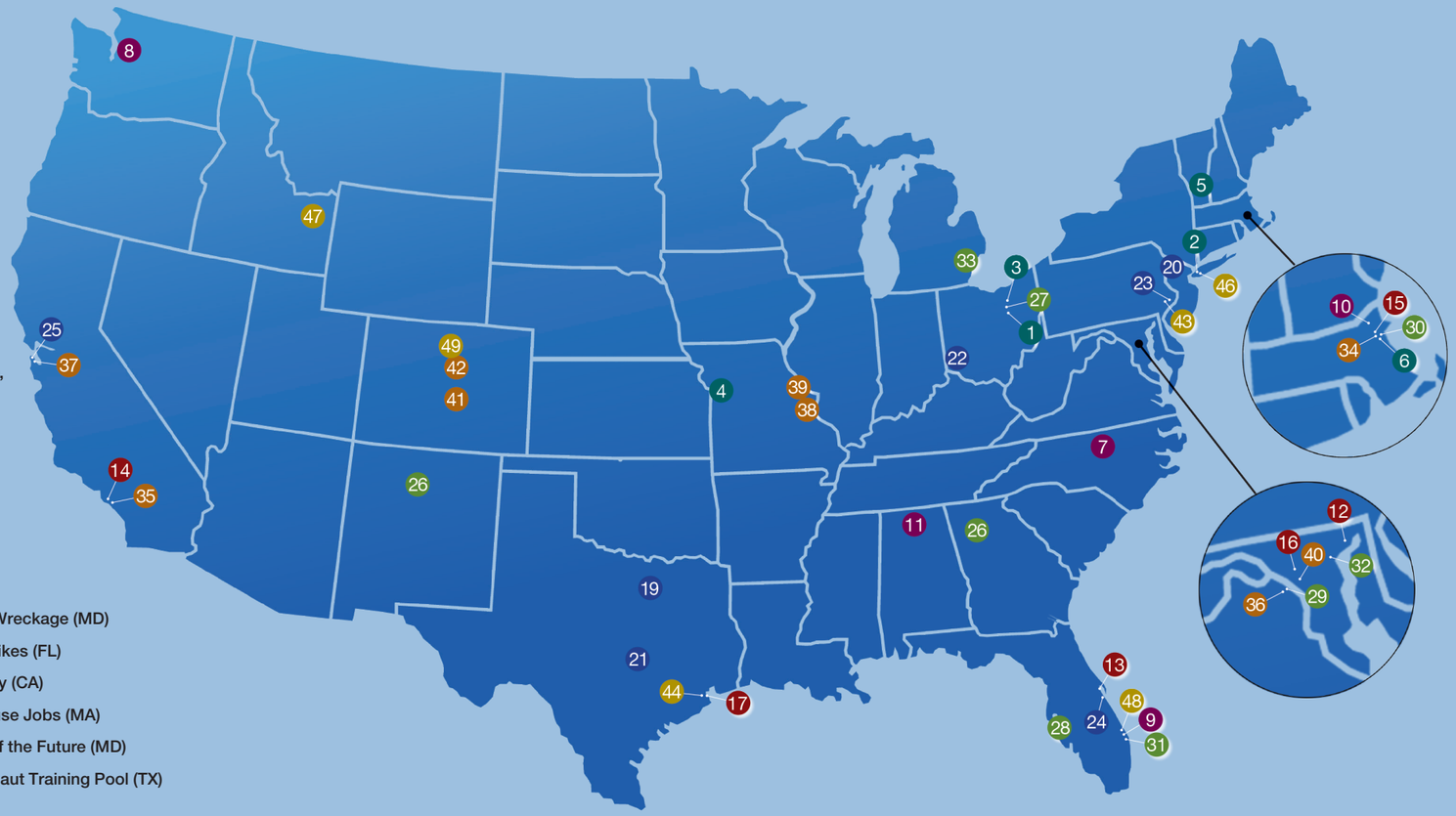
It's important to keep close track of rocket fuel temperatures, which must remain hundreds of degrees below zero. NASA uses special sensors to get the extremely accurate reads it needs at those low temperatures, and West Palm Beach, Florida-based Scientific Instruments Inc. has been supplying them to Kennedy Space Center since the Apollo Program. A more recent version, first used and improved for the Space Shuttle program, is now sold to private space companies and the medical industry.

49 Tunable Filter Grabs Particles and Cells Using Only Light

Filtering different wavelengths of light can help reveal important information, such as clues to how well a plant is growing. Frederick, Colorado-based Meadowlark Optics, with help from an SBIR contract from the Jet Propulsion Laboratory, developed a light filter that could be tuned to different wavelengths with a flip of a switch, hoping it could be useful for NASA's many Earth-observing missions, but the result turned out to have wide-ranging applications far beyond plant stress, from nuclear fusion to brain research.



NASA Spinoff Technology across the Nation



Health and Medicine

1. Sterilizing Fogger Cleans Ambulances with a Breeze (OH)
2. Biometric Sensors Optimize Workouts (NY)
3. Optimized Imager Tracks Cancer, Stem Cells in Medical Research (OH)
4. Weightless “Weight”-Lifting Builds Muscle on Earth (MO)
5. Virtual Therapist Offers Out-of-This-World Depression Treatment (VT)
6. Compact Spectrometers Unveil Clues to Diagnose Cancer (MA)

Transportation

7. Innovative Design Propels Small Jet Faster, Farther with Less Fuel (NC)
8. Design Software Transforms How Commercial Jetliners Are Built (WA)
9. Original Cryogenic Engine Still Powers Exploration, Defense, Industry (FL)
10. Time-Triggered Ethernet Slims Down Critical Data Systems (MA)
11. Simplified Aircraft Modeling Packs Weeks of Analysis into Minutes (AL)

Public Safety

12. Radar Device Detects Heartbeats Trapped under Wreckage (MD)
13. Surveillance System Captures, Maps Lightning Strikes (FL)
14. Virtual Reality Platform Helps Pilots Land in the Sky (CA)
15. Autonomous Robots Take On Dangerous Warehouse Jobs (MA)
16. Drone Traffic Forecasts Show Commercial Skies of the Future (MD)
17. Offshore Oil Workers Learn Survival Skills in Astronaut Training Pool (TX)

Consumer Goods

18. Apollo 11 History Archive Helps Virtual Reality Program Come to Life (Ireland)
19. Light-Induced Oxidation Cleans Air, Surfaces, Clothes (TX)
20. Ferrofluid Technology Becomes a Magnet for Pioneering Artists (NJ)
21 The Martian Garden Recreates Red Planet’s Surface (TX)
22. Aerogel Insulation Makes Thinner, Warmer Outerwear (OH)
23. Space-Grade Insulation Keeps Beer Colder on Earth (PA)
24. High-Efficiency LEDs Grow Crops, Stimulate Alertness (FL)
25. Paired Sleep Tracker, Light Therapy Tools Retrain Circadian Rhythms (CA)

This map details the geographic locations of the companies that appear in *Spinoff* 2018.

Energy and Environment

26. Organic Compound Turns Toxic Waste into Harmless Byproducts (GA)
27. LED Lighting Improves Efficiency, Imaging, Cuts Maintenance (OH)
28. Plant Food for Space Grows Crops on Earth (FL)
29. Remote Sensing Technology Fights Forest Fires Smarter (DC)
30. Earth Images Enable Near-Perfect Crop Predictions (MA)
31. Micronutrient Formula Strengthens Plants, Increasing Yields (FL)
32. Chemical Simulation Software Predicts Climate Change, Air Quality (MD)
33. NASA Kite Invention Spurs Ever-Growing Educational Program (MI)

Information Technology

34. Planet-Navigating AI “Brain” Helps Drones and Cars Avoid Collisions (MA)
35. Early NASA “Dream Computer Program” Still Optimizes Designs (CA)
36. 2D Analysis Software Clarifies Medical, Weather, Intelligence Images (VA)
37. Quake Hunter Maps a Century of Quakes Worldwide (CA)
38. Free Aerodynamic Simulation Code Supports Industry, Education (MO)
39. Software Models Atmosphere for Spacecraft (MO)
40. Software Takes Cost Estimating to the Stars (MD)
41. Communication Devices Ease Contact with Commercial Spacecraft (CO)
42. Mission Control Software Manages Commercial Satellite Fleets (CO)

Industrial Productivity

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47. 3D Printer Aims to Accelerate Materials Development (ID)
48. Silicon Diode Sensor Tracks Extreme Temperatures (FL)
49. Tunable Filter Grabs Particles and Cells Using Only Light (CO)

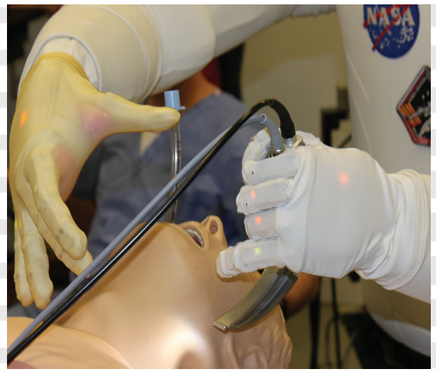
SPINOFFS OF TOMORROW

Spinoff 2018 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:

GRAPHENE SUPERCAPACITORS FOR ELECTRIC VEHICLES

Supercapacitors have received intense interest for power storage applications, yet commercially available batteries still have a significantly higher specific energy density than available supercapacitors. NASA has developed electrode composite materials with exceptionally high energy density, solving this problem. The technology can be manufactured at low cost and applications range from electric vehicles to renewable energy and backup power systems.

ROBONAUT 2: MEDICAL APPLICATIONS



Robonaut 2 is a state-of-the-art, highly dexterous, humanoid robot currently serving on the International Space Station. On Earth, the robot's nearly 50 patented and patent-pending component technologies have the potential to be game-changers in several markets—including the medical industry. These advances can aid in a variety of medical applications, ranging from telemedicine to the autonomous handling of logistics and medical procedures.

SHAPE MEMORY ALLOY ROCK SPLITTERS

A groundbreaking method uses shape memory alloys to split apart rock formations without the need for explosives or hydraulics. This technology could prove invaluable to enterprises as varied as oil drilling, mining, civil engineering, fossil collection, and search-and-rescue operations—any field that requires compact but large static forces.

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in your **life**
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