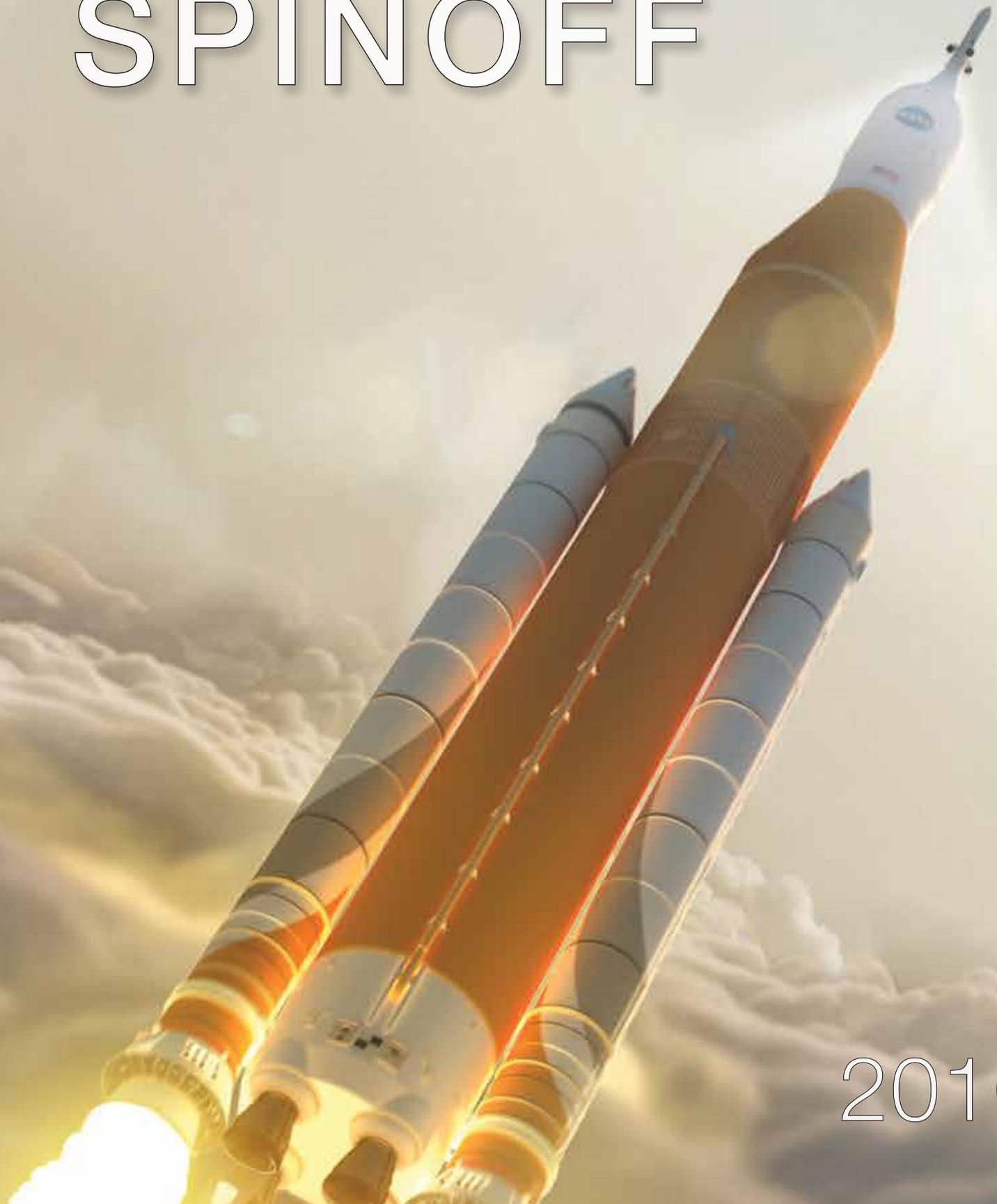


National Aeronautics and Space Administration



SPINOFF



2016

Spinoff 2016

NASA takes us farther into the universe every day, but it also makes sure that the results of its innovations in technology are brought down to Earth in the form of public benefits. Spinoff annually highlights stories of successful technology transfer from agency missions to commercial products and services. Since 1976, we've documented nearly 2,000 NASA technologies making life on Earth better in the fields of health and medicine, transportation, public safety, consumer goods, energy and environment, information technology, and industrial productivity.

The following summaries will give you a taste of what you can read about in this year's publication. To request your free copy of *Spinoff 2016*, or to read it in full online, visit us at <http://spinoff.nasa.gov>.

Monumental Opportunities of the SLS

NASA's Space Launch System will travel to new frontiers of human exploration—and bring home technologies that benefit the public. In *Spinoff 2016*, you can read about NASA's next big rocket and how it will transform space transportation in the coming years and yield a crop of benefits for future industry.

Health and Medicine



If preventing and treating health problems is complicated on the ground, it's far more challenging in space, where resources are limited and healthcare professionals are remote. Many of the solutions NASA funds or develops, such as quick and easy diagnostic tools or treatments to maintain the bone density that's lost in zero-gravity, however, are just as helpful on Earth as they are in space.

1

Rodent Research Contributes to Osteoporosis Treatments

Astronauts know their bodies will be tested during time spent on the International Space Station, from the multiple sunrises and sunsets wreaking havoc on their circadian rhythms to the lack of gravity causing bone-density and muscle loss. With missions to Mars on the horizon, NASA is increasingly interested in potential treatments to help protect astronauts' bodies.

Scientists from Ames Research Center teamed up with Amgen, a biotechnology company based in Thousand Oaks, California, for a series of three experiments conducted on mice using three different molecules. During space shuttle flights, groups of mice were sent into microgravity for two weeks after receiving one of the molecules, designed to mitigate loss of bone density and muscle strength.

The results were encouraging, and one of the molecules tested by Amgen became the foundation for Prolia, a treatment used to help protect against broken bones in women with osteoporosis. The treatments are also classified as biologics, because they incorporate recombinant DNA in the composition. That's good news for NASA, as similar treatments will allow astronauts to produce the drugs they need during space exploration far from Earth without having to store large supplies on crew vehicles.



2

Pressure Garments Save New Mothers' Lives

In the 1960s, Ames Research Center used an astronaut G-suit to successfully treat a woman suffering from post-obstetric hemorrhaging. Subsequent research showed that a noninflatable garment could effectively and more safely treat the condition. Suellen Miller, a professor of obstetrics and gynecology at the University of California, San Francisco and founder of the Safe Motherhood Initiative, now uses a garment developed using NASA's research to help women suffering from post-obstetric hemorrhaging in low-resource settings around the world.



3

Tool Kit Simplifies Development of High-Affinity Molecules

A human trip to Mars will require new medical diagnostic technology because antibodies, used in measuring biomarkers, degrade in space. Through SBIR funding from Johnson Space Center in 2007, AM Biotechnologies LLC in Houston developed X-Aptamers, antibody alternatives that are longer-lasting and easy and quick to produce. The company's X-Aptamer Selection Kit is now available to pharmaceutical companies and research universities for drug development.



4

Space-Ready Spectrometer Offers Terrestrial Advantages

Under two SBIR contracts with the Jet Propulsion Laboratory in the 1990s, Brimrose Corporation of Sparks, Maryland, made its acousto-optic tunable-filter (AOTF) spectrometers smaller, lighter, sturdier, and more energy-efficient. The company now sells 14 different AOTF spectrometer models that are used in industries ranging from pharmaceuticals and medical imaging to agriculture and oil and gas.



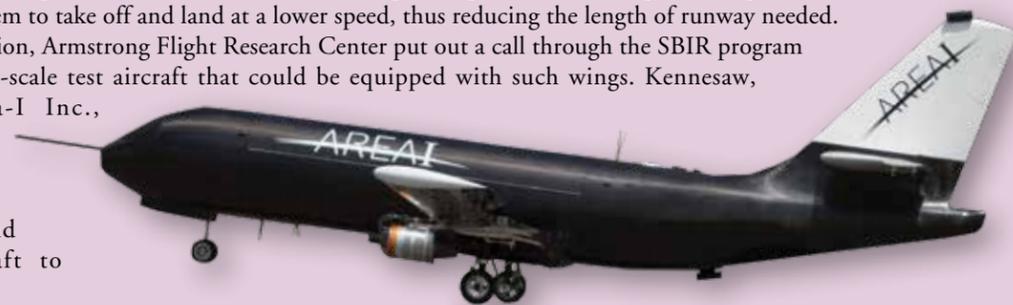
Transportation

No one knows transportation better than the agency that sent people to the moon and back and safely lands complex instruments on distant planets. Meanwhile, a major part of NASA's mission is to transform the field of aviation on Earth, and its researchers are constantly developing new test beds and design software to push the boundaries of aerodynamics, efficiency, and safety, leading not just to higher-performance vehicles but also to lives and money saved.

5

Unmanned Research Aircraft Test Cutting-Edge Innovations

Due to a desire for aircraft to be able to take off and land at airports with shorter runways, in the mid-2000s NASA began experimenting with the circulation control wing concept. The technology would give aircraft greater lift, allowing them to take off and land at a lower speed, thus reducing the length of runway needed. To validate the innovation, Armstrong Flight Research Center put out a call through the SBIR program for an unmanned, sub-scale test aircraft that could be equipped with such wings. Kennesaw, Georgia-based Area-I Inc., which specializes in the development of autonomous aircraft, won the contract and delivered the aircraft to Armstrong in 2011.



Fortuitously, the aircraft that Area-I developed for NASA was highly adaptable. So when Armstrong put out call for another research aircraft, this time a model akin to a medium-range, narrow-body, twinjet airliner, for aerodynamics investigations, and Langley Research Center solicited proposals for a regional-type, sub-scale airplane with a T-tail empennage and a rear engine mount to improve stall recovery, Area-I applied for and received SBIR funding from both centers. By reconfiguring its original NASA-funded, baseline aircraft, which it named the Prototype-Technology Evaluation Research Aircraft, or PTERA, the company successfully built both aircraft, which were delivered to their respective centers in 2014.

Building on its fruitful work with NASA, the company is developing unmanned aerial vehicle airframes for the US Navy and the US Air Force, and is also taking orders for PTERA aircraft from universities and companies. "PTERA is sitting there with an open source flight computer so that you can go in and load up everything you need," Area-I CEO Nick Alley says. "In a matter of a year you can be up and flying."

6

Data Visualizer Enhances Modeling for Cars, Consumer Products

Computational fluid dynamics has come a long way in the past few decades, and Intelligent Light Inc., of Rutherford, New Jersey, continues to be a leader in the field. From its first SBIR contracts with Langley Research Center, the company's FieldView product has evolved past visualization capabilities to provide the best solutions for complex problems, winning over Formula One teams and manufacturers in the process.



7

Lightweight, Ultra-Strong Nanotubes to Transform Industry

First synthesized in the mid-1990s, boron nitride nanotubes (BNNT) are strong, lightweight, and heat-resistant and absorb neutron and ultraviolet radiation—making them ideal spacecraft heat shields. But no method existed to create them in appreciable quantities until Langley Research Center accomplished the feat in 2008. Having licensed the NASA technology, Newport News, Virginia-based BNNT LLC is supplying the material to companies while working with the space agency to further improve the production process.



8

Multidisciplinary Software to Help Take Aircraft to the Next Level

Future advances in commercial aircraft will require multidisciplinary analysis and optimization (MDAO), which finds optimal designs by considering how each aircraft component interacts with every other in light of multiple engineering fields. In order to simplify this complex process, Glenn Research Center developed OpenMDAO, an open source software program that allows researchers to perform these analyses without needing to be experts in MDAO. The University of Michigan is among those now using OpenMDAO for research into fuel-saving aircraft wing designs.



9

Orbital Trajectory Analyzer Takes Mission Planning to New Heights

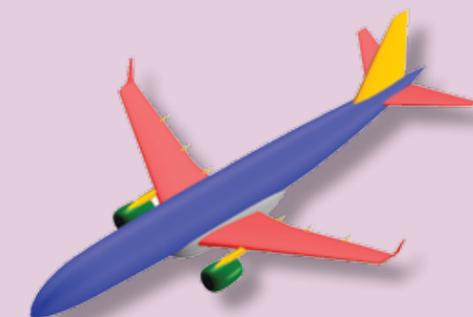
A team of engineers at Goddard Space Flight Center created the General Mission Analysis Tool (GMAT), specializing in trajectory optimization to design better flight plans for their spacecraft. Publicly released in 2013 as open source software, GMAT has been embraced by users around the world, with defense contractors like Columbia, Maryland-based Applied Defense Solutions Inc. making use of it. A number of universities also use the software as an educational tool.



10

Open Source Aircraft Design Software Helps Industry, Hobbyists

For years, the only people with access to computer-aided drafting software were engineers. Hobbyist aviators were left out until a group of engineers from Langley Research Center and California Polytechnic State University teamed up to create OpenVSP, an open source program for designing aircraft and other vehicles. Desktop Aeronautics Inc., of Palo Alto, California, is among several companies that use OpenVSP for new aircraft concepts.



Public Safety

Any agency that works with millions of pounds of thrust and puts people into one of the most hostile environments imaginable has to pioneer new safety measures. NASA spinoffs like surface-crack detectors that ensure structural safety or sensors that identify dangerous gas leaks are natural outgrowths of that concern, but other safety applications of NASA technology are more surprising, like software that uses satellite data for forecasting crop yields and preventing food shortages.

11

Rice Crop Models Stabilize Global Markets, Enable Efficient Irrigation

Among the world's major dietary staples, rice yields are the most difficult to predict, and that lack of reliable information makes the rice market volatile, putting investors, producers, and consumers at risk. And rice farming, in which fields are often inundated, also requires large quantities of water, which is becoming scarce in some rice-producing areas.

Applied Geosolutions, based in New Market, New Hampshire, decided to leverage a decade of research on applications for Earth-imaging satellite data to create a Rice Decision Support System (RDSS) with the help of two SBIR contracts from Stennis Space Center. The company designed web-based software that uses data from NASA's and other organizations' satellites, incorporating measures of rice fields, yield modeling, and weather forecasts to generate information in real time about expected yield around the globe.

Abroad, the system is focused on pilot sites in Java, Indonesia, and Vietnam, where the data gathered is used primarily for supporting food security programs and commodity markets. The company is also doing work in California and Arkansas, in part supported by NASA's Land-Cover/Land-Use Change Program, to support alternative rice management strategies and farming practices.



12

GPS Sensor Web Helps Forecasters Warn of Monsoon Flash Floods

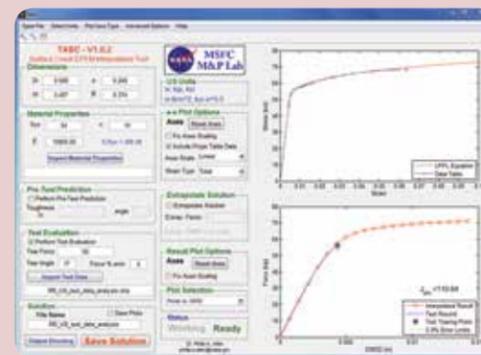
In Southern California, summertime monsoons bring a variety of hazards and are notoriously difficult to predict. In a project funded by NASA's Earth Science Technology Office through the Jet Propulsion Laboratory, 37 GPS stations were outfitted with meteorological sensors, generating data on air moisture. The National Oceanic and Atmospheric Administration's San Diego and Los Angeles/Oxnard Weather Forecast Offices use the data to improve monsoon forecasting and issue storm warnings.



13

Analytic Tool Simplifies Metal Fracture Assessments

Determining a metal's fracture toughness is critical to knowing when a spacecraft or structure needs repairs, but it's a time-consuming job and the disciplines involved are complex. Marshall Space Flight Center engineer Phillip Allen developed software called Tool Analysis of Surface Cracks, or TASC, to streamline the process. Quest Integrity Group in Boulder, Colorado, is one of many organizations that use the technology commercially to ensure the safety of structures.



14

Mars Methane Detector Identifies Harmful Gas Leaks

In order to determine whether Mars is, or ever was, host to life, the Jet Propulsion Laboratory (JPL) outfitted the Mars Science Laboratory rover with the Tunable Laser Spectrometer to detect methane, a possible sign of microbial life. Through a Space Act Agreement with various organizations, including San Francisco, California-based Pacific Gas & Electric, JPL utilized the technology to develop a handheld methane detector for industry that finds potentially dangerous and greenhouse-gas-contributing pipe leaks.



15

Hydrogen Detection Tape Saves Time and Lives

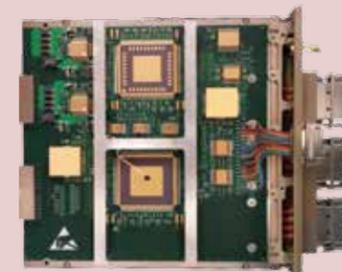
During the Space Shuttle Program, NASA relied on liquid hydrogen to fuel rocket launches, but the element's propensity to leak and its flammability meant miles of pipeline had to be inspected routinely. To make the process more efficient, Kennedy Space Center collaborated with the University of Central Florida (UCF) to develop a color-changing hydrogen detection tape. UCF chemist Nahid Mohajeri now sells the tape to industrial plants through her company, HySense Inc., headquartered in Rockledge, Florida.



16

Single-Photon Lidar Maps Ground Features Quickly, Efficiently

When John Degnan left Goddard Space Flight Center and joined Lanham, Maryland-based Sigma Space Corporation, four decades of NASA laser-ranging experience came with him. Sigma licensed two of Degnan's Goddard patents and developed low-energy, high-fidelity, airborne single-photon lidar (SPL) imagers. They provide reconnaissance, measure biomass, and map topography for the military, local governments, and companies. Sigma also helped Goddard develop the SPL device that will monitor polar ice on the ICESat-2 mission.



17

Temperature Sensors Cement Integrity of Bridges

When the White House called on government agencies to get involved in the community, Glenn Research Center responded by launching an Adopt a City Program to find companies to mentor. Pile Dynamics Inc. (PDI), in nearby Cleveland, Ohio, needed help crafting a sensor to ensure the structural integrity of concrete shafts like the ones it was pouring for a massive new bridge. With NASA's help, PDI validated its thermal integrity profilers, which have since been used in 40 construction projects worldwide.



18

Primer Stops Corrosion without Requiring Rust Removal

In the mid-1990s, Pittsburgh-based Surtreat Inc. developed two corrosion inhibitors that, applied to the surface of concrete, migrated to the rebar inside. The company entered into a Space Act Agreement with Kennedy Space Center, conducting tests that validated the inhibitors as among the most effective on the market. Recently, Surtreat used a compound similar to one tested at Kennedy to develop a new pigmented primer that can be applied directly to rusty steel to inhibit corrosion.





NASA develops and funds such a wide range of technologies—often with broad applications beyond the space program—that its technical DNA often turns up in the most unexpected places. Temperature-regulating clothing and heat-blocking device cases might not be surprising places to discover NASA’s influence, but you might not expect space technology in a coffee shop, microbrewery, or prayer mat—all spinoffs you can find in this section.

19

NODE+ Platform Integrates Sensors with Smartphones

Ames Research Center initially contracted George Yu to create a device that would let a gas and chemical detection system “sniff” the air for samples. What he ended up doing, though, was to develop the interface that allowed a module containing carbon nanotube sensors to draw its power from a smartphone battery and use the phone to digitally process the data it gathered and transmit it to a central location.

After founding Chattanooga, Tennessee-based Variable Inc., Yu incorporated most of the design for the technology he had developed for NASA into his NODE wireless sensor platform. Variable then converted off-the-shelf sensors, such as infrared thermometers, color referencers, motion sensors, and barcode readers, into interchangeable modules that can be snapped onto either end of NODE. Modules include everything from detectors for dangerous gases to sensors for measuring ambient light, room temperature, humidity, and barometric pressure.

The product line was released in 2012, and is already in its second generation, NODE+, which is faster, uses less power, is more durable, has more memory, and is compatible with both Android and iOS smart devices. The invention has garnered multiple technology awards and found markets in supply-chain management, transport, and logistics, among other areas of business.



20

Precision Coffeemaker Adapts Brews to Beans, Taste

During four summer internships at NASA Research Park, part of Ames Research Center, Matt Walliser learned various skills related to building intelligent, autonomous robotic systems. Some of these, like proportional-integral-derivative (PID) controllers and embedded communications, became central to the Blossom One coffee brewer created by San Francisco-based Blossom Coffee Inc., where Walliser is now chief engineer. The technology holds brew temperatures constant, ensuring consistent results, and allows the machine to brew according to recipes stored in the cloud.



21

CO₂ Recovery System Saves Brewers Money, Puts Bubbles into Beer

Work that Robert Zubrin did with Johnson Space Center focused on breaking down elements abundant on Mars and turning them into resources, including capturing and manipulating carbon dioxide (CO₂). In the beer world, large systems allow major brewers to capture CO₂ generated during fermentation and use it for carbonation, but the technology hasn’t been available on smaller scales. Now, the CO₂ Craft Brewery Recovery System, made by Zubrin’s Lakewood, Colorado-based Pioneer Energy Inc., is available for microbreweries.



22

Space Blanket-Inspired Cases Protect Expensive Devices

Smartphones, laptops, and tablets are susceptible to damage if exposed to very high or low temperatures. Inspired by the “space blankets” he used as a Boy Scout, Nick Blanton, founder of Portland, Maine-based Salt Cases Company, developed fabric cases that incorporate thermal sheet technology created by Marshall Space Flight Center decades ago to protect 21st-century technology.



23

Antimicrobial Agent Updates Ancient Industry of Prayer Mats

Two NASA experiments testing the antimicrobial properties of chitosan, derived from the main compound in arthropod exoskeletons—especially one test carried out on Johnson Space Station’s Cell Culture Module aboard the International Space Station—inspired a feature of what Calgary-based TIMEZ5 Inc. calls “the world’s first physiological prayer mat.” NASA’s research resulted in chitosan’s incorporation into the company’s mats, where it fends off bacteria, fungi, and mold.



24

Heat-Reflecting Material Regulates Body Temperature

In the 1990s, NASA was researching the feasibility of rocket planes to reduce the cost of launching payloads into space, and Protective Ceramic Coating Material, or PCCM, was developed as a heat shield for use during reentry. The versatile technology has since been licensed for a variety of uses, such as a substrate in various combustion processes. In its latest incarnation, Mooresville, North Carolina-based Trizar Technology Inc. is incorporating PCCMs into clothing lines for heat management.



25

Modified Monitor Provides Glasses-Free 3D for Pilots, Gamers

Pilots have to vigorously monitor a mental checklist while flying planes. In the hopes of making things easier for them, Langley Research Center has been working with Rochester, New York-based Dimension Technologies Inc. for several years to develop displays capable of 3D imaging without requiring glasses. The monitor has already won over video-game enthusiasts for its lifelike imagery and eye-tracking software that allows users freedom of movement.



Energy and Environment

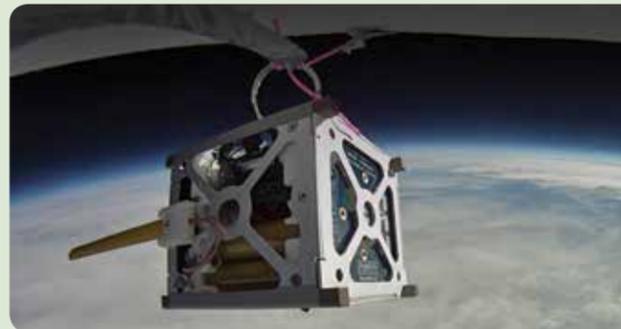
The agency responsible for powering interplanetary sojourns and gathering data on alien worlds naturally has a keen interest in developing technologies that also fuel operations on Earth and examine our own globe. In fact, Earth observation has been one of NASA's key functions since before it produced the first image of our home from space. The results benefit everyone from farmers to firefighters, while new energy solutions harness resources that might otherwise be wasted.

26

Flock of Nanosatellites Provides a Daily Picture of Earth

While working at Ames Research Center, physicist Chris Boshuizen helped start the PhoneSat project, which aims to make satellites more affordable to build and launch without sacrificing performance. He took those same ideas with him when he cofounded San Francisco-based Planet Labs Inc. in 2011. The company is launching flocks of nanosatellites made from cheap, off-the-shelf parts that will provide a daily snapshot of Earth, benefitting a range of industries.

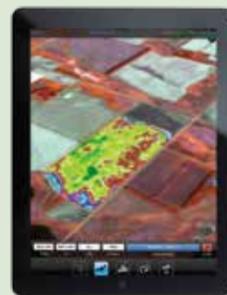
The company has raised more than \$160 million in capital and has generated interest from a number of industries. Insurance companies could verify homeowner damage claims by examining before-and-after images of properties, and oil and gas companies could monitor pipelines to ensure integrity and safety. Mobile-phone companies can use fresher satellite imagery to improve their map applications.



27

Multispectral Satellite Imagery Shows Farmers' Fields in New Light

When the Internet was young, Goddard Space Flight Center granted the University of Minnesota funds to develop applications to let the state of Minnesota make use of satellite imagery of its forests. Needing to process datasets and make them accessible on the web, the team created MapServer, an open source development environment thousands of websites still use, including that of Fargo, North Dakota-based Satshot. Satellite images the company distributes help farmers allocate resources, spot equipment problems, and monitor crop health.



28

Software Helps Restore Fire-Ravaged Habitats

The Bureau of Land Management not only puts out wildfires but also restores the charred land. To help the agency draft its required restoration plans more quickly, Idaho State University wildlife biologist Keith Weber worked with Goddard Space Flight Center scientists through funding from NASA's Research Opportunities in Space and Earth Science program to develop the Rehabilitation Capability Convergence for Ecosystem Recovery, or RECOVER software. The program has also found use in fire containment and prevention.



29

Buildings for Manipulating Magnetism Revolutionize Magnetometers

A pair of buildings where magnetism can be manipulated at Ames Research Center fell into disuse by the 1990s, but they piqued the interest of San Jose, California-based Geometrics Inc., which needed a test facility for its magnetometers, used to find magnetic anomalies in soil and water. The company leased the buildings through a Space Act Agreement, and its devices are now used to find buried objects and calibrate underground drill rigs.



30

Cost-Saving Method Yields Solar Cells for Exploration, Gadgets

Solar cells are expensive, but through a series of SBIR contracts from Glenn Research Center, Niles, Illinois-based MicroLink Devices Inc. has come up with a new way to create flexible cells that reduces manufacturing costs. NASA is considering the technology for massive solar arrays on future space exploration missions, and the award-winning commercial version has already been employed by the military for use as a portable power supply.



31

Wide Area Thermal Imaging System Brings the Landscape into Focus

NASA has a number of imaging systems for finding fires, but none were capable of identifying small fires or indicating the flames' intensity. Thanks to a series of SBIR contracts between Ames Research Center and Ypsilanti, Michigan-based Xiomax Technologies LLC, the Wide Area Imager aerial scanner does just that. While NASA and the US Forest Service use it for fire detection, the tool is also being used by municipalities for detailed aerial surveillance projects.



32

Photocatalytic Water Splitter Stores Energy as Hydrogen

When titania is exposed to ultraviolet light, it becomes a photocatalyst to split water into hydrogen and oxygen. Only 4 percent of sunlight, however, is ultraviolet. Under two SBIR contracts with Ames Research Center, Nanoptek Corp., based in Concord, Massachusetts, grew titania crystals with such surface tension that they became responsive to 29 percent of total sunlight. Nanoptek's photocatalytic panels convert energy to stored hydrogen, representing the first electrolyzer to be competitive with batteries.



33

Recycling Technology Converts Plastic Waste to Energy

Through the Obama administration's Strong Cities, Strong Communities Initiative, Glenn Research Center worked with Vadxx Energy LLC, based in Cleveland, Ohio, to optimize the company's proprietary process for converting used plastics into diesel additives, fuel gas, and inert char. The technology stands to lessen both the hazardous emissions from landfills and the amount of trash ending up in the world's oceans and other waterways, while also reducing the nation's dependence on foreign oil.



34

Tiny Capsules Enable a World of Possibilities

Tiny capsules made of beeswax, dreamed up by engineers at Marshall Space Flight Center and perfected by Lenoire, North Carolina-based RMANNCO Inc., have revolutionized the way oil spills are cleaned. Joe Resnick, who worked with NASA to develop the capsules in the 1980s, has made them even smaller and has developed a host of products, ranging from medical kits for dogs to synthetic pollen that could result in natural honey suitable for diabetics.



Information Technology



Whether monitoring mechanical systems worlds away, analyzing the dynamics of Earth's climate, designing vehicles that push the limits of sturdiness and efficiency, or modeling the behavior of air around vehicles in flight, NASA has a constant need for innovation in software and information systems. The products of these endeavors might find use in anything from optimizing wind turbines and predicting engine failures to cloud computing and targeting online advertising.

35

System-Health Monitor Predicts Failures before They Happen

Although many devices now are “smart,” few are able to monitor their own functions. CEMSol LLC, based in Phoenix, plans to change that, beginning with its Integrated System Health Management (ISHM) software. The first version, known as the Inductive Monitoring System (IMS), was developed in 2003 at Ames Research Center. The program collects data on physical processes and, by mining an archive of such data samples, establishes a baseline and parameters for normal system behavior. Deviations from that norm suggest a problem and a possible future failure.

In 2012, CEMSol teamed up with Ames and Lockheed Martin to try ISHM on the Lockheed C-130 Hercules, which had problems during start-up. The program was able to predict a start-up failure three starts before it occurred. Lockheed Martin saved \$700,000 in reduced maintenance costs and mission delays.

Equating system-health monitoring with the ability to verbalize symptoms to a doctor, the company sees ISHM as just a step toward near-universal self-monitoring in everything from cell phones to medical devices, and from refrigerators to automobiles.



36

Algorithm Predicts and Evaluates Storm Surges

With new remote sensing technologies able to provide more accurate observations of Earth's weather and topography, in the early 2000s Stennis Space Center put out a call through the SBIR program for technologies that could make use of those advances. Stennis awarded funding to WorldWinds Inc., based at the Stennis campus in Mississippi, which developed what would become StormWinds—a program that can model storm surges and help homeowners file insurance claims following a disaster.



37

Mars Rover Work Spawns PDF Collaboration Software

Among the first projects undertaken by Alliance Space Systems, founded by NASA engineers, were robotic arms for Jet Propulsion Laboratory rovers Spirit and Opportunity. The company wanted to streamline circulation and editing of documents and improve conversions of computer-aided designs into PDFs. The software it developed became the first product from spinoff company Bluebeam Software Inc. of Pasadena, California. The company has more than 650,000 users and was recently purchased for \$100 million.



38

Open Source Tools Popularize Infrastructure for Cloud Computing

Shortly after software developers at Ames Research Center partnered with industry to create OpenStack, the world's most popular open source cloud-computing platform, Canonical Ltd., an international organization with offices in Boston, incorporated the software into its Linux-based operating system called Ubuntu. Canonical then created a tightly integrated suite of hardware and software products based on OpenStack that make cloud computing available to more users than ever before.



39

Software Optimizes Designs from Spaceships to Wind Turbines

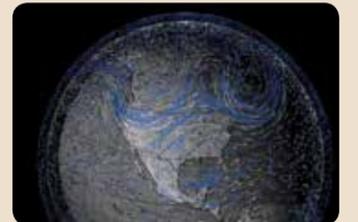
Craig Collier created software at Langley Research Center in the late 1980s to optimize designs for a planned hypersonic spaceplane. He later founded Newport News, Virginia-based Collier Research Corporation and continued developing the software, which calculated weights of different vehicle configurations and suggested changes to meet load requirements, as HyperSizer. Several NASA SBIR contracts geared HyperSizer toward developing alternate designs for the Orion spacecraft. Having optimized countless commercial craft, the company recently broke into the wind turbine industry.



40

NASA Climate Analytics Support Biological Research

NASA's Modern-Era Retrospective Analysis for Research and Applications, or MERRA, integrates data from a variety of observational instruments to create a synthetic data record of the weather. To make the data more accessible to outside researchers, Goddard Space Flight Center computer scientists created Climate Analytics-as-a-Service, or CAaaS. Tucson-based iPlant Collaborative is among the first organizations to adopt the service. Member scientists can use CAaaS to investigate, for example, climate change's impacts on agriculture and husbandry.



41

Artificial Intelligence Targets Advertising by Understanding User

Thousand Oaks, California startup Beyond Limits Corporation licensed an artificial intelligence program and language-understanding software from the Jet Propulsion Laboratory in 2013 and retooled the programs to target online advertising. Rather than simply remembering that a user once bought something from a particular store or pushing content based on words a user has typed, the software seeks to understand a person's intent and sentiment at a given time and use that data to push relevant content.



42

Modeling Software Helps Rocket Scientists Go with the Flow

To facilitate development of the Fastrac turbo pump, in the mid-1990s Marshall Space Flight Center coded the Generalized Fluid System Simulation Program (GFSSP) to model computational fluid dynamics. The software is free to government agencies and contractors, and Concepts NREC Inc., based in White River Junction, Vermont, licensed the technology and now sells the code to other entities as part of its turbomachinery software package.



43

Electro-Optic Ceramic Creates High-Speed Fiber-Optic Networks

A 2002 SBIR with Langley Research Center allowed Boston Applied Technologies Inc. (BATi) to demonstrate an electro-optic ceramic it had developed but not proven. Electro-optic ceramics alter properties of light based on applied electrical charges. The Woburn, Massachusetts-based company designed a laser Q switch that proved its OptoCeramic to have nearly 100 times the electro-optical effect of more traditional options. The material became central to most BATi products—components used in telecommunications, lidar, remote sensing, and other applications.



Industrial Productivity



NASA's various missions have spawned groundbreaking advances in industrial applications as varied as predicting machine lifespans, transmitting power in new ways, and producing both extreme temperatures and materials capable of surviving them. These and countless other innovations have steadily found their way from space applications into terrestrial industry, helping to keep American businesses at the forefront of efficiency and productivity.

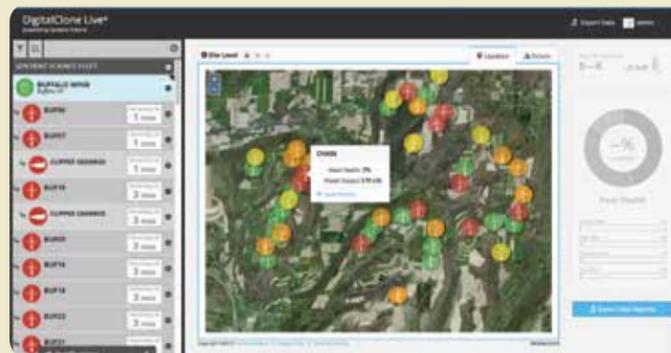
44

DigitalClone Software Predicts, Extends Machine Life

Medical scientists have made progress in recent years toward understanding how genetics play a role in susceptibility or resistance to various diseases. Meanwhile, the engineers at Sentient Science have been figuring out how to do similar prognostics for machine systems and components.

"We set out to decode the material genome," says Ward Thomas, president and CEO of the Buffalo-based company.

Following almost a decade of work and a string of SBIR contracts, it was a validation test at Glenn Research Center, carried out under another NASA SBIR contract, that proved Sentient had cracked the code. The company's predictions generated by their model matched real-world data from Glenn's massive gear-performance database from 25 years of tests.



The software, which generates material-performance test data, is now used on the Hubble Space Telescope, several military helicopters, one medical company's hip implants, and the wind turbines of eight operators, including giants like NextEra Energy and Clipper Windpower. Since DigitalClone's validation with NASA data, Sentient's staff grew from 10 to 26 by 2014, and annual revenues rose from \$1 million in 2010 to \$3.5 million in 2013.

45

Cryocoolers Fuel Exploration in Space and on Earth

When NASA needed a cryocooler to install on the Reuven Ramaty High Energy Solar Spectroscopic Imager, engineers at Goddard Space Flight Center turned to Athens, Ohio-based Sunpower Inc. for help. The company's cryocoolers feature just two moving parts and have a long lifespan. After 18 SBIR contracts, the company has a dozen models of cryocoolers that are aiding research in space and are employed in high-powered telescopes, multispectral and hyperspectral scanners, and superconductors on Earth.



46

Temperature-Resistant Materials Enable Space-Like Cold on Earth

Since the 1980s, Dunmore Corporation of Bristol, Pennsylvania, has worked with the Jet Propulsion Laboratory and other NASA centers to develop temperature-resistant products, helping the company establish a massive catalog. Many of its multilayer insulations were developed for NASA and are now used in building insulation, cryogenic material transport, MRI machines, and particle accelerators. Heat-resistant labels and electrostatic shields for circuit boards, as well as temperature-resistant tapes for electronics, also have stemmed from products designed for spacecraft.



47

Lasers Enable Alternative Power Transmission

To advance the concept of a space elevator, the NASA Space Technology Mission Directorate's Centennial Challenges Program held the Power Beaming Challenge, which called on inventors to wirelessly power robot "climbers" using lasers. The winning group for the 2009 competition founded Seattle-based LaserMotive Inc., which provides power for applications that require electrical and radio-frequency isolation. The company's upcoming technology will use laser light to power unmanned aerial vehicles in mid-air.



48

Helium Recapture System Reclaims Hydrogen for Industry Use

Under two STTR contracts with Stennis Space Center, Sustainable Innovations LLC, based in East Hartford, Connecticut, built a system that filters, cleans, and pressurizes hydrogen, based on a reverse fuel cell technology. The H2RENEW device will enable industries like glass, steel, and silicon manufacturers to efficiently recycle hydrogen used in production processes. The company also sees an opportunity in the nascent hydrogen-fuel market, and it's working on two more products based on the same electrochemical platform.



49

Laser Vision Helps Hubble, Package Shippers See Clearly

In preparation for a repair mission for the Hubble Space Telescope, which was launched with a misshapen mirror, Goddard Space Flight Center issued a call for optics companies to accurately measure replacement parts. AOA Xinetics, a division of Northrop Grumman Corporation based in Cambridge, Massachusetts, created a tool to detect mirror defects, which it has incorporated into a commercial 3D imaging system. Among its applications is a package-detection device now used by all major shipping companies.



50

Space-Ready Durometers Measure Hardness on Earth

When the space shuttles were flying, NASA needed a tool to ensure any tiles repaired on the craft's underbelly after launch could withstand the heat of reentry into Earth's atmosphere. Johnson Space Center called on Buffalo Grove, Illinois-based Rex Gauge Durometers Inc. to modify its existing durometer for use in space by astronauts. Sales of the company's improved digital durometers increased 35 percent after its NASA work.



51

High-Temperature Superconductors Deliver Power without Heat

In 2008, Goddard Space Flight Center hired Knoxville, Tennessee-based Tai Yang Research Company, now known as Energy to Power Solutions, to develop superconducting ceramic leads to carry power to an electromagnet operating near absolute zero. While superconductive ceramics operate at higher temperatures than their metal counterparts, they produce no heat and conduct almost none. The resulting durable, ultra-low-heat lead is the first of its kind and is being marketed for MRI machines and other devices with cryogenic components.



52

Electrospray Thrusters Boost Efficiency, Precision

To equip the disturbance reduction system it provided for the European Space Agency's LISA Pathfinder mission, the Jet Propulsion Laboratory hired Natick, Massachusetts-based Busek to develop the most delicate thrusters ever flown. Using electrospray technology, the highly efficient and long-lived thrusters can control the number of atoms of ionic liquid they spray, and they max out at a thrust weight equivalent to a grain of sand.



With origins in NASA research and missions, each spinoff now benefits the public in the form of commercial products and services. NASA technologies are creating jobs, generating revenue and reducing costs for businesses, and even saving lives. *Spinoff* 2016 profiles 52 stories of successful technology transfer—but that's not all you'll find in this year's publication.

TECHNOLOGY TRANSFER PROGRAM

NASA's Technology Transfer Program is the agency's longest continuously operated mission. In this year's *Spinoff* you can learn how the program is making it easier than ever for businesses to find and use NASA technology—including, among other things, the launch of its reorganized invention portfolio.



SPINOFFS OF TOMORROW

In addition to its many spinoffs already benefiting society, NASA has a host of technologies available for licensing and partnership opportunities. *Spinoff* 2016 features 20 industry-ready technologies that are on offer, as well as information on how to partner with us.



PARTNERSHIP NEWS

While NASA's primary missions are in aeronautics and space exploration, the agency also lends its expertise to partner with private companies, universities, nonprofit organizations, and government to pioneer new technologies, conduct studies, and engage the public. Collaborations with the space agency are improving everything from self-driving cars to diagnostic tools for brain injuries.



AWARD-WINNING TECHNOLOGIES

Each year NASA gives and receives numerous honors for cutting-edge achievements. Read about what the agency is doing to foster efficient technology development through its prize competitions and crowdsourcing efforts. *Spinoff* 2016 also profiles more than a dozen awards recently given to NASA researchers and scientists, mission teams, and centers.



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NASA Spinoff Technology across the Nation

Health and Medicine

1. Rodent Research Contributes to Osteoporosis Treatments (CA)
2. Pressure Garments Save New Mothers' Lives (CA)
3. Tool Kit Simplifies Development of High-Affinity Molecules (TX)
4. Space-Ready Spectrometer Offers Terrestrial Advantages (MD)

Transportation

5. Unmanned Research Aircraft Test Cutting-Edge Innovations (GA)
6. Data Visualizer Enhances Modeling for Cars, Consumer Products (NJ)
7. Lightweight, Ultra-Strong Nanotubes to Transform Industry (VA)
8. Multidisciplinary Software to Help Take Aircraft to the Next Level (MI)
9. Orbital Trajectory Analyzer Takes Mission Planning to New Heights (MD)
10. Open Source Aircraft Design Software Helps Industry, Hobbyists (CA)

Public Safety

11. Rice Crop Models Stabilize Global Markets, Enable Efficient Irrigation (NH)
12. GPS Sensor Web Helps Forecasters Warn of Monsoon Flash Floods (CA)
13. Analytic Tool Simplifies Metal Fracture Assessments (CO)
14. Mars Methane Detector Identifies Harmful Gas Leaks (CA)
15. Hydrogen Detection Tape Saves Time and Lives (FL)
16. Single-Photon Lidar Maps Ground Features Quickly, Efficiently (MD)
17. Temperature Sensors Cement Integrity of Bridges (OH)
18. Primer Stops Corrosion without Requiring Rust Removal (PA)

Consumer Goods

19. NODE+ Platform Integrates Sensors with Smartphones (TN)
20. Precision Coffeemaker Adapts Brews to Beans, Taste (CA)
21. CO₂ Recovery System Saves Brewers Money, Puts Bubbles into Beer (CO)
22. Space Blanket-Inspired Cases Protect Expensive Devices (ME)
23. Antimicrobial Agent Updates Ancient Industry of Prayer Mats (Canada)
24. Heat-Reflecting Material Regulates Body Temperature (NC)
25. Modified Monitor Provides Glasses-Free 3D for Pilots, Gamers (NY)

Energy and Environment

26. Flock of Nanosatellites Provides a Daily Picture of Earth (CA)
27. Multispectral Satellite Imagery Shows Farmers' Fields in New Light (ND)
28. Software Helps Restore Fire-Ravaged Habitats (ID)
29. Buildings for Manipulating Magnetism Revolutionize Magnetometers (CA)
30. Cost-Saving Method Yields Solar Cells for Exploration, Gadgets (IL)
31. Wide Area Thermal Imaging System Brings the Landscape into Focus (MI)
32. Photocatalytic Water Splitter Stores Energy as Hydrogen (MA)
33. Recycling Technology Converts Plastic Waste to Energy (OH)
34. Tiny Capsules Enable a World of Possibilities (NC)

Information Technology

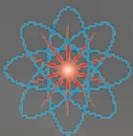
35. System-Health Monitor Predicts Failures before They Happen (AZ)
36. Algorithm Predicts and Evaluates Storm Surges (MS)
37. Mars Rover Work Spawns PDF Collaboration Software (CA)
38. Open Source Tools Popularize Infrastructure for Cloud Computing (MA)
39. Software Optimizes Designs from Spaceships to Wind Turbines (VA)
40. NASA Climate Analytics Support Biological Research (AZ)
41. Artificial Intelligence Targets Advertising by Understanding User (CA)
42. Modeling Software Helps Rocket Scientists Go with the Flow (CA)
43. Electro-Optic Ceramic Creates High-Speed Fiber-Optic Networks (MA)

Industrial Productivity

44. DigitalClone Software Predicts, Extends Machine Life (NY)
45. Cryocoolers Fuel Exploration in Space and on Earth (OH)
46. Temperature-Resistant Materials Enable Space-Like Cold on Earth (PA)
47. Lasers Enable Alternative Power Transmission (WA)
48. Helium Recapture System Reclaims Hydrogen for Industry Use (CT)
49. Laser Vision Helps Hubble, Package Shippers See Clearly (MA)
50. Space-Ready Durometers Measure Hardness on Earth (IL)
51. High-Temperature Superconductors Deliver Power without Heat (TN)
52. Electro spray Thrusters Boost Efficiency, Precision (MA)



This map details the geographic location of each company that appears in *Spinoff* 2016.



TECHNOLOGY
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