National Aeronautics and Space Administration

SPINOFF

NASA **TECHNOLOGY TRANSFER** PROGRAM

National Aeronautics and Space Administration

Technology Transfer Program
NASA Headquarters
Washington, DC 20546

www.nasa.gov

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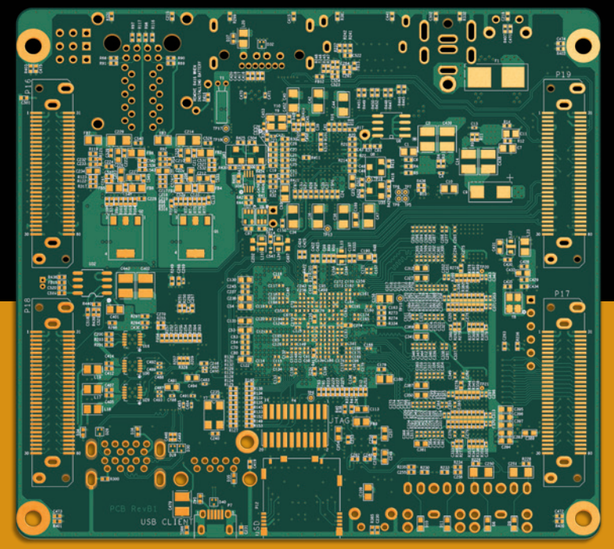
SPINOFF Features

We send rovers to Mars and beyond. Our satellites constantly monitor Earth. Our technology is always advancing to enable exploration of our solar system and beyond. But this technology has improved life on the ground too. From the small businesses that thrive thanks to NASA's innovations to the aid groups that use our data to make a difference around the world, to the first steps that turned into leaps in computing, read on for an in-depth look at some of the ways there's more space in your life than you think.

The Rewards of Perseverance

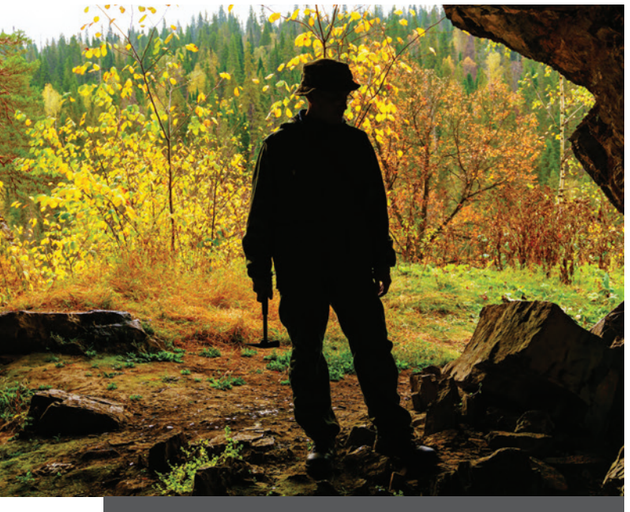
Even before the Perseverance rover gets to Mars, the work that went into it is paying off on Earth



Home Videos from Mars

As Tempo Automation built a circuit board for a Perseverance camera system, the company added new inspections and documentation to its production process and developed a novel preproduction tool. All these now benefit Tempo's customers.

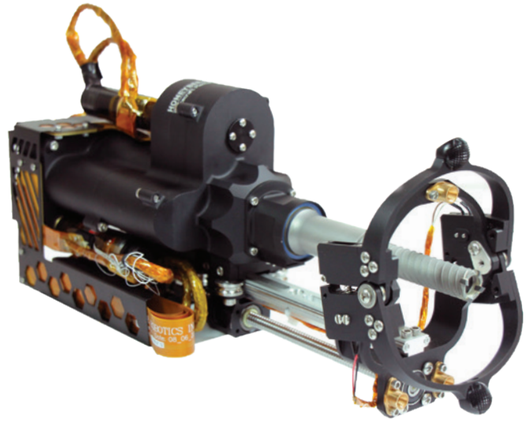
Tempo Automation, Jet Propulsion Laboratory



Giving Geologists a Break

Honeybee Robotics developed coring drill bits with SBIR funding that can break off and retain rock samples. The bits are flying for the first time on Perseverance and are available to geologists on Earth.

Honeybee Robotics, Jet Propulsion Laboratory



Ultraviolet Lasers Scan for Chemical Clues

NASA funding, including JPL SBIR contracts for Mars exploration, helped Photon Systems make small, inexpensive spectrometers in the deep-UV range, where they're so sensitive they can identify bacteria. They're being used in pharmaceutical quality control, wastewater treatment, and more.

Photon Systems, Jet Propulsion Laboratory

In the Right Hands, NASA Satellite Data and Analysis Make Earth Better

NASA data and imagery aid humanitarian and environmental efforts

Self-Reflection

Founded by former NASA officials, Earthrise gave satellite data from NASA and other organizations to Massachusetts ninth graders, who used it to identify illegal gold mines in Brazil. The organization also helps conservationists and decision-makers use Earth imagery and data.

Earthrise Alliance, NASA Headquarters

Striking Gold, Helping Farmers

Officials in five African countries are using a NASA-developed satellite data tool to identify illegal gold mines and conditions on the ground for small farmers struggling with climate change. Parts of the program are expanding to cover more countries across Africa.

Digital Earth Africa, Langley Research Center

Informing Better Decision-Making

Mercy Corps is collaborating with NASA through a Space Act Agreement, using satellite data to inform its humanitarian aid work and sometimes to pass on relevant information – about weather patterns or groundwater, for example – directly to farmers in Africa.

Mercy Corps, NASA Headquarters

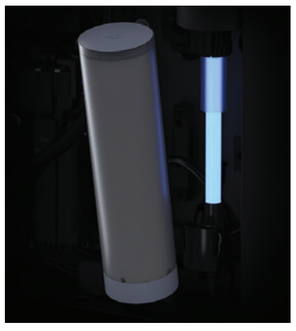
Space-Age Water Conservation

NASA's need to conserve water in space has long supported terrestrial water-purification techniques

Shower like a Martian

Inspired by a NASA design exercise, a Swedish inventor used filter material developed with help from NASA to create the first recirculating shower, saving water and energy.

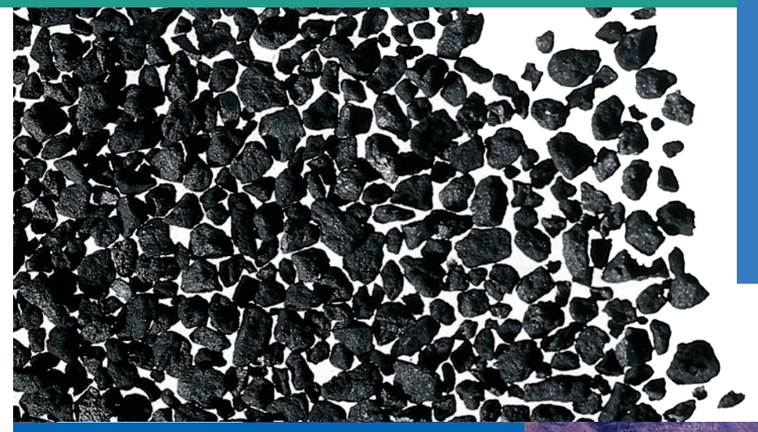
Orbital Systems, Johnson Space Center



Ancient Technology Enters the Space Age

After helping another company implement silver-ion water purification technology from the space shuttle, Puronics has incorporated its SilverShield version into whole-house water conditioners to prevent bacterial growth in filters.

Puronics, Johnson Space Center



Using Nature's R&D Lab

With early NASA funding and testing, a company incorporated nature's water-filtering proteins into membranes. Now companies and researchers are trying them out for many applications, from wastewater treatment to dialysis.

Aquaporin, Ames Research Center

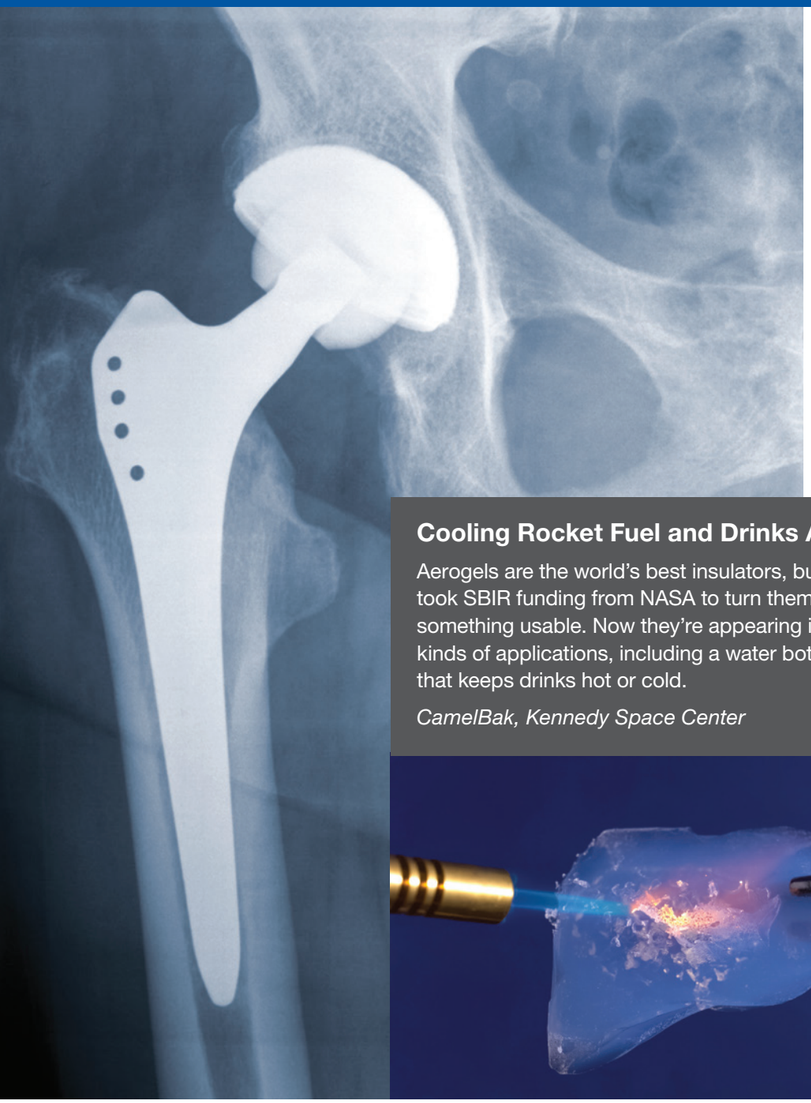
A Case Made in Space

NASA investment in small businesses helps both thrive

From Supersonic Jets to Medical Tech

NASA SBIR funding to research resilient materials for supersonic airplanes helped to create a new kind of polymer. This material caught the eye of a medical technology company, which is now trying it out in more durable medical implants.

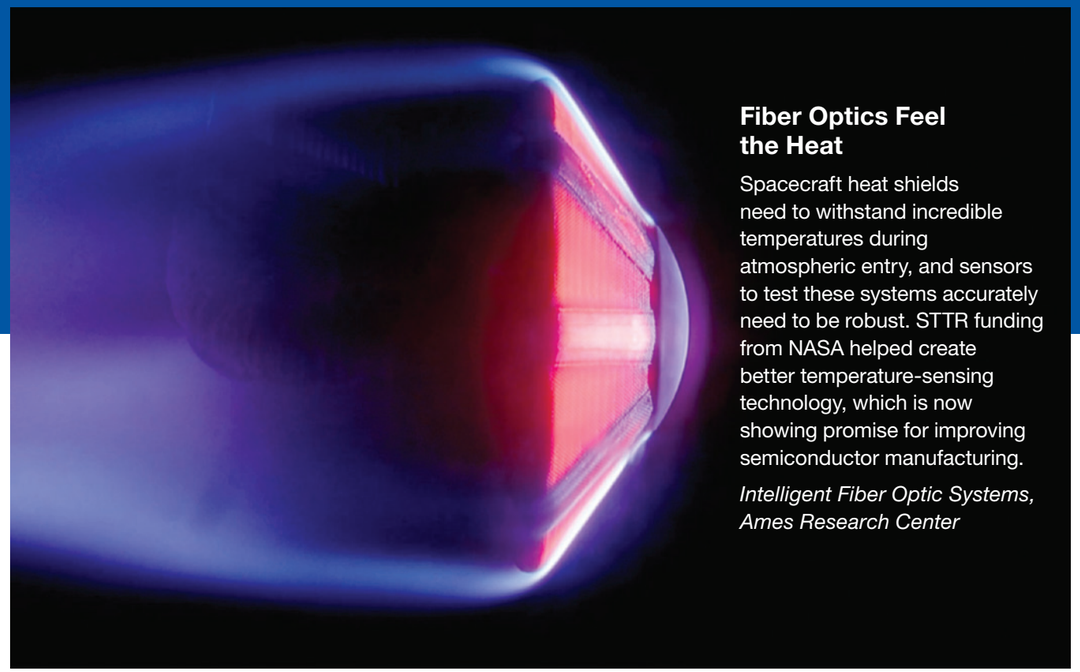
Imitec, Langley Research Center



Cooling Rocket Fuel and Drinks Alike

Aerogels are the world's best insulators, but it took SBIR funding from NASA to turn them into something usable. Now they're appearing in all kinds of applications, including a water bottle that keeps drinks hot or cold.

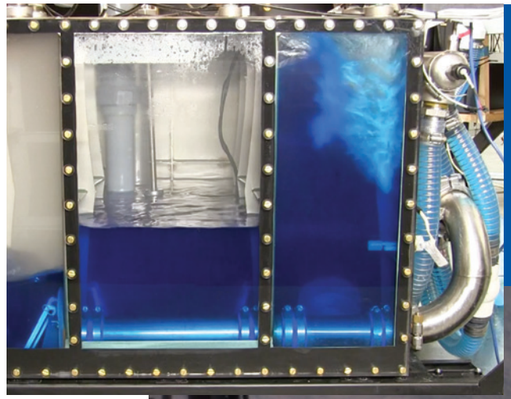
CamelBak, Kennedy Space Center



Fiber Optics Feel the Heat

Spacecraft heat shields need to withstand incredible temperatures during atmospheric entry, and sensors to test these systems accurately need to be robust. STTR funding from NASA helped create better temperature-sensing technology, which is now showing promise for improving semiconductor manufacturing.

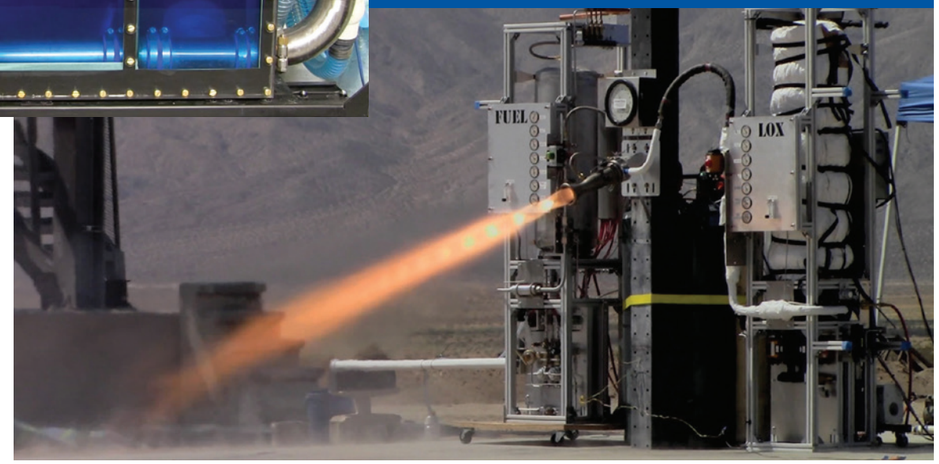
Intelligent Fiber Optic Systems, Ames Research Center



Engine Pump Helps Computers Chill Out

When NASA wanted a lighter, more reliable rocket pump, it awarded SBIR funding to a fluid dynamics specialist to develop one. While the resulting pump didn't find its way into a space rocket, it soon became the starting point for a liquid cooling system for supercomputers and servers.

Chilldyne, Glenn Research Center



Food Safety Program for Space Has Taken Over on Earth

System created for Apollo astronaut food has become the global standard for hazard prevention

Safe Enough for Space

Facing strict reliability requirements, NASA and Pillsbury personnel invented a system to prevent hazards from entering foods processed for the Apollo astronauts. Their approach, called the Hazard Analysis and Critical Control Point (HACCP) system, now assures safe processed foods all over the world.

Pillsbury/General Mills, Johnson Space Center

Contamination-Free Canning

Critical control points to monitor for cranberry sauce production can include a washing station for the berries, filtration and metal detection that ensure against foreign materials, heat treatment for pasteurization, and checks of acidity levels, among others.

Ocean Spray, Johnson Space Center

From Farm to Table

A HACCP plan for turkey processing means monitoring crucial points such as those where any residual farm chemicals are removed, proper refrigeration must be maintained, and antimicrobial sprays or dip tanks are used. High-pressure processing has recently become popular for poultry and various other foods as a way to eliminate potential pathogens and extend shelf life.

Butterball, Johnson Space Center

The Seven Principles of HACCP

Principle 1: Conduct a Hazard Analysis

List all steps in the process and identify those where hazards might be introduced. Identify possible control measures.

Principle 2: Identify the Critical Control Points (CCPs)

Identify points, steps, or procedures where hazards can be prevented, eliminated, or reduced to acceptable levels. A CCP may control more than one hazard, or more than one CCP may control a single hazard.

Principle 3: Establish Critical Limits

These are the maximum and/or minimum parameters under which each CCP can produce safe food. Limits are usually measured in time, temperature, pH, or other measures based on science or regulations.

Principle 4: Monitor CCPs

Develop procedures to ensure each CCP remains within its critical limits. Decide how, when, and how frequently each measurement is taken.

Principle 5: Establish Corrective Action

Describe the steps that will prevent hazards from entering the product in the event of a deviation from critical limits. Describe the steps to correct the process and ensure the problem won't recur.

Principle 6: Verification

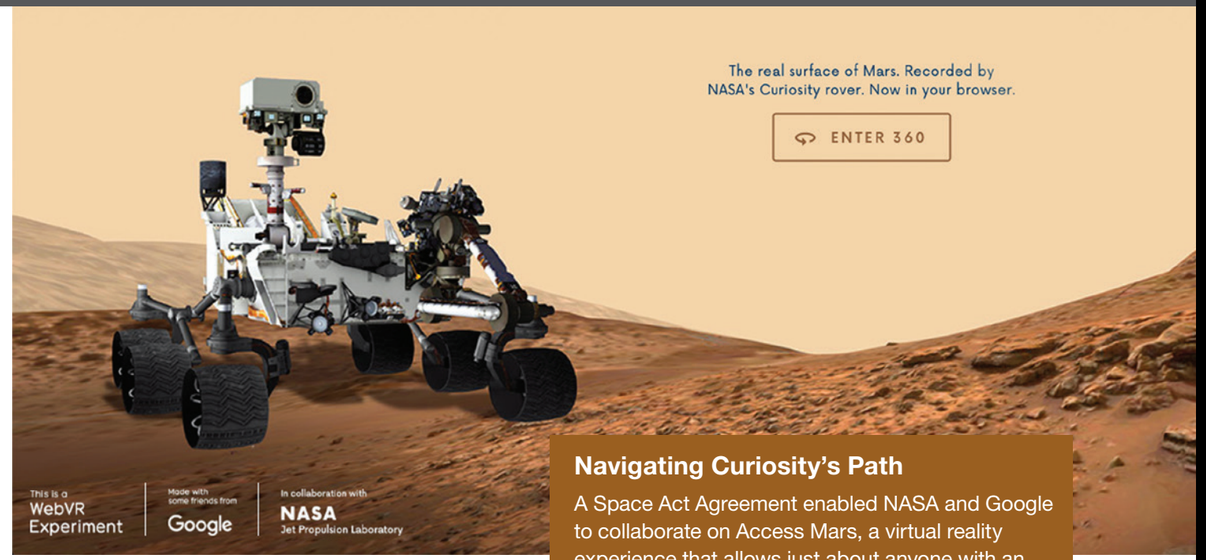
Determine that the HACCP plan is valid and that the system is operating accordingly. This may include reviewing records, auditing CCPs, calibrating instruments, testing products, and more.

Principle 7: Recordkeeping

Record information proving food was produced safely. Include procedures and policies; records of training, monitoring, and sampling; invoices and receipts; and information about the implementation of all seven HACCP principles, including recordkeeping.

Planets Take Virtual Shape on Earth with NASA Knowledge and Imagery

Companies are creating virtual worlds with NASA's planetary data and augmenting our own, enabling immersive experiences of space



Navigating Curiosity's Path

A Space Act Agreement enabled NASA and Google to collaborate on Access Mars, a virtual reality experience that allows just about anyone with an internet connection to explore the Red Planet.

Google, Jet Propulsion Laboratory

The World at Your Fingertips

AstroReality uses publicly available NASA data to create models of the Moon and planets that pair with the company's apps, which provide additional information about specific lunar and planetary features.

Quantum AR Technologies, Goddard Space Flight Center

SPINOFF Capsules

NASA works continually to uncover mysteries of the universe, and as you have seen, many of its innovations have been adapted to benefit all of us. Read on for additional examples. For more, visit spinoff.nasa.gov

Gecko Gripper Finally Sticks

After two decades of effort, gripper imitating a gecko's toe pads outfits industrial robots

NASA was interested in the technology for astronaut mobility and grappling satellites in orbit. A former JPL researcher licensed it and received NASA SBIR funding to develop it for industrial grippers, which are now going into factories.

OnRobot, Jet Propulsion Laboratory

Medical Mission Control

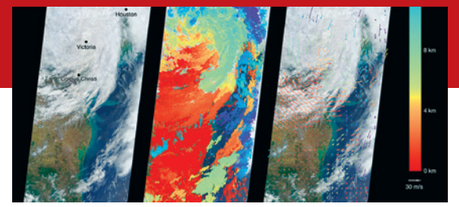
Software that monitors astronaut health in space now monitors high-risk patients at home

Custom software automated data collection from the space station, distributing it across NASA. Under exclusive license, that same program is now organizing and disseminating patient data for healthcare systems.

Ejenta, Ames Research Center

In Cloud Computing, Open Source Becomes Big Business

OpenStack, co-created by NASA, gained a huge user base and gave rise to other open source cloud computing tools

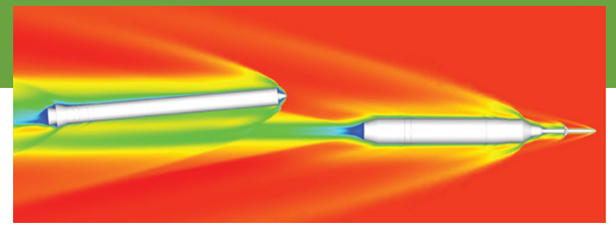


NASA co-created the first open source cloud infrastructure, OpenStack, which companies have commercialized and built upon with other open source tools like the OpenShift platform. Open source cloud computing subsequently exploded across industries.

Red Hat, Ames Research Center

TetrUSS Stacks Up Building Blocks for Aircraft Design

NASA's most popular and most-awarded software simulates aerodynamics for aircraft development and much more

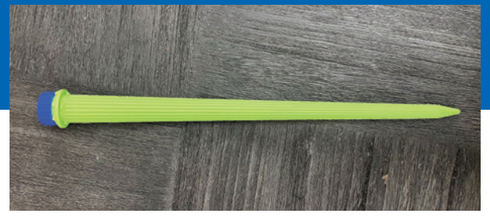


The TetrUSS software suite is available for free to U.S. citizens through a software usage agreement. Aircraft and spacecraft designers, government agencies, academics and many others use the software for a variety of purposes.

Helden Aerospace, Langley Research Center

Cleaning Up a Toxic Legacy

System for removing toxins from buildings is repackaged to clean up contaminated sediment



NASA created technology that absorbs toxins from sediment and groundwater. A company licensed it and now sells a system that is both cheaper and more effective than traditional cleanups.

ecoSPEARS, Kennedy Space Center

Airports Go Digital

NASA's aviation expertise helps usher in digital communications at airports worldwide

Airport communications are getting safer and more efficient thanks to a new international technology standard developed with decades of NASA expertise, leveraged in a Space Act Agreement with the FAA and now used by private companies.

Telrad, Glenn Research Center

Answering the Call of Distress

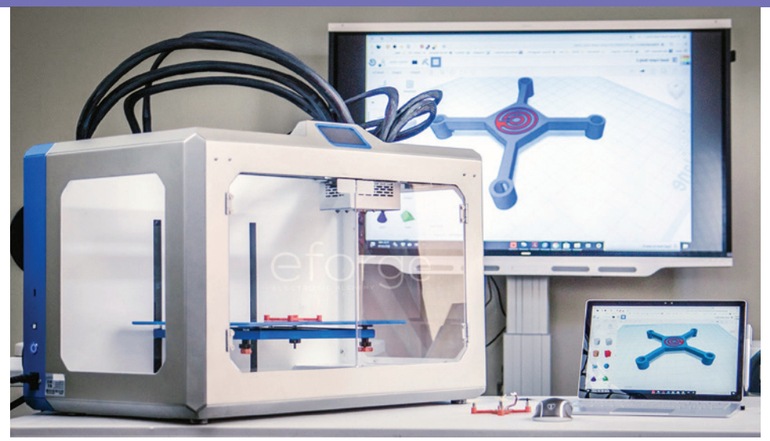
Software created with NASA expertise helps improve search and rescue system established under NASA's lead

NASA helped establish the Search and Rescue Satellite Aided Tracking (SARSAT) system and remains its research and development lead. Now software built with NASA know-how is helping additional satellites significantly improve response time and location accuracy.

Orbit Logic, Johnson Space Center, Goddard Space Flight Center

NASA Research Helps Make Electronics on Demand

The agency's interest in printing components in space results in a commercially available 3D printer for electronic devices and parts



Electronic Alchemy developed the eForge 3D printer with NASA STTR and SBIR funding. The space agency was interested in 3D printing electronics in orbit and beyond.

Electronic Alchemy, Marshall Space Flight Center

Fix it Like an Astronaut with Augmented Reality

A program to help astronauts visualize repairs assists workers on the ground

Augmented reality and 3D animation can help astronauts conduct maintenance in low-Earth orbit. A system NASA contracted to guide procedures in space is now helps businesses improve training and field operations on this planet.

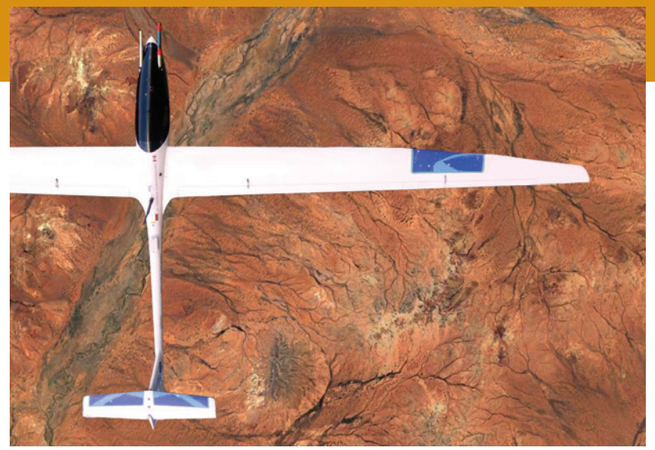
Tietronix, Johnson Space Center

Hearing Silence from the Stratosphere

NASA microphone detects unseen air turbulence

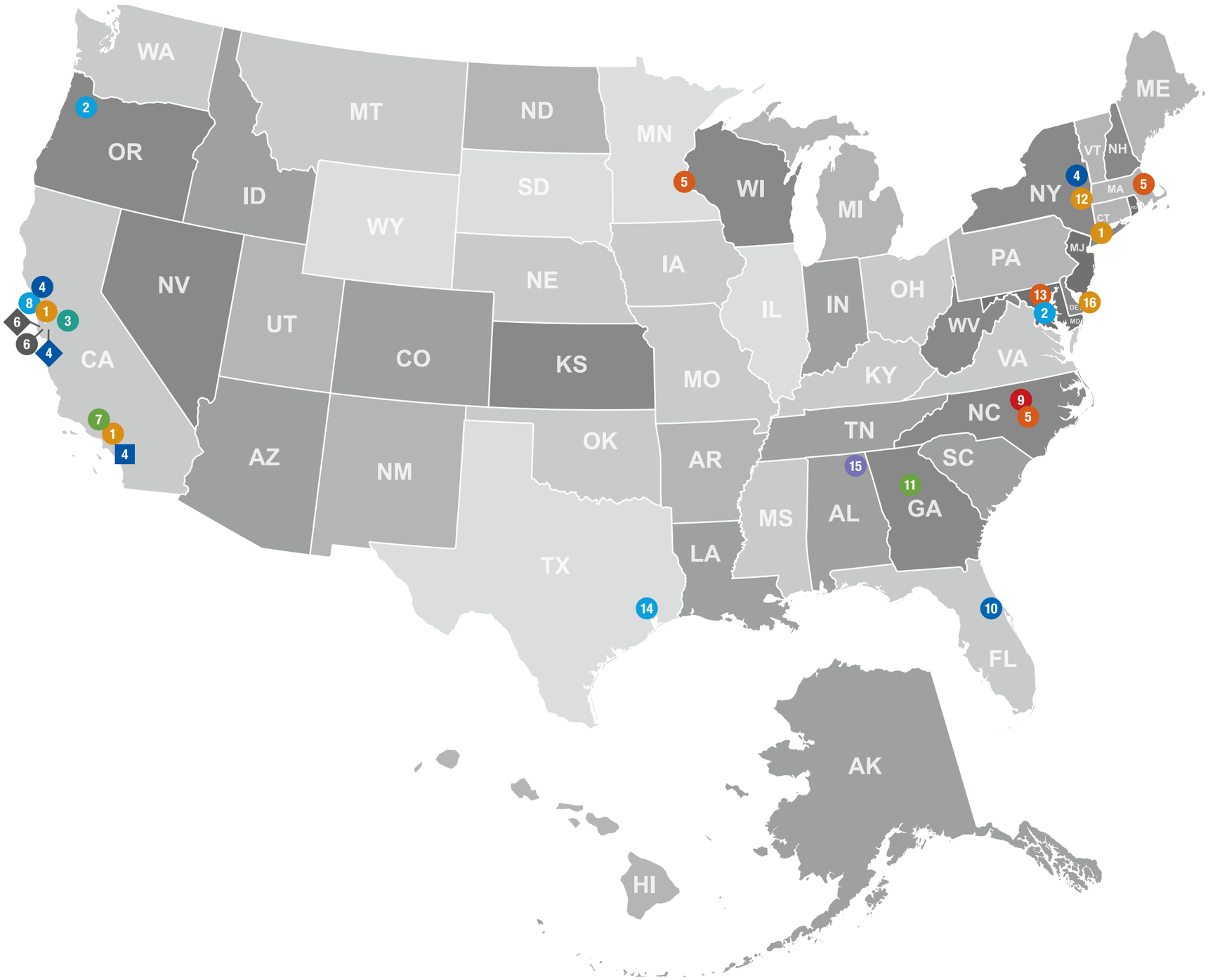
NASA researchers developed a specialized microphone to pick up sounds made by clear-air turbulence. Now private industry is using it to help conduct research and keep high-altitude UAVs in the air longer.

Stratodynamics, Langley Research Center



NASA SPACE TECH WHERE YOU LIVE

	Article/Technology	Company, Location
1	**The Rewards of Perseverance**	
	Rock core breakoff drill bits	Honeybee Robotics, Brooklyn, NY
	Extremely sensitive spectrometer	Photon Systems, Covina, CA
	Improved circuit board manufacturing	Tempo Automation, San Francisco, CA
2	**In the Right Hands, NASA Satellite Data and Analysis Make Earth Better**	
	Earth data analysis for conservation	Digital Earth Africa, Addis Ababa, Ethiopia
	Data tool to manage climate change	Earthrise Alliance, Washington, DC
	Satellite data for African farmers	Mercy Corps, Portland, OR
3	**Space-Age Water Conservation**	
	Water-recycling shower	Orbital Systems, Malmö, Sweden
	Filtration for water softeners	Puronics, Livermore, CA
	Forward-osmosis water purification	Aquaporin, Copenhagen, Denmark
4	**A Case Made in Space**	
	Aerogel-insulated bottle	CamelBak, Petaluma, CA ●
	Liquid cooling pump for supercomputing	Chilldyne, Carlsbad, CA ■
	Durable polymer for medical implants	Imitec, Schenectady, NY
	Precise, high-temperature sensors	Intelligent Fiber Optic Systems, San Jose, CA ◆
5	**Food Safety Program for Space Has Taken Over on Earth**	
	Hazard prevention protocol for food	Butterball, Garner, NC
		Pillsbury/General Mills, Minneapolis, MN
		Ocean Spray, Lakeville-Middleboro, MA
6	**Planets Take Virtual Shape on Earth with NASA Knowledge and Imagery**	
	Immersive virtual reality experience	Google, Mountain View, CA ◆
	Planet and Moon models with VR	Quantum AR Technologies, Cupertino, CA ●
7	**Gecko Gripper Finally Sticks**	
	Industrial robotic gripper	OnRobot, Culver City, CA
8	**Medical Mission Control**	
	Remote health-monitoring system	Ejenta, San Francisco, CA
9	**In Cloud Computing, Open Source Becomes Big Business**	
	Open source cloud computing infrastructure	Red Hat, Raleigh, NC
10	**Cleaning up a Toxic Legacy**	
	Toxic chemical cleanup	ecoSPEARS, Altamonte Springs, FL
11	**TetrUSS Stacks Up Building Blocks for Aircraft Design**	
	Aerodynamics-simulation software	Helden Aerospace, Acworth, GA
12	**Airports Go Digital**	
	Digital airport communications	Telrad, Delmar, NY
13	**Answering the Call of Distress**	
	Software to improve search and rescue	Orbit Logic, Greenbelt, MD
14	**Fix It like an Astronaut with Augmented Reality**	
	Augmented reality procedures program	Tietronix Software, Houston, TX
15	**NASA Research Helps Make Electronics on Demand**	
	3D Printer for electronic components	Electronic Alchemy, Huntsville, AL
16	**Hearing Silence from the Stratosphere**	
	Infrasound microphone	Stratodynamics, Lewes, DE

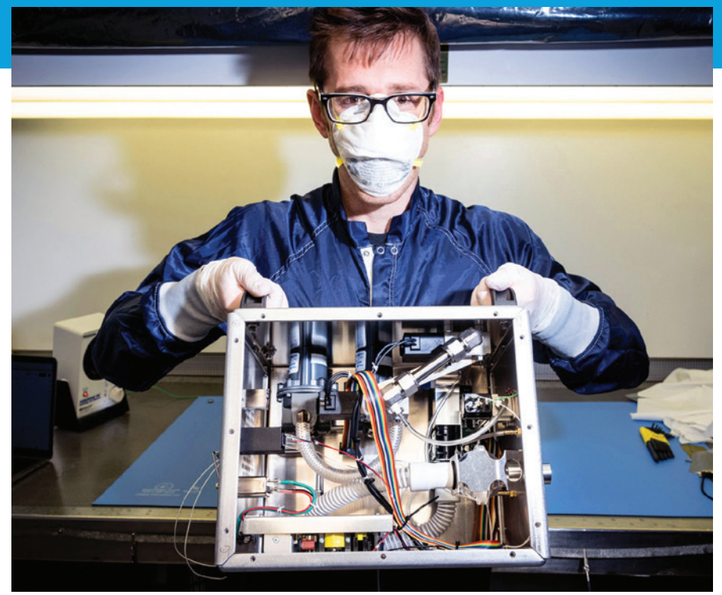


Inside NASA's Pandemic Response Campaigns

Marathon efforts, new approaches, old expertise are poised to pay off

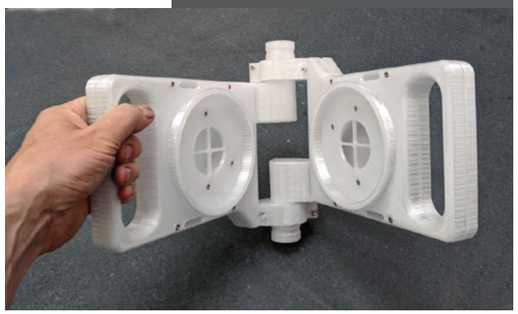
If It Helps Save One Life

In just over five weeks, engineers at the Jet Propulsion Laboratory designed a new, low-cost ventilator that uses none of the parts in traditional ventilators, so as not to compete for supply lines. About 30 entities have licensed the Ventilator Intervention Technology Accessible Locally, or VITAL technology, free of charge.



Human-Powered Solutions

A team at Johnson Space Center designed a 3D-printable ventilator that can be powered with both hands for use in the Orion capsule. The center has repurposed it for use on COVID-19 patients and is working with companies around the world to get it out to hospitals. Only a few parts, such as the accordion-like bellows, can't be 3D printed.



A Second-Generation Sterilizer

With help from a Glenn Research Center engineer, the company Emergency Products and Research (EP+R) improved its AMBUstat sterilizing fogger. The new AMBUstat G2 is better at eliminating airborne contaminants and adjusting to different-sized spaces.

Comfort, Convenience, and Safety

A public-private task force led by Armstrong Flight Research Center came up with a low-cost oxygen helmet for COVID-19 patients. The design includes a magnetically sealed port to allow easier access to the patient's face for vitals checks and even a sip of water. The center has licensed the design to a private company for manufacturing.

Spinoffs of Tomorrow

Each year we document dozens of spinoff success stories, but the work of the Technology Transfer Program is ongoing. Our technology portfolio contains many exciting innovations ready for an enterprising company or entrepreneur to license and develop into a commercial product.

Here are two examples that we think show great promise.

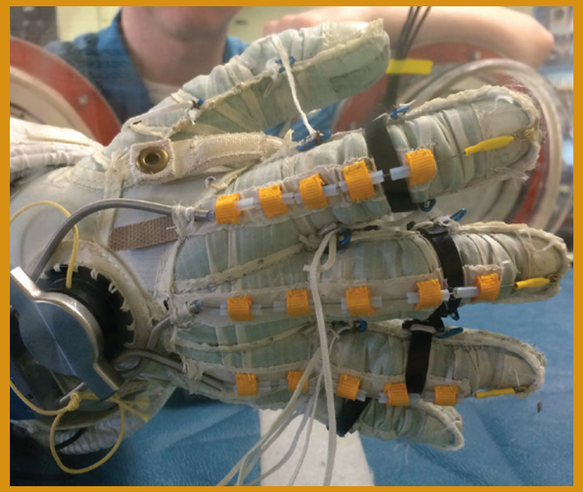
To learn more about – and get started licensing – these or any of the others in our extensive portfolio, please visit **technology.nasa.gov.**

Passive Porous Tube Irrigation System

System autonomously supplies water and nutrients to plants

The Passive Porous Tube Nutrient Delivery System is a plant growth technique that delivers a nutrient solution to the roots of plants via capillary action. The system was originally designed for use in microgravity. It uses a ceramic porous tube and water-filled nutrient bags connected in a loop. No electricity or moving parts are required. Instead, the nutrients are pumped in through a combination of capillary force and evapotranspiration from the plant. The porous tube supplies the plants with the water and nutrients needed to germinate and grow.

This system provides an autonomous plant growth apparatus that is simple to assemble, plant, and harvest, minimizing the amount of intervention needed.



New Capabilities for Grasp-Assisting Gloves

Spacesuit robotic glove

Researchers at Johnson Space Center have designed and developed spacesuit gloves with grasping and restorative capabilities to increase both strength and mobility. These new capabilities comprise components that can be integrated into existing grasping gloves to enhance operation and range of motions. In particular, actuators were designed to have a greater force output, better efficiency, and higher reliability and thermal range than commercially available actuators. Also, position sensors were added to improve the accuracy of the grasping motion, as was a built-in restorative force to assist movement back into a relaxed, non-grasping position. Industries such as manufacturing and healthcare can benefit from these components.

Want to Make the Next Spinoff?

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- More than 700 software codes

Whether you're looking to start a new company using NASA technology, enhance an existing product, or create a new product line, you can gain a competitive edge in the marketplace by putting NASA technology to work for you.