



SPINOFF



2012

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2012

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On the Cover:

Background: *A view of the aurora borealis—or northern lights—as seen from the International Space Station.*

Front Insets: *Images representing NASA spinoff technologies and their benefits in the areas of (from left to right) information technology, health and medicine, consumer goods, and energy and the environment.*

Back Insets: *Images representing NASA spinoff technologies and their benefits in the areas of (from left to right) public safety, transportation, and industrial productivity.*

Introduction

NASA and the Nation are embarking on an ambitious program of space exploration that builds on new technologies as well as proven capabilities as we expand humanity's reach into the solar system. While reaching for new heights in space, NASA is creating new jobs right here on Earth—especially for the next generation of American scientists and engineers—by supporting cutting edge aeronautics and space technology innovations, research and development that will help fuel the Nation's economy for years to come.

NASA provides America with unique capabilities simply because of how we ask questions about our universe. By taking humans to inhospitable places we learn more about how Earth sustains us, because we have to recreate that environment for our astronauts to survive. NASA solves difficult technical problems and thereby inspires Americans to invent technologies that make life better right here on Earth.

Investments in space and aeronautics technology stimulate the economy and contribute to the Nation's global competitiveness through the creation of new products and services, new business and industries, and high quality, sustainable jobs. A technology-driven NASA will maintain the Nation's aerospace community as a global technological leader for many years to come. NASA innovation also serves as an inspiration for young people to pursue science, technology, engineering, and mathematics education and career paths.

Whether we're developing needed technologies for space exploration or advancing the Nation's aeronautics capabilities, great ideas from NASA have a way of spreading, to everyone's benefit. So, it should come as no surprise that the technologies powering NASA missions are used by pioneering individuals and organizations to create and improve products and services that make life better here on Earth. Those benefits include everything from life-saving medical devices to improved solar power, fuel-saving aircraft designs and enhanced manufacturing techniques.

Increasingly we are finding that NASA's technological needs for space exploration overlap with our everyday needs. The partnerships we form to achieve NASA's objectives often make an immediate economic impact, with technologies being commercialized as spinoffs.

Every spinoff is a tangible reminder of NASA's commitment to investing in the future. The spinoffs featured in this book are inspiring examples of how NASA and its commercial partners have used space technology to solve everyday challenges—solutions that are being deployed in communities across America right now. These technologies are generating jobs, increasing productivity, creating revenue, cutting costs, and even saving lives. *Spinoff* 2012 presents 44 of these technologies, each with its own story. Here are just a few:

- A NASA partnership to develop a multivitamin regimen for astronauts resulted in a range of supplements for enhancing nutrition on Earth. Consumers have reported reduced healthcare costs and the elimination of allergies thanks to this spinoff. (page 38)
- One company received funding from NASA's SBIR program to investigate a superconductor material for future aircraft propulsion systems. The material is now helping enable lower cost MRI medical imaging devices. Thanks to its NASA partnership the company has created 16 jobs and has generated \$3 million in revenue from its spinoff products. (page 46)
- A NASA partnership produced unique instruments for measuring ocean color—essential data for understanding our planet's marine ecosystems. These innovations not only provide scientists with new tools for studying our oceans, but they also have resulted in more than \$2 million in contracts for the partner company. (page 94)
- Building on a patented innovation originally designed to create a unique marker for Apollo 11's mission to the Moon, a company has created silicon-based archiving technology that now preserves essential



Mason Peck
Chief Technologist
National Aeronautics and
Space Administration

records in a format resistant to fire and water damage. The 4-year-old company has grown from 2 to 10 employees and has now opened an international office. (page 126)

- Set to launch in 2018, the James Webb Space Telescope is already yielding spinoffs in health and medicine and industrial productivity. Now innovations designed to perfect the telescope's massive mirrors have been incorporated into technology for mapping the eye and diagnosing sight-threatening conditions. (page 44)

These and the other spinoffs in this book show that yesterday's investments in technology continue to repay the public today.

Pushing the boundaries of aeroscience and taking informed-risks, NASA and our Nation remain at the cutting edge. By making steady investments in technology, we will enable future human and robotic exploration of near-Earth asteroids, the Moon, and Mars just as current and past mission successes were supported by decades of vital technology investments.

A NASA focused on advancing technology helps ensure that high-tech jobs will be available for young people when they complete their studies. And in sponsoring this sort of research and development, it will do its part to encourage the next generation of aerospace engineers, ensuring that our Nation retains the critical capabilities in advanced technology that will ensure its economic competitiveness.

Spinoffs in Manufacturing

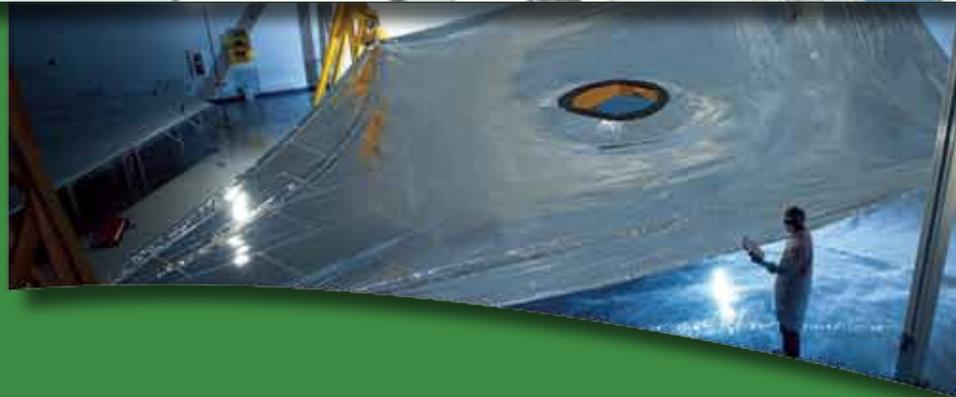
Spinoff has documented more than 350 NASA technologies that have been commercialized to enhance the Nation's industrial productivity. From innovative manufacturing techniques to materials that allow for entirely new structures, higher performance electronics, and improved energy efficiency—these spinoffs have created hundreds of jobs while ensuring that American companies remain world leaders across industries.



Executive Summary

Since 1976, NASA *Spinoff* has featured over 1,800 of the most compelling, beneficial technologies to emerge from the Agency's innovative technology transfer initiatives. The stories of these spinoffs begin with NASA's world-class scientists and engineers, who, in the course of guiding and supporting space exploration and Earth observation missions, develop new technologies and capabilities with uses that extend beyond NASA. Through partnerships with private industry, academia, Government agencies, and others, NASA transfers these innovations for the public good, creating jobs and advancing the fields of health and medicine, transportation, public safety, consumer goods, energy and environment, information technology, and industrial productivity.







Energy and Environment

While NASA explores the universe, it also focuses on understanding Earth. Whether contributing to the reduction of air pollution, a greater comprehension of ocean ecosystems, or the advancement of solar power systems, NASA technologies play a major role in preserving our planet's health for future generations. The spinoffs featured in this section:

- Reveal Ocean Health, Climate Change
- Enable Plants to Text Message Farmers
- Cut the Cost of Solar Power
- Inform Solar Power Analysis
- Create Self-Cleaning Surfaces
- Enhance Solar Power Systems
- Potentially Lower Facility Maintenance Costs



Photocatalytic Solutions Create Self-Cleaning Surfaces

NASA Technology

Hazy smog over cities and smoke pouring from the stacks of factories and power plants are visible reminders of the threat posed by air pollution to the environment and personal health. But air quality is often an unseen influence on our lives. Even on clear days, the air can be rife with particulate matter and other irritants that can trigger everything from minor allergies to life-threatening asthma attacks and other respiratory ailments. Indoors—where we spend as much as 90 percent of our time—pollutant levels can be 2–50 times higher than outdoors. The World Health Organization estimates that urban outdoor air pollution causes 1.3 million deaths worldwide per year, while in developing countries, indoor air pollution causes an estimated 2 million premature deaths.

Fortunately, there may be an equally invisible solution for reducing the damage air pollution causes—not only to people, but to buildings and infrastructure as well.

NASA has explored the beneficial applications of a process called photocatalysis for use both in space and on Earth. Photocatalysis is essentially the opposite of



NASA has explored photocatalytic technologies as a means for keeping space environments such as the International Space Station clean.

photosynthesis, the process used by plants to create energy. In photocatalysis, light energizes a mineral, triggering chemical reactions that result in the breakdown of organic matter at the molecular level, producing primarily carbon dioxide and water as byproducts.

NASA has studied the benefits of photocatalysis for purifying water during space missions, and plant growth chambers featuring photocatalytic scrubbers have flown on multiple NASA missions, using the photocatalytic process to preserve the space-grown crops by eliminating the rot-inducing chemical ethylene. (The scrubber technology resulted in a unique air purifier, featured in *Spinoff* 2009, now preserving produce and sanitizing operating rooms on Earth.)

Lauren Underwood, a senior research scientist at Stennis Space Center, began studying photocatalytic materials as part of a NASA partnership with the US Department of Homeland Security, which was investigating the materials for multiple applications, including protecting infrastructures against terrorism threats. From NASA's perspective, Underwood explains, "We don't want to introduce anything into space that could be potentially harmful. This is a future promising application of these materials—to keep surfaces not only clean, but potentially germ free."

Intrigued by the technology's potential, Underwood saw a way for photocatalytic materials to provide benefits for NASA on Earth, as well.

"At Stennis, we have a lot of buildings and facilities that are primarily white, and there are maintenance costs associated with keeping these buildings clean," Underwood says. She began testing photocatalytic materials as a valid solution for reducing these maintenance costs—with an eye not only for potential NASA benefits, but for the greater public as well.

Technology Transfer

Among the technologies selected for Underwood's research were those developed by New York City's

PURETi Inc., a company that had created a new approach to titanium dioxide-based photocatalysis. (Titanium dioxide, a common compound found in everything from paint to suntan lotion to food coloring, acts as a photocatalyst when exposed to ultraviolet light.) Common methods of incorporating titanium dioxide involve melting or mixing the compound into building materials, or applying it with solvent-based carriers like paint. With these methods, however, the nanoparticles of titanium dioxide clump together, reducing their exposed surface area and thus their exposure to light. Much of the compound ends up buried in the building material, providing no benefit.

PURETi (pronounced "purity") devised a liquid-based method of growing nanocrystals of highly photoactive titanium dioxide, which are suspended in a highly adhesive and durable water-based solution. To study the effectiveness of the technology, Underwood applied PURETi's solution to building surfaces at Stennis and monitored any changes through standard photography as well as remote sensing technology that measured the surfaces' spectral reflectance—how much they reflect light.

"Not only did the photographs show that the coated surfaces maintained the clean, white state seen when they were initially painted, from an analytical perspective, it was also demonstrated that the surfaces that were photocatalytically coated maintained higher reflectance values, when compared to the uncoated surfaces," Underwood says, implying that there is less dirt build up on the photocatalytically treated surfaces. "I was very pleased with the outcome. It's exciting that there is a nontoxic mechanism to keep buildings clean and at the same time reduce maintenance costs, energy costs, and the use of harsh chemicals."

Through its participation in Underwood's research, PURETi became a NASA Dual Use Technology partner, a cost-sharing collaboration aimed at the development of products that meet both NASA and commercial needs.

Benefits

PURETi now offers a range of nontoxic, environmentally sound commercial photocatalytic formulations designed to transform nearly any surface—from buildings to textiles to glass—into a self-cleaning air purifier. One spray application of the photocatalytic solution breaks down organic pollutants, keeps surfaces clear of grime and mold, and purifies surrounding air for at least 3 years.

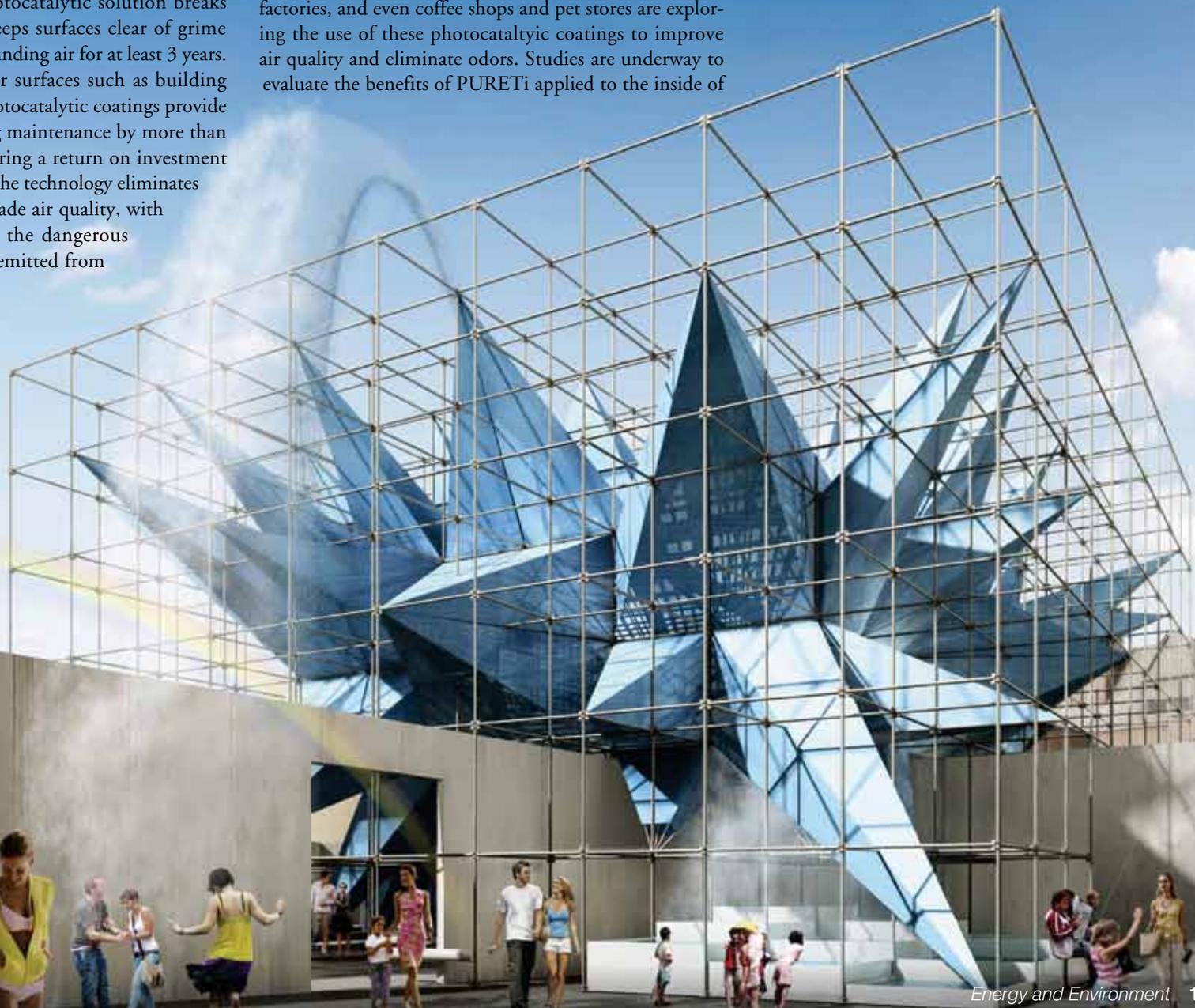
When applied to outdoor surfaces such as building facades, these proprietary photocatalytic coatings provide extensive savings by reducing maintenance by more than 50 percent and typically offering a return on investment in less than 2 years. Indoors, the technology eliminates odors and creates hospital-grade air quality, with an 85 percent reduction in the dangerous volatile organic compounds emitted from

some paints, new furniture and carpets, and photocopy machines and other office equipment.

PURETi's innovation is now being applied by manufacturers of textiles, porcelain tiles, and home furnishings, with expectations to expand into the glass, precast concrete, and roofing membrane industries. Schools, hotels, factories, and even coffee shops and pet stores are exploring the use of these photocatalytic coatings to improve air quality and eliminate odors. Studies are underway to evaluate the benefits of PURETi applied to the inside of

animal barns; previous research indicates that livestock breathing cleaner air grow faster with less food and require less need for antibiotics and steroids. Roads coated with PURETi act as effective depolluters, according to university studies.

This sculpture—called *Wendy* and coated with PURETi's technology—became the world's most unusual air purifier during the summer of 2012.





PURETi's photocatalytic solutions keep building surfaces (left, with the treated segment on the left), solar panels (above, with treated cells in the foreground), and windows (right, with treated windows toward the middle) free of grime—reducing maintenance costs, increasing efficiency, and providing all of these surfaces with air purifying capabilities.

A number of projects are also testing the ability of PURETi's solutions to keep solar panels clean for longer, improving their efficiency. The company even collaborated with an architectural firm to transform the firm's massive modern art sculpture—called Wendy and on display at the Museum of Modern Art's Queens, New York, campus in 2012—into perhaps the world's most unusual air purifier.

"The applications are virtually endless," says Glen Finkel, PURETi's president. "There is no surface that light can reach that PURETi can't enhance."

While photocatalysis is well known in Japan and Europe, PURETi's mission, Finkel says, is to gain traction for its unique version of the technology as a real answer to air quality issues in the United States. With the help of its NASA collaboration, PURETi is seeing ongoing returns on its efforts. The company's technology has won mul-

multiple awards, including the *Popular Science* Green Tech 2011 Innovative Product of the Year and the Material of the Year Award from Material ConneXions. One of the company's customers, the Asthma and Allergy Prevention Company, recently received Class II Medical Device approval from the Federal Drug Administration for its protocol—centered on PURETi's technology—that creates hospital-grade pure air environments in homes to prevent respiratory problems for cystic fibrosis patients. And a Yale University team is set to study PURETi as a means for enhancing infection control in rural health clinics in developing countries.

"We all love innovation," Finkel says. "But you can only have innovation if someone has the guts to go first. We will forever be indebted to NASA for taking us seriously, for engaging with us as a Dual Use Technology partner. We have this technology that sounds too good to

be true. Our challenge is to raise awareness in a credible way, and the involvement with NASA lends support to our credibility."

At Stennis, Underwood is continuing to explore the full potential of PURETi's technology, with an additional study set to begin using the new INFINITY at NASA Stennis Space Center as a testbed. Partnerships like the one between NASA and PURETi are a key driver of innovation, says Underwood, who says she is always looking for ways to help NASA give back to the taxpaying public.

"You can't do everything by yourself," she says. "It's a combination of expertise and skill sets that helps bring things to fruition." ❖

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“We all love innovation, but you can only have innovation if someone has the guts to go first.”

—Glen Finkel, PURETi Inc.



Stennis Space Center's new INFINITY Science Center not only inspires learning in the science, technology, engineering, and math disciplines, but will serve as the site of ongoing research on PURETi's photocatalytic technologies. For a deeper look at INFINITY, scan this code.

NASA's investment in technology yields spinoffs that have saved tens of thousands of lives, created tens of thousands of jobs, reduced billions of dollars in costs, and generated billions of dollars in revenue.

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