

National Aeronautics and Space Administration



# SPINOFF

2017

# Health and Medicine



From tools for brain surgery to dental X-rays, NASA research yields technologies that enhance medical treatments and save lives. In this section you can learn—among other things—how fabrics, cooling suits, and diagnostic tests designed for astronauts have led to new medical products for infants, injured athletes, and those most at risk for sudden epidemics.

## 1 Active Pixel Sensors Lead Dental Imagery into the Digital Age

In the early 1990s, Jet Propulsion Laboratory (JPL) engineer Eric Fossum set out to build an efficient image sensor based on complementary metal oxide semiconductors (CMOS), which are microelectronic transistors that had been integral to computers since the 1960s. To develop the sensors, JPL entered into several Technology Cooperation Agreements with companies, including dental device manufacturer Schick Technologies of Long Island City, New York, which wanted to use them for dental X-rays.

In 1995, Fossum and colleagues founded Photobit with an exclusive license for CMOS imaging, and Schick obtained an exclusive license for CMOS dental imagers.

As CMOS sensors came to dominate the entire digital imaging industry, Schick, now owned by Sirona Dental Systems, benefited from rapid improvements in size, speed, memory, and quality, as well as cheaper mass production. Today any company using CMOS dental image sensors has licensed the technology from Sirona, which still holds the license from JPL's managing entity, the California Institute of Technology.



## 2 Mini Heat Pipes Wick Away Heat in Brain Surgery

Over the course of more than 40 SBIR contracts since the 1980s, many at Glenn Research Center, NASA has helped Lancaster, Pennsylvania-based Thermacore advance the technology of heat pipes, a tool used to move heat so it can dissipate safely. In the last decade or so, the NASA-improved heat pipes have been adapted to medical uses, including in bipolar forceps used in brain surgery.



## 3 Fluorescent Diagnostic Test Readers Offer Fast, Low-Cost Results

Ames Research Center wanted a simple, lightweight device to diagnose astronauts' illnesses within minutes. Los Angeles-based Holomic, now Cellmic LLC, was hired as a subcontractor to develop a device that used a smartphone to read results from a lateral flow test strip—the same technology as a home pregnancy test—with ultraviolet light. The company had made similar devices using visible light. Cellmic markets its resulting HRDR-300 Fluorescent Immunoassay Reader to companies that develop their own tests.



## 4 Cooling Garments Find New Medical, Athletic, and Industrial Uses

In the 1960s and '70s, Bill Elkins worked with engineers at NASA and the Air Force, including several at Ames Research Center, on liquid cooling garments to be worn under spacesuits and flight suits. He has spun that experience off into several companies, including Downers Grove, Illinois-based WEIkins LLC. The company markets varieties of the cooling technology to prevent brain damage after heart attacks or strokes, improve sports performance, treat concussions, and keep workers from overheating under heavy protective gear.



## 5 Space-Based Bone Scanner Expands Medical Research

As a part of an effort to upgrade ISS research facilities managed by Johnson Space Center, the Center for the Advancement of Science in Space (CASIS) worked with Techshot Inc. to build a bone densitometer suitable for use in space. The Greenville, Indiana-based company's product, dubbed Bone D, is operating commercially on the station for a number of clients looking to take advantage of studies performed in microgravity.



## 6 Temperature-Regulating Fabrics Keep Babies Comfortable

One method Johnson Space Center investigated for managing heat inside a spacesuit was the use of phase-change materials (PCMs). Like ice cubes in a drink, PCMs absorb heat as they change from solid to liquid, and, if exposed to colder temperatures, they release that heat as they refreeze. An SBIR contract led to the creation of fabrics incorporating PCMs, most recently commercialized by San Francisco-based Embrace Innovations in wraps and blankets that help keep babies at an optimal temperature.



# Transportation



However you get around on the road or in the air, NASA is with you when you travel. Technologies developed by NASA track flights worldwide, help aircraft designers minimize the effect of sonic booms, keep commercial space cargo safe during landing, monitor vehicle carbon-dioxide emissions, and more.

## 7 Reconfigurable Radio Tracks Flights Worldwide

When Malaysia Air Flight 370 disappeared over the Indian Ocean in 2014, it had flown far beyond radar range. Under a new space-based air tracking system, no plane would ever be off the grid that way—thanks in part to a reconfigurable radio developed with NASA.

Through a 50/50 cost-share cooperative agreement, Glenn Research Center and Harris Corporation developed a high-frequency radio that can be reprogrammed with software updates. The final product flew in the space station's SCaN Testbed and was honored with an R&D 100 Award.

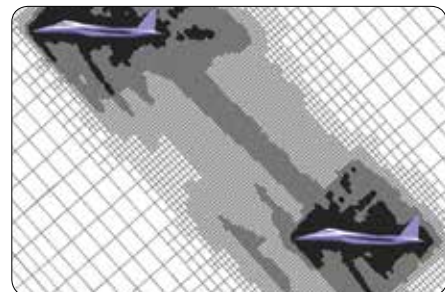
The Palm Bay, Florida-based company used what it built to create its commercial AppSTAR radio, which quickly became a popular seller in part because of how easily it can be reconfigured for new applications.

One early contract with a huge potential impact is a company sending the radios into orbit on Iridium's new satellite constellation. These AppSTARs are programmed to receive signals from new airplane transceivers that send out a flight's number, location, heading, and other details.

Currently, aircraft communication requires line-of-sight to land-based receivers—so many planes flying over the ocean and other remote areas can't be tracked at all. Putting the receivers into orbit solves that problem. "Within seconds you can keep track of all the aircraft in the world," explains Harris systems engineer Jeff Anderson. The first iteration of the system is scheduled to go live in 2018.

## 8 Design Software Shapes Future Sonic Booms

Computational fluid dynamics (CFD) was hailed as a way to replace costly wind tunnel testing, but the software was time-consuming and itself costly to implement. Michael Aftosmis at Ames Research Center came up with a way to simplify and automate CFD processes. Desktop Aeronautics, now owned by Reno, Nevada-based Aerion Corporation, acquired the commercial license and added features to make it more user-friendly, and they have clients among universities, Government contractors, and commercial aerospace companies.



## 9 Orion Parachute Innovations Carry Commercial Rockets Back to Earth

Airborne Systems Inc., whose Space and Recovery Systems branch is in Santa Ana, California, worked as a subcontractor to build the parachute system for the Orion capsule. The design is based in part on the Apollo spacecraft's parachutes but incorporates updates and improvements requested by Johnson Space Center, which managed the contract. Johnson also carried out costly, repeated drop tests to prove the parachutes, which Airborne Systems now sells to several commercial spacecraft companies.



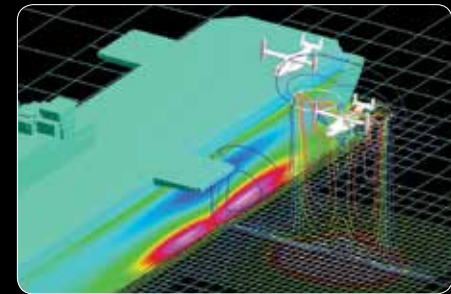
## 10 CO<sub>2</sub> Sensors Monitor Vehicle Emissions from Above

Through the ASCENDS project, NASA hopes to learn more about how carbon dioxide (CO<sub>2</sub>) seasonally concentrates and dissipates in the atmosphere. A contractor from Langley Research Center who worked on the project went on to found Knoxville, Tennessee-based Hager Environmental and Atmospheric Technologies (HEAT) Inc. HEAT's first product, based on a NASA sensor designed to measure atmospheric CO<sub>2</sub> from space, remotely measures car and truck emissions and is currently used by four U.S. states to check vehicle compliance.



## 11 Software Opens Computational Fluid Dynamics to the Uninitiated

Following a 1999 SBIR contract with Ames Research Center, Sukra Helitek Inc. released its Rot3DC program to model air flows generated by aircraft rotors. A series of additional NASA and military SBIR contracts for the Ames, Iowa-based company, including seven more from Ames, has resulted in RotCFD—short for rotor computational fluid dynamics. The software simplifies the esoteric and time-consuming work of modeling how rotorcraft designs would move the air around them, opening the field of CFD to students and NASA engineers alike.



## 12 Hydraulic Carts Streamline Structural Tests for Aircraft

Aircraft hydraulic testing facilities can be jungles of hoses, wires, and pipes. When replacing its hydraulic system, the Flight Loads Laboratory at Armstrong Flight Research Center significantly reduced the miles of connections by hiring East Aurora, New York-based Moog Inc. to develop a series of hydraulic carts. Each SmartCART can connect eight hydraulic actuators to a front-end computer with just two connections. The system is especially useful for facilities that have to reconfigure test setups frequently.



# Public Safety



The day-to-day environments NASA deals with are nothing if not extreme: the vacuum and wildly fluctuating temperatures of space, the fiery reentry into Earth's atmosphere, and the explosive rigors of rocket launches. The tools the space agency has created to navigate these harsh conditions often have applications on Earth, as you'll learn in this section. Earthquake dampers that stop buildings from shaking, high-speed cameras used in car crash safety testing, and vibration sensors monitoring railway lines are just a few examples of how NASA keeps people safe through public safety spinoffs.

## 13 Orion Video Requirement Advances High-Speed, Compact Cameras

To monitor parachute deployment during the Orion spacecraft's 2014 test flight, engineers at Johnson Space Center needed a compact, lightweight, high-speed video camera that could store data almost as fast as it captured it and could endure all the rigors of liftoff, the space environment, atmospheric reentry, and splashdown. They and contractor Lockheed Martin approached Pasadena, California-based Integrated Design Tools (IDT), which specializes in cameras mainly aimed at the industrial and scientific markets for uses like crash testing.

The camera the company created is capable of incredibly fast memory storage, backing up data at rates of 10 to 12 gigabits per second. At the same time, it's small and light, rugged, radiation-hardened, waterproof, and capable of adjusting for exposure in milliseconds.

Many of these improvements have been incorporated into IDT's Os series of cameras, including the high-speed, solid-state memory developed for NASA. This and the cameras' durability are important for capturing crash tests or military weapons testing. Even broadcast film crews can benefit from lighter cameras that don't take all day to back up high-speed sequences. And the mission mode can allow preprogramming of recording sequences, for example when a military test is too dangerous for personnel to approach.



## 14 Rocket Technology Stops Shaking in Its Tracks

In testing, the Ares I launch vehicle displayed a serious vibration problem—shaking that resonated dangerously, causing potentially hazardous conditions in the crew capsule right above the booster. Engineers at Marshall Space Flight Center found a solution, creating a brand new, low-cost, lightweight damper that could become the industry standard for buildings, bridges, and many other structures that vibrate or shake. New York City-based Thornton Tomasetti markets the technology to make buildings safer against the wind and from earthquakes.



## 15 Micromachined Sensors Monitor Train Rails, Predict Failures

Ridgetop Group of Tucson, Arizona, created its RotoSense rotational vibration sensor under SBIR contracts with Glenn Research Center, intending it to be installed on gears in helicopter transmissions to monitor their condition. To create its new Railsafe system, Ridgetop repackaged the sensors to sit on train axles and retooled its algorithms to identify anomalies in rails. The company tested Railsafe and launched it in 2015. Next, Ridgetop will enable it to predict failures in rails and wheels.



## 16 Wire Sensors Alert to Dangerous Conditions in the Clouds

Under two SBIR contracts with Glenn Research Center, Anasphere Inc. designed a vibrating wire sensor that can give scientists information on how much supercooled liquid water is lurking in the skies. The inexpensive, lightweight sensor is helping NASA develop a ground-based system to warn of dangerous icing conditions for airplanes. The Bozeman, Montana-based company is also selling it to others, including the Department of Energy and the Chinese affiliate of German radiosonde company GRAW.



## 17 Fast-Flow Nanofiber Filters Purify Water at Home and in the Field

Tom Smokoff, founder of Water Pure Technologies Inc. in Murray, Utah, wanted to build low-cost water filtration systems fast enough to efficiently supply whole villages. He found the NanoCeram filter, originally developed for Johnson Space Center, which quickly eliminates better than 99.9 percent of viruses and bacteria. Smokoff buys the NASA-created filters from a licensed manufacturer and now sells portable, battery-operated or hand-cranked systems that can be packed up and brought to a water source.



## 18 Miniaturized Vacuum Pumps Play Big Roles on Mars and Earth

One of Curiosity's tools is a mass spectrometer used to analyze rock and gas samples on the Red Planet. Through a series of SBIR contracts with the Jet Propulsion Laboratory, Creare Inc., based in Hanover, New Hampshire, built the vacuum chamber for the spectrometer by heavily modifying existing technology. The company has since commercialized its smaller, more rugged vacuum pumps for Earth-based applications, including mining operations, chemical-weapon and bomb detectors, and more.



# Consumer Goods



You might be surprised by the number of space technologies in your home and among the products you use every day. This year's *Spinoff* shows how NASA technology can be found in your cell phone camera, golf clubs, ski goggles, and bottle of wine. Spinoffs are also improving large-scale 3D printers, enabling rechargeable hearing aid batteries, and strengthening sporting goods with nanomaterials.



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## CMOS Sensors Enable Phone Cameras, HD Video

By the early 1990s, sensors based on the charge-coupled device (CCD), had enabled high-quality digital photography, but Jet Propulsion Laboratory (JPL) engineer Eric Fossum believed he could make imagers with smaller and lighter machinery using complementary metal oxide semiconductor (CMOS) technology to create what he called active pixel sensors.

Using CMOS sensors, he and his team were able to produce images using lower voltages and charge transfer efficiencies than CCD imagers required, and almost all the other camera electronics could be integrated onto the computer chip with the pixel array, a development that would make CMOS imagers more compact, reliable, and inexpensive.

In the end, it was the cell phone camera, which needed to be small and energy-efficient, that drove the widespread mass production of CMOS image sensors. Resulting improvements to the technology and its manufacture drove costs down and quality up until CCD-based devices couldn't compete.

CMOS imagers have enabled small, high-definition video cameras, including the popular body-mountable action cameras marketed by San Mateo, California-based GoPro.

By 2015, the technology's market, which also includes the automotive, surveillance, and medical industries, reached nearly \$10 billion.

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## Novel Threading Enables New Approach to Golf Clubs

A researcher at Goddard Space Flight Center came across Spiralock threading, a 1979 invention that increased the clamping power of screws and bolts, enabling them to survive repeated Shuttle launches. He tested it extensively and published the results, after which a variety of industries adopted the technology. Most recently, it let Carlsbad, California-based Cobra Puma Golf put a "spaceport" in the head of its new driver, which allowed for the lowest center of gravity ever achieved in a golf club.



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## Blue-Light-Cancelling Lens Gives Skiers a Clearer View

In the 1990s, a scientist at Ames Research Center developed optical filters to block blue and green light, allowing other hues to stand out and making camouflaged objects more visible in forests. His work was later commercialized through a Space Act Agreement with NASTEK, which then partnered with Wheatridge, Colorado-based Optic Nerve Inc. to create a line of ski goggles that filter about 95 percent of blue light, giving professional and amateur skiers alike a clear view on the slopes.



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## Rechargeable Hearing Aid Batteries Draw from NASA Research

In its early days, NASA spent much effort developing rechargeable silver-zinc batteries, as the pairing offers a higher power-to-weight ratio than any other battery couple. Significant advances in the batteries' durability were made at Glenn Research Center, which ZPower of Camarillo, California, used as part of its starting point, undertaking years of additional development before releasing its rechargeable hearing aid batteries, the first that can last all day on a single charge.



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## Large-Scale 3D Printer Brings Manufacturing to the Masses

A team of former Johnson Space Center employees founded re:3D in Houston, Texas with a vision to bring additive manufacturing power to the developing world. Drawing on skills they honed at NASA, the team built an inexpensive printer 30 times larger than competing desktop models. They have customers worldwide, including right at NASA, but they continue to work toward their development mission by donating one for every hundred printers sold.



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## Professional Development Program Gets Bird's-Eye View of Wineries

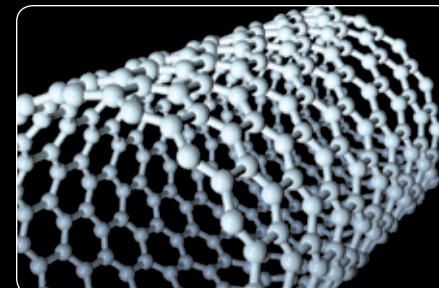
As a part of Langley Research Center's DEVELOP Program—in which students and young professionals from across the country get opportunities to work in the fields of science, technology, engineering, and mathematics—NASA used satellite imagery to map vineyards across Virginia in unprecedented detail. State officials are using the maps to encourage an expansion in local wineries and may also use NASA data in the future to map pesticide use and monitor crop health.



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## Carbon Nanotube Resin Shores Up Boats, Bikes

Carbon nanotubes offer 100 times the strength of steel at just one-sixth the weight. The potential for space applications seemed huge, but the material was challenging to work with, so NASA awarded SBIR funding to Zyvex Technologies, based in Columbus, Ohio. That was instrumental in helping move forward the early research needed to help the company put it to use in commercial products from sporting goods to ships.



# Energy and Environment



With eyes on Earth through more than two dozen satellites, plus a range of ground-based observation missions, NASA keeps close watch on our ever-changing planet. These scientific data have found numerous applications among public and private initiatives, including software tools that spot rainforest wildfires and monitor agricultural water use. The Agency has also transferred technology to industry, leading to self-driving farm equipment, improved fertilizers, new mineral analyzers, and much more.

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## GPS Correction Technology Lets Tractors Drive Themselves

In the 1990s, scientists at the Jet Propulsion Laboratory, where the first global tracking system for Global Positioning System (GPS) satellites had been developed, were working to stream satellite tracking data in real time via the Internet. The result ended up being one of NASA's most important contributions to modern society, enabling accurate GPS navigation anywhere on the planet.

In 2001, John Deere licensed the JPL's software and also contracted with JPL to receive data from the center's global network of reference stations. The company, based in Moline, Illinois, had already developed its own GPS receivers for tractor guidance, but NASA's ground stations and software finally enabled self-driving equipment worldwide.

The trackers were accurate down to about four inches, an improvement over uncorrected GPS readings that could be off by as much as 30 feet.

Typically, when a farmer crisscrosses a field pulling a seeder, plow, or other equipment, the rows overlap by about 10 percent, meaning a significant portion of the field receives double the necessary resources, and the job takes longer than necessary. Eliminating overlap also cuts down on fuel costs and wear and tear on the machinery. And higher accuracy also means more reliable yield maps, which are created by combining location data with mass flow data from sensors on a harvesting combine.



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## Controlled-Release Fertilizer Takes Root in Fields, Groves Worldwide

Fertilizer helps crops grow better, but nutrient runoff can lead to serious environmental problems. Ed Rosenthal, founder of Sarasota, Florida-based Florikan, had an idea to control the nutrient release to avoid runoff and maximize the benefit to the plant. He perfected the formula thanks to 40 hours of NASA consulting, and the fertilizer is now sold around the world—and also used on the ISS for project Veggie.



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## Satellite Imagery Sheds Light on Agricultural Water Use

Keeping track of how water gets used across millions of acres of crop land is no simple task. Researchers created a program called EEFlux to make it easier. It works with Earth Engine from Mountain View, California-based Google to quickly map evaporation and transpiration, based on infrared images captured by Landsat's Earth-observing satellites, and is already used by the California Department of Water Resources, by the California Water Control Board, and the World Bank.



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## Building Sensor Monitors Power Usage, Device by Device

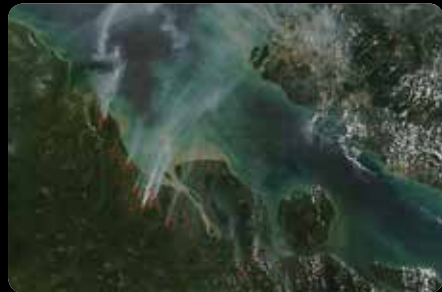
Verdigris Technologies Inc. created a sensor that "listens" to electronic signals as they pass through a circuit panel to determine how much power each device is using. Thanks to a nonreimbursable Space Act Agreement and testing at Ames Research Center's Sustainability Base, the Moffett Field, California-based company was able to bring its product to market and has found happy customers in hotels, hospitals, corporate offices and more.



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## Earth Observation Spots, Helps Prevent Rainforest Fires

A partnership between NASA and Arlington, Virginia-based Conservation International let the company use funding from the Agency's headquarters and the supercomputing power of the NASA Earth Exchange at Ames Research Center to upgrade, combine, and expand its fire alert and fire risk forecasting systems to create Firecast. The system lets authorities and conservationists in developing countries spot rainforest wildfires, including illegal burns, and limit legal burning activities to times when fire risks are low.



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## Mineral Analyzer Shakes Answers Out of Soil and Rocks

A small, rugged X-ray diffraction (XRD) tool, CheMin, went to Mars on the Curiosity rover, and one of its inventors, Philippe Sarrazin, started a company to sell devices based on the same technology. The final product incorporated SBIR-financed work as well as a license for a patent filed while Sarrazin worked at Ames Research Center. Now Olympus Scientific Solutions America, based in Waltham, Massachusetts, sells the XRD devices to mining and drug companies as well as Government drug watchdogs.



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## Low-Cost Flow Meters Bring Efficiency, Reliability to Nuclear Plants

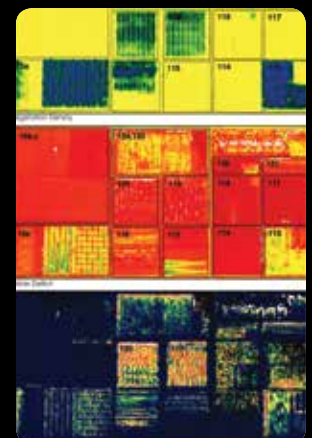
Innovators at Marshall Space Flight Center co-invented a deceptively simple device to measure the flow of liquid oxygen into rocket engines. The so-called balanced flow meter was then commercialized in industrial applications where it has saved millions, if not billions, of dollars in costs. Most recently, Graftel LLC of Elk Grove Village, Illinois, has brought the inexpensive device to the nuclear industry, where it has dramatically increased flow-measurement accuracy, reduced noise, increased safety, and saved on operation costs.



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## Computer Learning Program Inventories Farmers' Fields

Under a 2014 SBIR contract with Goddard Space Flight Center, GeoVisual Analytics of Boulder, Colorado, improved techniques for using satellite imagery to classify land and assess vegetation indexes. The work spawned the Computer Learning Imagery Platform (CLIP), now used with drone images to assess the types, stages of growth, and health of crops in fields for Taylor Farms, the product's first customer and the world's largest fresh-cut vegetable producer. This allows Taylor Farms to predict annual yields.



# Information Technology



When NASA wants to model the dynamics of atmospheric reentry, capture data from the launch pad, or undertake any number of ambitious data-driven projects, it develops cutting-edge software and information technology to get the job done. These innovations are often valuable in other applications ranging from archaeology and consumer product design to oil drilling and commercial space missions.

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## Laser Imaging Helps Archaeologists Dig Up History

Some 10,500 years ago, hunters gathered each year near the Beaver River in what is now western Oklahoma. There, they killed bison en masse, sliced off the choicest meat, and left behind piles of skeletons.

Today there is little visible evidence of these hunting expeditions. But laser-based remote sensing equipment called lidar can give archaeologists hints of the fossils and bones hidden beneath the earth's surface. And the technology owes a lot of its development to scientists looking at something very different: planets, moons, and asteroids.

NASA has been incorporating lidar devices into missions dating as far back as Apollo 15 in 1971. More recently, the OSIRIS-REx asteroid return mission managed at Goddard Space Flight Center was equipped with a lidar scanner designed by Canadian firm Teledyne Optech.

The 40-year-old company, which also has offices in Henrietta, New York, as well as Mississippi, specializes in designing and building lidar instruments and has contributed to more than one NASA mission. It has incorporated the innovations needed for those space-ready devices into commercial models that are now also helping archaeologists, such as the team who discovered the site in Oklahoma.

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## Program Predicts Aerothermodynamics of Reentry, Subsonic Flight

An engineer at Ames Research Center created software called Configuration-Based Aerodynamics (CBAERO), capable of importing spacecraft models created with computer-aided design and predicting the aerodynamic and aerothermodynamic forces they would experience during reentry. The program generates results with nearly the accuracy of traditional computational fluid dynamics in far less time. Through software usage agreements, more than 20 businesses, including Dulles, Virginia-based Orbital ATK, and several Department of Defense agencies and universities use CBAERO.



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## Data Acquisition System Captures Machine Performance

Under contract with Kennedy Space Center, Wakefield, Rhode Island-based Dewetron delivered a powerful system to monitor performance on the Space Launch System mobile launch platform. The easy-to-use system captures data with one universal signal conditioner—allowing easy analysis across multiple signals—and is now a popular part of Dewetron's product line. Updated versions have sold to aerospace companies and car companies from Ford to BMW, as well as many other industries.



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## Light-Analysis Software Explodes across Industries

Under two SBIR contracts with the Jet Propulsion Laboratory, Lambda Research Corporation of Littleton, Massachusetts, developed its TracePro light ray-tracing software in the mid-1990s to help engineers predict stray light in imagers. Since then, the program—the first of its kind compatible with computer-aided design software—has found uses in industries as diverse as overhead lighting, light pipes for electronics, solar collection, noninvasive health-monitoring, laser surgical devices, car dashboard displays, optics for missile systems, and more.



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## Connectors Link Data Networks for Orion, Industry

The Orion crew capsule may resemble its Apollo ancestor on the surface, but its internal systems reflect nearly half a century of development. Among these is a 21st-century data system capable of quickly transmitting massive amounts of data, overseen by Johnson Space Center and designed by Smiths Connectors, based in Costa Mesa, California. The company has commercialized data connectors it designed for NASA in other demanding applications, such as in the aviation and oil and gas exploration markets.



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## Scheduling Software Plans Public, Private Space Missions

Alex and Ella Herz learned about space mission scheduling while working payload operations at Johnson Space Center, and Alex and Doug George later created scheduling software for a planned lidar mission at Goddard Space Flight Center. The three founded Greenbelt, Maryland-based Orbit Logic, where one of their first products was STK Scheduler, a generic, reconfigurable scheduling program for space operations. Orbit Logic has sold licenses for the program to around 250 customers, including most NASA field centers.



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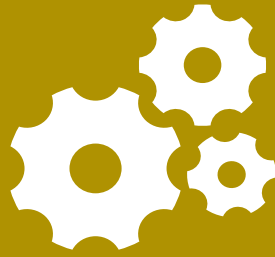
## Power Amplifiers Boost Radar, Communications, Defense Systems

As a subcontractor under an SBIR contract from the Jet Propulsion Laboratory, QuinStar Technology Inc. of Torrance, California, developed a solid-state power amplifier of unprecedented efficiency. While most comparable devices lose 20 percent of their amplified energy when their signals recombine, QuinStar's lose 8 percent. The solid-state technology requires lower voltage and is lighter, more compact, and more reliable than its tube-based predecessors, making it ideal for radars, communications equipment on spacecraft, and unmanned aerial vehicles.



# Industrial Productivity

To explore the frontiers of space and other worlds, NASA often has to engineer technologies unlike anything seen before. It might partner with a company to produce 3D-woven heat shields, for example, or to create a vibration table large enough to test a space telescope the size of a tennis court. Other innovations come about from NASA's unique facilities, such as a laboratory for testing how materials perform when exposed to space. Commercial spinoffs from these and other endeavors are playing a big part in our Nation's industrial base.



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## 3D Weaving Technology Strengthens Spacecraft, Race Cars

Most of the Orion spacecraft's heat shield is low-density and very good at insulating, but it's not very strong. There are points across the surface, however, that must connect the crew capsule to its service module and, ultimately, the rocket. These points require a very strong, robust material.

Researchers at Ames Research Center worked with partners at high-tech weaving company Bally Ribbon Mills on next-generation heat-shielding materials and found a new candidate, 3D-woven quartz composite. The material and technique for weaving it were developed using funds from multiple NASA contracts, and the result "is like a brick," explains Bally Ribbon Mills' Curt Wilkinson.

Unlike many designs that tend to focus on doing just one thing really well, the 3D composite is versatile: it can carry loads, act as a shock absorber, conduct electricity well, and serve as thermal insulation. Now the Bally, Pennsylvania-based company sells the quartz composite material to aerospace companies and uses the modified weaving equipment to make larger, denser blocks of 3D carbon composites for race cars.



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## Vibration Tables Shake Up Aerospace, Car Testing

Team Corporation has been building vibration-testing equipment for NASA since the 1950s. Most recently, the Burlington, Washington-based company built a high-powered system to test the James Webb Space Telescope at Goddard Space Flight Center. Innovations the company has made to satisfy the Agency's requirements over the years have been used in their commercial products for testing nuclear warheads, cars, and many other items.



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## Astronauts Instruct Newcomers on Peculiarities of Spaceflight

The growing numbers of engineers, managers, and others in the space industry generally do not graduate with much knowledge of the unique challenges posed by space travel. The International Flight Test Institute in Mojave, California, aims to fill that knowledge gap with crash courses in spaceflight taught in part by two former astronauts. Largely based on the training they received at Johnson Space Center, the curriculum includes everything from orbital mechanics to space law.



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## Polyimide Aerogels Boost Antennas, Insulate Pipes

Glenn Research Center's Mary Ann Meador is an expert in aerogels: low-density solids that make excellent insulators. Using polyimide polymers, she and her team created a new aerogel five times stronger than earlier polymer-reinforced silica aerogels and one that can be cast into a thin, very flexible layer. FLEXcon, in Spencer, Massachusetts, licensed the patent in 2015 and is selling the aerogel as insulation for pipes in extreme environments, among other applications.



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## Privately Built Facility Offers Advantages in Space Exposure Testing

NASA's Materials International Space Station Experiment (MISSE) series tests the effects of exposure to space on various materials, housing them outside the ISS. Under cooperative agreements with Johnson Space Center, Houston-based Alpha Space is designing the next MISSE facility to provide advantages over previous versions at lower costs. Space not reserved for NASA on the new facility, scheduled for launch in 2017, will be available for purchase by companies, universities, and Government agencies.



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## Optical Filters for NASA Imagers Focus on Cutting Edge

For a mission to upgrade the Hubble Space Telescope, Goddard Space Flight Center selected optical filters manufactured by Materion Corporation, based in Westford, Massachusetts. The project stretched the company's expertise and capabilities and has led to a range of improved products and new devices that are matching paint in hardware stores and depositing thin coatings in industrial settings, among other applications.

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## Zinc-Silicate Coating Blocks Corrosion

NASA chemists designed an anti-corrosion coating for metals and used it to protect launch structures at Kennedy Space Center from the tropical air as well as the temperature spikes of a rocket launch. Polymer manufacturer Polyset, of Mechanicville, New York, helped the original license holder for the coating make a key ingredient in the 1980s and is now producing the coating itself, for use in bridges, hydroelectric facilities, rail cars, and oil rigs.



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## Outgassing Test Facility Brings New Materials into Space Industry

In 2013, the Goddard Space Flight Center Outgassing Laboratory tested four varieties of Windform fiber-reinforced polyimides for their manufacturer, CRP USA, headquartered in Mooresville, North Carolina. The lab found that the materials, which are used for 3D printing, met NASA's standards for low outgassing. As a result, the company entered the space business, where it has found around a dozen clients. High strength and temperature resistance are among the materials' advantages for space applications.



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## Shuttle, Hubble Work Lead to Strength in Custom Current Sensors

Subcontracts to provide current and voltage sensors first for the Space Shuttle at Johnson Space Center and then for the Hubble Space Telescope at Marshall Space Flight Center led American Aerospace Controls to develop the ability to create, test, and document highly reliable, customized components. Having started out making standardized parts, the Farmingdale, New York-based company leveraged these capabilities to cultivate a broad, international customer base for specially tailored, space-grade transducers.



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## High-Heat Cement Gives Ashes New Life

Stennis Space Center engineers are always on the lookout for materials that can hold up better in the inferno of a rocket test. A Louisiana Tech University team had a good candidate: geopolymers made with fly ash left over after burning coal. Testing under a dual-use cooperative agreement confirmed the material's strong resistance to heat and corrosion, prompting the Louisiana Tech team to start Ruston, Louisiana-based Alchemy Geopolymer Solutions LLC, to help turn waste ash into concrete across the country.





# NASA Spinoff Technology across the Nation

## Health and Medicine

1. Active Pixel Sensors Lead Dental Imagery into the Digital Age (NY)
2. Mini Heat Pipes Wick Away Heat in Brain Surgery (PA)
3. Fluorescent Diagnostic Test Readers Offer Fast, Low-Cost Results (CA)
4. Cooling Garments Find New Medical, Athletic, and Industrial Uses (IL)
5. Space-Based Bone Scanner Expands Medical Research (IN)
6. Temperature-Regulating Fabrics Keep Babies Comfortable (CA)

## Transportation

7. Reconfigurable Radio Tracks Flights Worldwide (FL)
8. Design Software Shapes Future Sonic Booms (NV)
9. Orion Parachute Innovations Carry Commercial Rockets Back to Earth (CA)
10. CO<sub>2</sub> Sensors Monitor Vehicle Emissions from Above (TN)
11. Software Opens Computational Fluid Dynamics to the Uninitiated (IA)
12. Hydraulic Carts Streamline Structural Tests for Aircraft (NY)

## Public Safety

13. Orion Video Requirement Advances High-Speed, Compact Cameras (CA)
14. Rocket Technology Stops Shaking in Its Tracks (NY)
15. Micromachined Sensors Monitor Train Rails, Predict Failures (AZ)
16. Wire Sensors Alert to Dangerous Conditions in the Clouds (MT)
17. Fast-Flow Nanofiber Filters Purify Water at Home and in the Field (UT)
18. Miniaturized Vacuum Pumps Play Big Roles on Mars and Earth (NH)

## Consumer Goods

19. CMOS Sensors Enable Phone Cameras, HD Video (CA)
20. Novel Threading Enables New Approach to Golf Clubs (CA)
21. Blue-Light-Cancelling Lens Gives Skiers a Clearer View (CO)
22. Rechargeable Hearing Aid Batteries Draw from NASA Research (CA)
23. Large-Scale 3D Printer Brings Manufacturing to the Masses (TX)
24. Professional Development Program Gets Bird's-Eye View of Wineries (VA)
25. Carbon Nanotube Resin Shores Up Boats, Bikes (OH)

## Energy and Environment

26. GPS Correction Technology Lets Tractors Drive Themselves (IL)
27. Controlled-Release Fertilizer Takes Root in Fields, Groves Worldwide (FL)
28. Satellite Imagery Sheds Light on Agricultural Water Use (CA)
29. Building Sensor Monitors Power Usage, Device by Device (CA)
30. Earth-Observation Spots, Helps Prevent Rainforest Fires (VA)
31. Mineral Analyzer Shakes Answers Out of Soil and Rocks (MA)
32. Low-Cost Flow Meters Bring Efficiency, Reliability to Nuclear Plants (IL)
33. Computer Learning Program Inventories Farmers' Fields (CO)

## Information Technology

34. Laser Imaging Helps Archaeologists Dig Up History (NY)
35. Program Predicts Aerothermodynamics of Reentry, Subsonic Flight (VA)
36. Data Acquisition System Captures Machine Performance (RI)
37. Light-Analysis Software Explodes across Industries (MA)
38. Connectors Link Data Networks for Orion, Industry (CA)
39. Scheduling Software Plans Public, Private Space Missions (MD)
40. Power Amplifiers Boost Radar, Communications, Defense Systems (CA)

## Industrial Productivity

41. 3D Weaving Technology Strengthens Spacecraft, Race Cars (PA)
42. Vibration Tables Shake Up Aerospace, Car Testing (WA)
43. Astronauts Instruct Newcomers on Peculiarities of Spaceflight (CA)
44. Polyimide Aerogels Boost Antennas, Insulate Pipes (MA)
45. Privately Built Facility Offers Advantages in Space Exposure Testing (TX)
46. Optical Filters for NASA Imagers Focus on Cutting Edge (MA)
47. Zinc-Silicate Coating Blocks Corrosion (NY)
48. Outgassing Test Facility Brings New Materials into Space Industry (NC)
49. Shuttle, Hubble Work Lead to Strength in Custom Current Sensors (NY)
50. High-Heat Cement Gives Ashes New Life (LA)



This map details the geographic location of each company that appears in *Spinoff* 2017.

**S**pinoff 2017 profiles 50 commercial products and services with origins in NASA research and missions—technologies that are creating jobs, improving the bottom line for businesses, and even saving lives. 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 an innovative licensing program that's launching new startups around the country.

## SPINOFFS OF TOMORROW

In addition to the many spinoffs already benefitting society, NASA has a host of technologies available for licensing and partnership opportunities. *Spinoff 2017* features 20 industry-ready technologies on offer, as well as information on how to partner with us.



## PARTNERSHIP NEWS

While NASA's primary missions are in aeronautics and space, 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 treatment for a childhood heart defect to air-pollution monitoring.



## AWARD-WINNING TECHNOLOGIES

Each year NASA gives and receives numerous honors for cutting-edge technologies. *Spinoff 2017* profiles more than a dozen awards recently given to NASA researchers, scientists, mission teams, and field centers in recognition of their achievements.



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National Aeronautics and Space Administration  
Technology Transfer Program  
NASA Headquarters  
Washington, DC 20546

[www.nasa.gov](http://www.nasa.gov)

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