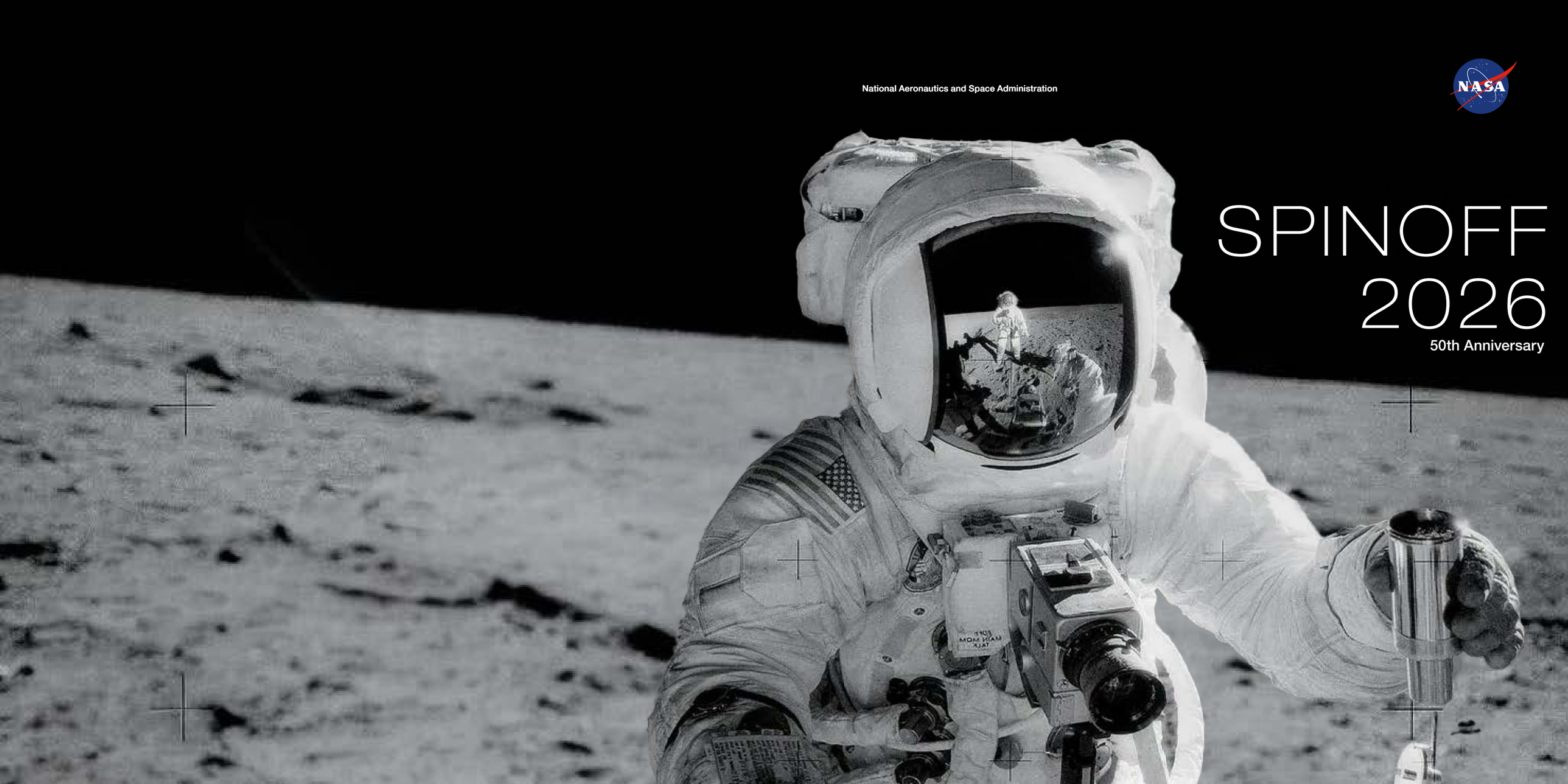
National Aeronautics and Space Administration



SPINOFF 2026

50th Anniversary

On the Cover

Astronaut Alan Bean holds an environmental sample container filled with lunar soil during the Apollo 12 mission of November1969. Astronaut Charles Conrad Jr., who took this picture, is reflected in Bean's helmet visor. *Credit: NASA*

NASA's Orion spacecraft parachutes down from the sky over Arizona during a test on September 13, 2017. The spacecraft, which is designed to take astronauts beyond Earth orbit, dropped 4.7 miles from an aircraft to simulate a situation in which the astronauts would abort the launch, ejecting the capsule from the SLS (Space Launch System) rocket. *Credit: NASA*

SPINOFF

2026

NASA Technology Transfer Program

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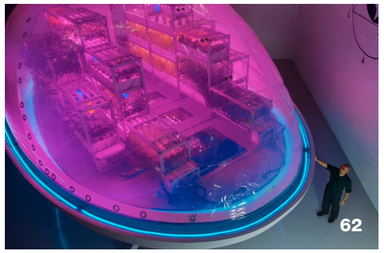

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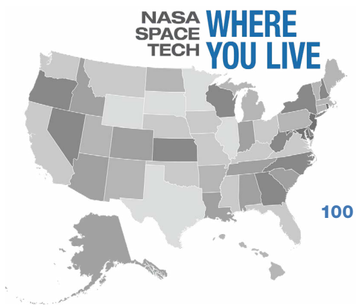

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Spinoff (spin´ôf) -noun.

1. A commercialized product or service incorporating NASA technology or expertise that benefits the public. These include products or processes that:
   - were designed for NASA use, to NASA specifications, and then commercialized;
   - are developed as a result of a NASA-funded agreement or know-how gained during collaboration with NASA;
   - are developed through Small Business Innovation Research (SBIR) or Small Business Technology Transfer (STTR) contracts with NASA;
   - incorporate NASA technology in their manufacturing process;
   - receive significant contributions in design or testing from NASA personnel or facilities;
   - are successful entrepreneurial endeavors by former NASA employees whose technical expertise was developed while employed by the agency;
   - are commercialized as a result of a NASA patent license or waiver;
   - are developed using data or software made available by NASA.
2. NASA's premier annual publication, featuring successfully commercialized NASA technologies.

Space station astronauts captured a clear image of rare "night shining" clouds high over Tibet, which appear as delicate, shining threads against the darkness of space. *Credit: NASA*

Introduction

Welcome to the 50th edition of NASA Spinoff

This year marks half a century since Spinoff began capturing the commercial impact of NASA. As we explore the universe for the benefit of all, NASA remains committed to ensuring technologies developed for space exploration and discovery have direct benefits here on Earth.

This edition highlights life-saving industry solutions enabled by NASA technology. An implantable cardiac monitor inspired by NASA innovation is helping heart failure patients stay out of the hospital and live healthier lives (page 82). Recent developments continue to improve personal locator beacons for the search and rescue network based on satellite communication technology developed by NASA (page 76).

As we set our sights on the Moon and pave the way to Mars, NASA's return to the lunar surface is fueling America's commercial marketplace.

Featured on pages 79 and 84, you will find companies 3D printing structures and materials that could house astronauts and equipment on other planetary bodies. Through NASA's Commercial Lunar Payload Services initiative, one featured company licensed an autonomous navigation system to help land robots on the Moon and navigate its terrain (page 14). Another company used NASA's lunar data to build a platform to support mission planning for the commercial space industry (page 6).

NASA's technology solutions are advancing operations in low Earth orbit as well. One of the agency's most widely used software codes helps organizations worldwide safely deorbit spacecraft (page 7). NASA Small Business Innovation Research funding helped another company develop thrusters using safer, more efficient fuel for satellite orbit maintenance (page 36).

NASA also unlocks Earth-based discovery, as demonstrated by a rock art enthusiast who used a NASA algorithm to develop a plug-in that archaeologists have used to discover faded ancient images (page 96).

NASA offers hundreds of patented inventions for commercialization. This publication's "Spinoffs of Tomorrow" section beginning on (page 108) features 20 promising options with licensing information.

Since its first publication in 1976, Spinoff has featured more than 2,400 commercial technologies that benefited from NASA inventions, funding, research, and expertise. This endeavor represents the next "small step" in our history of "giant leaps" to improving life on Earth from space.

Daniel Lockney
Program Executive
NASA's Technology Transfer Program
NASA Headquarters

Cosmonaut Anna Kikina sits in a mockup of the spacecraft that will take NASA's SpaceX Crew-5 mission to the International Space Station during a training at SpaceX in Hawthorne, California. *Credit: NASA*

SPINOFF
Capsules

Technology spun off from NASA is in your pocket, your car, the office, your home — it's everywhere, including space. NASA technology is increasingly helping private companies make advancements into orbit and beyond, whether that means making satellite missions more affordable, improving rocket hardware, or saving space on a commercial lunar lander. Here are examples of repurposed NASA technology showing up everywhere from your smartphone to the Moon.

Teaching an Old Metal New Tricks

After it deforms, a part made of the alloy nitinol will return to its original shape under a set temperature. This twisted paperclip made of nitinol wire demonstrates how warm water activates the metal memory. *Credit: Petermaerki CC BY-SA 3.0*

NASA data enables industry's continued use of shape-changing memory alloy

A memory alloy invented more than 60 years ago isn't gracefully sliding into old age — it's just getting started. With new formulations and manufacturing techniques, nitinol is proving its staying power. An alloy of nickel and titanium, nitinol's name takes letters from the two metals and the Naval Ordnance Laboratory that discovered its properties in 1959. Decades of innovation by the space agency and commercial companies have resulted in new formulations and manufacturing processes that are finding new uses on Earth and in space.

Extensive testing of the alloy sponsored by NASA's Langley Research Center in Hampton, Virginia, in the late 1960s generated a wealth of data. The center's Technology Utilization Office, recognizing the commercial potential, published a paper about it in 1972. That paper became the basis for the nitinol products developed by Metalwerks Inc., located in Aliquippa, Pennsylvania.

NASA continues to work with the alloy to improve applications in the aeronautics and automotive industries.

"These materials have the ability to convert heat into motion," said Othmane Benafan, a materials research engineer at NASA's Glenn Research Center in Cleveland. It exhibits "shape memory." After a part is manufactured in a specific shape, it will change or deform into another shape when heat is applied. That same part will return to the original form when cooled. This superelastic property means the part can also be twisted or extended.

Because nitinol functions in both hot and cold environments, it's particularly beneficial in space, where temperature swings are extreme. "One space application is using nitinol as part of a thermal system. It can absorb heat to support cooling and then eject that same heat when warming is needed," said Benafan. "It can be used to cool habitats or to maintain a fuel tank temperature and doesn't require a motor to accomplish either." It's also strong and corrosion-resistant.

All of these characteristics make it a valuable resource on Earth. Nitinol is used in dentistry as orthodontic wires (Spinoff 1979) and in medicine for heart valves and stents. Metalwerks produces medical-grade nitinol for a number of customers, and its nitinol formulations started with the published NASA data.

"The industry is still developing applications for nitinol 66 years later as a result of research in the space program," said George Kramer, president of Metalwerks. In addition to manufacturing nitinol, the company established an induction melting process that produces the alloy "in its cleanest form," according to Benafan.

Because the substance is difficult to manufacture, and therefore expensive, aerospace companies were the only customers for a while. But Metalwerks now supports customers in commercial space and has expanded its reach in the medical and dental-device manufacturing industry, said Kramer. In addition to supplying NASA with batches of nitinol using new formulas for its ongoing research, the company supports high-tech manufacturing customers.

In one example of NASA's continued work with the alloy, in the 2000s, the agency worked with Abbott Ball to develop a manufacturing process for corrosion-resistant ball bearings (Spinoff 2015).

As NASA continues to research nitinol's capabilities, new applications will benefit from the durability, light weight, flexibility, and shape-changing characteristics of the alloy, said Benafan. Some of those include automotive, commercial aviation, air conditioning, and mining. ●

3D Printable Alloy Can Take the Heat

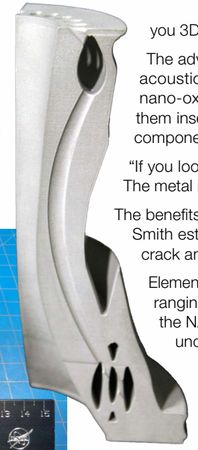
GRX-810 is a new metal alloy developed by NASA for 3D printing parts that can withstand the extreme temperatures of rocket engines, allowing affordable printing of high-heat parts. *Credit: NASA*

NASA-developed metallic alloy fills big materials gap for printed parts

Two requirements that rockets and high-speed jet engines have in common are durability and the ability to function in extreme temperatures. Until now, additive manufacturing, commonly known as 3D printing, could only produce certain engine components, because there were no affordable metal alloys for durable parts in the mid-temperature range, from 1,900°F to 2,400°F. Expensive higher-heat alloys were the only option until NASA developed GRX-810. This was the first time NASA used computational modeling to develop a custom alloy for 3D printing, but this novel material also required a new manufacturing process.

A team led by Tim Smith, materials engineer with NASA's Glenn Research Center in Cleveland, developed the new alloy, which was named NASA's 2025 Commercial Invention of the Year. Before any physical material was prepared, the team simulated and tested alloy mixtures on a computer to determine which recipes would yield the necessary properties.

"We used different elements, adding different amounts of each, and looked at the properties each iteration had," he said. The primary metals in GRX-810 include nickel, cobalt, and chromium. But even with the right mix, the powdered metal particles required a ceramic oxide coating to increase heat resistance and other performance. Known as oxide dispersion strengthened (ODS) alloys, these powders were impossible to manufacture at a reasonable cost when the project started. "We were also trying to develop new manufacturing techniques to incorporate nano-oxides into a metal when you 3D print," said Smith.



3D printing metal parts using special alloys like GRX-810 makes it possible to fabricate a single complex part. The new alloy means a part like this one fabricated by Elementum 3D can last up to a year in conditions that would crack other alloys within hours. *Credit: Elementum 3D Inc.*

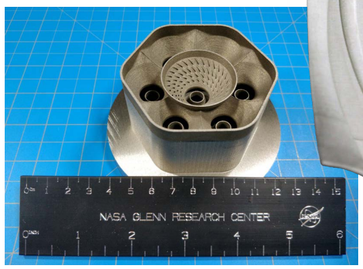
The advanced dispersion coating technique Smith and his team developed employs resonant acoustic mixing. Rapid vibration is applied to a container filled with the metal powder and nano-oxide particles. The vibration evenly coats each metal particle with the oxide, making them inseparable. Even if a manufactured part is ground down to powder and reused, the next component will have the benefits of ODS.

"If you look at the metal powder under a microscope, it looks like powdered-sugar donut holes. The metal is the donut, and the nano-oxide material is the powdered sugar," said Smith.

The benefits over common alloys are significant — higher heat resistance and increased durability. Smith estimated that GRX-810 could last up to a year at 2,000°F under stress loads that would crack any other affordable alloy within hours.

Elementum 3D, an Erie, Colorado-based company, produces GRX-810 for customers in quantities ranging from small batches to one ton or more. The company has a co-exclusive license for the NASA-patented alloy and manufacturing process and continues to work with the agency under a Space Act Agreement to improve the material.

"A material under stress or a heavy load at high temperature can start to deform and stretch almost like taffy," said Jeremy Iten, chief technical officer with Elementum 3D. "Initial tests done on the large-scale production of our GRX-810 alloy showed a lifespan that's twice as long as the small-batch material NASA produced, and those were already fantastic."



This turbine engine combustor was 3D printed at Glenn Research Center using the GRX-810 alloy and is the kind of part NASA needs that can benefit from higher heat resistance. *Credit: NASA*

Commercial space and other industries, including aviation, are testing GRX-810 for various applications, Iten said. For example, flow sensors monitor the speed of gases flowing through a turbine, helping engineers optimize engine performance. However, they can burn out in minutes due to extreme temperatures. One Elementum 3D customer, Vectoflow, is testing a GRX-810 flow sensor. This could improve airplane fuel efficiency, reduce emissions, and eliminate frequent hardware replacements. ●

Living Off Our Moon

NASA has been taking pictures of the Moon for decades, collecting a wealth of data. This false-color picture is a composite of 15 images of the Moon taken through three color filters on NASA's Galileo solid-state imaging system. *Credit: NASA*

The Lunar Reconnaissance Orbiter carries seven instruments to create detailed maps of the lunar surface, enhancing our understanding of the Moon's topography, lighting conditions, mineralogical composition, and natural resources. *Credit: NASA*

NASA lunar data finds resources to inform technology, mission planning

The barren lunar landscape has some resources, such as water and minerals like iron and titanium, but extracting and processing them will require special equipment. Where those resources can be found will dictate where to land and how to mine them. To help with that, Lunar Station Corp. is using a wealth of NASA data in multiple computer models.

"With 60 years of lunar data available to us, we help our clients understand the environmental factors for any given location on the Moon," said Blair DeWitt, CEO of Lunar Station. Combining disparate data from different sensors used by NASA and other space agencies is a critical first step. One NASA resource the Cambridge, Massachusetts-based company used to build terrain maps is the Ames Stereo Pipeline. The open-source code automatically processes images captured from satellites, robotic rovers, and more to create a 3D model revealing features such as rock placement and elevation.

The availability of in situ lunar water resources at any location is largely unknown, according to Gerry Sanders, former in situ resource utilization system capability lead at NASA's Johnson Space Center in Houston.

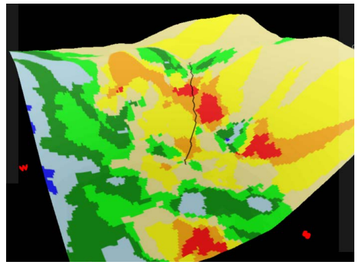
"We have reasonably good information about the lunar regolith itself through orbiter sensors and the Apollo samples," said Sanders. "But we don't know a lot about where or in what form water might be in permanently shadowed craters." To begin to fill that gap, the Lunar Crater Observation and Sensing Satellite was designed to crash its upper stage into the Moon's South Pole in 2009. The examination of the resulting plume revealed the presence of water ice. The agency is using this and other data to develop the hardware and processes necessary to extract those resources.

Lunar Station is building on that work to help commercial space companies with their mission planning, which includes scientific research for mining operations. The company's MoonHacker program uses its proprietary geospatial analytics platform and advanced algorithms to fuse all the lunar data in NASA's Planetary Data System to help identify indicators for shallow pits of lunar water.

MoonHacker includes models to identify the environmental factors for any given location on the Moon, including minerals, water, and topography elements such as slope and sunlight. NASA's Advanced Composition Explorer, a deep space satellite, also provides data about space radiation. In MoonHacker's Radiation Simulator, an electronic version of a company's rover or satellite, called a digital twin, can be subjected to the radiation en route or at the mission site to determine the protection required.

"Electronics do not like radiation, and we can identify the need for more or less radiation shielding. That saves customers money on design and launch costs." said Dr. Fredrick A. Jenet, head of technology at Lunar Station.

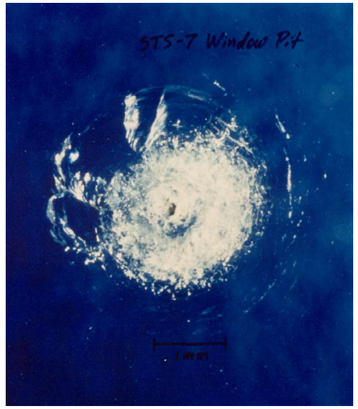
"We can find sites for landing pads, for cultivating the best paths for roving, and inform our clients about communications. If you can't see Earth at a given location like in the polar regions or the far side of the Moon, you have to come up with a relay strategy," said DeWitt. "We can do this in part thanks to NASA data that has been sensed and stored over more than six decades." ●



This multi-colored terrain map generated by the MoonHacker program indicates the likely location of water in a permanently shadowed crater on the lunar surface. Multiple data sources make it possible to identify the best locations (in red), and the black line is a proposed rover path into the area. *Credit: Lunar Station Corp.*

The Impact of Space Junk

The Long Duration Exposure Facility tested the performance of spacecraft materials, components, and systems in low Earth orbit, exposing them to the environment of micrometeoroids and space debris for an extended period of time. *Credit: NASA*



An impact crater on one of the windows of the space shuttle Challenger created by a paint chip shows how dangerous space debris can be. To help limit junk in space, companies like Kepler Communications use Debris Assessment Software to ensure their spacecraft will deorbit safely. *Credit: NASA*

Software from NASA gives industry a space debris-mitigation resource

A stone hitting a windshield on a freeway can make a driver panic. Imagine a tiny piece of debris hitting a window on the International Space Station at 17,500 mph. Fortunately, when that happened, it only caused a pit in the glass, posing no risk to the astronauts on board. But they may not have been so lucky had the object been larger. Problems caused by orbiting debris are getting worse as the number of satellites and rockets launched into space increases.

International guidelines and federal regulations are in place to reduce debris in low Earth orbit. To meet those requirements, space companies and agencies around the world develop safe reentry plans using a NASA software the space agency developed for its own use. One of the most requested space agency codes, Debris Assessment Software (DAS), has helped NASA mission developers assess debris mitigation requirements for everything launched into space since 1996.

Federal agencies that manage access to space require a company to submit an orbital debris mitigation plan for every launch vehicle upper stage or satellite, which includes end-of-life deorbit, when the spacecraft drops into Earth's atmosphere. DAS generates data requiring complicated calculations in a matter of minutes or hours, saving the end users time and expensive software development to achieve those results.

The program includes a module that creates a virtual spacecraft to test the effectiveness of the planned deorbit scenario. Every part of a craft must be included, from the materials used to fabricate components to the internal systems, structure, and more. Decades of NASA data replicate the conditions of space, Earth's atmosphere, and the way materials react to both. That flexibility means DAS can model and test anything from rockets to CubeSats.

Kepler Communications Inc., a Toronto-based satellite communications company, frequently uses DAS as a first step to generate performance data.

"As we release new spacecraft, a new generation, we are required to update our filings and launch authorizations and orbital debris assessment reports or orders. DAS works wonderfully when creating new orders," said Jared Bottoms, senior director of strategic initiatives for Kepler.

Companies can also model what happens to anything jettisoned into space. But accurate results depend on accurate information, said Dr. J.-C. Liou, program manager for the Orbital Debris Program Office at NASA's Johnson Space Center in Houston.

"A piece of aluminum released from the space station probably will not survive reentry. But if you release a chunk of stainless steel or titanium, pieces will likely survive reentry to reach the ground or ocean," he said. So DAS includes an extensive database of materials that's continually updated to include new ones requested by users.

Because of the risk space debris poses to life and property, governments around the world implement the best practices of the Space Debris Mitigation Guidelines developed by the Inter-Agency Space Debris Coordination Committee. Many were originally developed by or include input from NASA.

The DAS mission editor and science and engineering utilities also share the space agency's experience, according to Bottoms.

"Having access to software like this available is incredibly beneficial to expanding the space economy," said Bottoms. "DAS ensures we're limiting the potential devastation that could occur to the space environment and would limit our future use." ●

New Insulation Can Benefit Many Industries

The secret to Integrated Multilayer Insulation is that it replaces the netting that has traditionally separated reflective layers in multilayer insulation with a series of fixed plastic spacers designed to hold everything in place while allowing as little heat conduction as possible. *Credit: Quest Thermal Group LLC*

Large parts of the Nancy Grace Roman Space Telescope's Wide Field Instrument are insulated with Integrated Multilayer Insulation. The observatory, which has a field of view at least 100 times larger than that of the Hubble Space Telescope, is expected to launch in 2027. *Credit: NASA*

Enhancements to a classic spinoff can benefit hydrogen energy, refrigeration, more

One of NASA's most significant, widespread technologies in space and on Earth is finally getting an upgrade, more than 60 years after its invention.

Traditional multi-layer insulation (MLI), also known as radiant barrier insulation, comprises layered sheets of Mylar coated with reflective metal and separated by netting. Nothing can beat it for thin, lightweight protection against radiated heat, a primary concern in the vacuum of space.

On Earth, MLI has found applications in winter gear, buildings, MRI machines, and cryogenic tanks, among others (Spinoff 2022, 2020, 2018, and more).

But Dave Plachta thought it could be better. "Traditional MLI can slip and slide together. It's not strong nor structural," said the retired NASA researcher, noting that its performance depends heavily on the quality of assembly and seam joining, adding uncertainty to missions.

Around 2006, as a senior researcher at NASA's Glenn Research Center in Cleveland, Plachta led the "zero boil-off" initiative, aiming to store liquid hydrogen indefinitely with no evaporation. Future crewed Mars missions may require hydrogen tanks to orbit Earth and Mars for hundreds of days, and the technology to enable this didn't exist.

With that in mind, NASA sought proposals for Small Business Innovation Research (SBIR) contracts focused on cryogenic technologies, including improved radiant barrier insulation. Among the companies selected was Quest Product Development Corp., which proposed novel improvements to MLI. This sparked a long, fruitful collaboration.

Quest's key innovation involved replacing the netting between Mylar layers with tiny polymer spacers shaped like tripods, preventing the layers from touching. Alan Kopelove explained, "Heat has to conduct through a long, thin part to get from one layer to the next." And these tripod arms are made of a particularly poor heat conductor.

Kopelove is CEO of Quest Thermal Group LLC of Arvada, Colorado, which spun off from the original company.

"The performance is better and much more consistent," Plachta said.

The company named its invention Integrated MLI, or IMLI. Subsequent NASA SBIR contracts supported the development of versions that could wrap around pipes, survive micrometeoroid strikes, or support a thermal shield for active cooling by a cryocooler.

It wasn't until 2019 that any of these flew on a NASA mission. Since its successful demonstration on the Green Propellant Infusion Mission and others, IMLI has been incorporated into NASA landers, rovers, satellites, space telescopes, and more. Artemis mission planners, aiming to land astronauts on the Moon, are considering IMLI for long-duration hydrogen propellant storage.

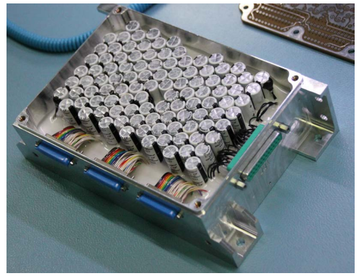
With governments around the world investing in technology to support hydrogen energy infrastructure, Quest's innovations are also poised to benefit that entire industry. The insulation will also decrease losses of other cryogenic fuels, such as liquid natural gas.

But Quest is just finding its way to commercialization. IMLI is slated to fly on Blue Origin's Mark 1 and other private lunar landers NASA is supporting through the Commercial Lunar Payload Services program. The company has also been contracted for preliminary design work on an aircraft hydrogen tank, insulation for superconducting power lines, insulating telecommunications satellites, and micrometeoroid protection for new satellite platforms.

"What we're developing for NASA will find use in other places," Kopelove said. "We've only started exploring the many potential commercial applications." ●

Knowledge Is Battery Power

This Fiat 500e traveled from Italy to England on a single charge to demonstrate Electra's battery management technology, derived from work done at NASA. *Credit: Electra Vehicles Inc.*



Ultracapacitors can store and release energy on demand, which makes them an appealing power solution for aircraft and spacecraft. NASA Small Business Innovation Research funding into use of capacitors on scientific balloons resulted in battery management technology that became the backbone of Electra Vehicles' products. *Credit: ESA/Airbus Defence and Space*

A cross-country trip in a modified Tesla Cybertruck from Electra's Boston headquarters to the Consumer Electronics Show in Las Vegas further showcased how Electra's battery management technology improved the vehicle's long-range performance. *Credit: Electra Vehicles Inc.*

Smart battery management software traces lineage to work with NASA

Modern electric vehicles can go hundreds of miles without a recharge, but that long range can diminish faster if battery health isn't properly tracked and managed. And to do that, you need some smart software — and some smarts from working with NASA.

"Whether it's for a balloon or a drone or a rover, we realized that for anything we are working on, you needed a complex system of batteries and energy storage, and every time, the software makes a difference," said Fabrizio Martini, founder of Electra Vehicles Inc.

Based in Boston, Electra was founded in 2015. Around that time, Martini was the principal investigator on two Small Business Innovation Research (SBIR) contracts with NASA's Goddard Space Flight Center in Greenbelt, Maryland. These focused on creating power systems for long-duration balloon and rover missions, organized with Martini's then-employer FastCAP Systems Corp. After six months, the company ultimately developed a high-energy capacitor and achieved the goals set in the contract for the battery management software.

"We ended up using three batteries — one primary and two secondary," said Martini. "In order to manage these three systems, you need a control strategy. Something to manage the energy flow between them, and so you need an accurate battery management model to come up with that control plan."

While the SBIR did not proceed beyond Phase I, Martini believed some of the developments made in active energy management on balloons could be transferred to electric vehicles. With some negotiations, FastCAP transferred the work done on the management system and its intellectual property to Electra Vehicles, and Martini began working at Electra full-time as the CEO and cofounder.

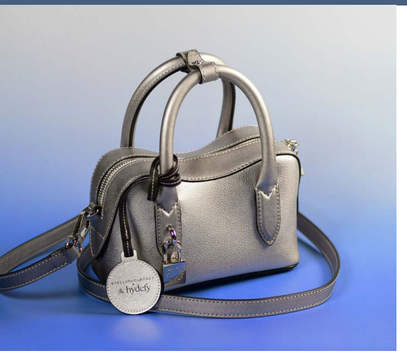
Unlike most battery management systems, which passively manage how power is distributed, Electra's battery management system uses machine learning and AI to determine how and when the battery cells are most used, and to make sure the cells all have that power when they need it. This helps keep efficiency high and ensure battery longevity.

Martini says Electra is in the "business-to-business" technology market, which means most of its sales are to companies that create vehicles and components, as opposed to consumers. The battery efficiency measurements are especially important to companies operating vehicle fleets, where ensuring cars last for years means conserving battery life for as long as possible.

The company has cultivated relationships with battery manufacturers like LG, and partnerships with automakers such as Stellantis, which is introducing electric vehicles to several of its brands. One of these vehicles, the Fiat 500e, uses Electra's battery management technology, and Electra demonstrated it by driving from Italy to London on a single charge. A second showcase used a Tesla Cybertruck to demonstrate how its battery intelligence system can boost range, performance, and thermal management. Martini credits his time working with NASA for bringing some of the inventiveness needed to travel to other worlds back to traveling on this planet.

"I often say working with NASA was the most inspiring time of my life. Because the framework of NASA is to really think out of the box and look for people with the capability to say yes to trying something, even if it seems impossible," he said. ●

Handbag Made from Basic NASA Research



A fungi-based leather alternative made by Hydefy, a Nature's Fynd brand, debuted in a handbag from environment-focused designer Stella McCartney. The Stella Ryder Hydefy Crossbody Bag was introduced on the spring/summer 2025 Paris runway and retailed for $1,650. *Credit: Stella McCartney*

Astronaut Jessica Watkins holds a Nature's Fynd bioreactor on the International Space Station. The company received Small Business Innovation Research funding to research protein biomats in space. Then it sent its signature Fy protein to the space station with support from the NASA Established Program to Stimulate Competitive Research. *Credit: NASA*

Space agency interest in organisms and protein result in a fungi faux leather

NASA-funded research on extremophiles — organisms that thrive in harsh conditions — led to the discovery of a microbe that has for several years been available in grocery stores as an ingredient in Nature's Fynd meatless breakfast patties and dairy-free cream cheese and yogurt (Spinoff 2023).

Now The Fynder Group Inc., the company doing business as Chicago-based Nature's Fynd, is producing textiles under the brand name Hydefy, which debuted its first material this spring in a $1,650 Stella McCartney handbag called the Stella Ryder Hydefy Crossbody Bag.

Hydefy and Nature's Fynd's food products both use the fungi protein they call Fy, which the company grows from the organism Fusarium strain flavolapis, originally identified in acidic hot springs in Yellowstone National Park by one of the company's cofounders during graduate research funded by NASA's astrobiology program. The space agency is interested in life that thrives in hostile environments like those on other planets or in Yellowstone's volcanic caldera.

Nature's Fynd received Small Business Innovation Research funding from the National Science Foundation, the Agriculture Department, and the Environmental Protection Agency before winning NASA Phase I and II Small Business Technology Transfer, or STTR, contracts.

NASA was interested in the company's fungi protein biomats, which were produced in trays with minimal input requirements and almost no water waste. Nature's Fynd developed bioreactors for space and eventually grew Fy on the International Space Station. The resulting biomass was a high-fiber complete protein, like the Fy the company had developed for Earth.

"It can be really hard to make a good protein in space," said John Hogan, who worked with Nature's Fynd on the STTR projects as head of the Bioengineering Branch at NASA's Ames Research Center in Silicon Valley, California, before he retired in 2023.

"This was a basis for a healthy, high-protein meat and dairy substitute," he said. Although the project came to an end and the company is not currently working on any space-related projects, Hogan said this or something similar could still one day fill protein production gaps in future space missions.

Debbie Yaver, The Fynder Group's chief science officer emeritus, said the NASA STTR work informed how the company currently produces Fy. Under the space agency contracts, company scientists researched optimal acidity, carbon sources, and salt concentrations to grow the Fy protein as quickly as possible.

"We learned an awful lot about how the inputs and conditions affect growth," she said. Ultimately, based on that knowledge and further research, the company transitioned to cultivating Fy in broth vats for its terrestrial offerings.

Meanwhile, the company's "small but mighty" team of biochemists, material scientists, and biomaterial experts have been working on using Fy in textiles, Yaver said. They combine the fungi's strong, flexible fibers with sugarcane-derived inputs and shape it into sheets.

The Stella handbag has a leathery look with a metallic finish, but Yaver said a variety of materials are possible.

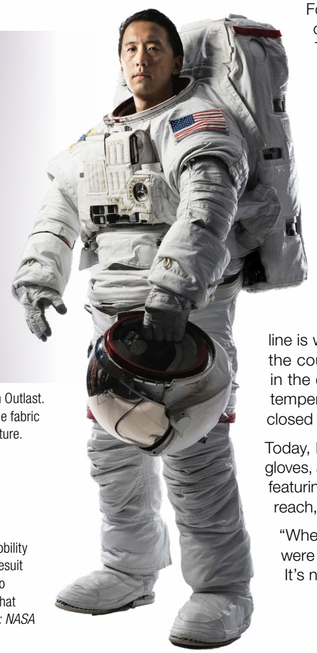
Stella McCartney is known for her commitment to sustainability and vegan fashion. "I am constantly exploring plant and fungi-based, regenerative alternatives that do not harm animals and heal Mother Earth," she said when the handbag was first introduced.

The company said it is ushering in a new era of fungi-based textiles. "We're actively working with a range of brands across fashion, footwear, furnishings, and automotive," said Thomas Jonas, CEO of The Fynder Group. ●

NASA-Derived Textiles Go on Tour

Ekoï makes all sorts of clothing for active cyclists, including products made with Outlast — a material developed with NASA's assistance. *Credit: Ekoï*

This woman is wearing an Ekoï jersey made from Outlast. The phase-change materials incorporated into the fabric help the wearer stay comfortable in any temperature. *Credit: Ekoï*



Astronaut Jonny Kim wears an Extravehicular Mobility Unit spacesuit. Looking to improve existing spacesuit temperature controls, NASA funded research into phase-change materials, resulting in the textile that would later be commercialized as Outlast. *Credit: NASA*

Temperature-controlling fabric helps athlete cyclists perform

Bicycle racing is one of the most physically intense sports, requiring athletes to maintain a constant speed while riding for dozens of miles. During particularly long races, through cold rains and summer heat, athletes need gear that will adapt to the different environments they encounter. Now, a company is using a material with NASA origins to ensure these athletes stay comfortable while taking their grand tours.

Phase-change materials use basic properties of matter to maintain a steady temperature. When a substance melts from a solid to a liquid, the material absorbs heat, and when it becomes solid again, it releases that heat. In the 1980s, NASA provided Small Business Innovation Research funding to Triangle Research Corp. to explore how phase-change materials could be incorporated into textiles to control temperatures in spacesuit gloves. By placing phase-change materials in small capsules woven throughout a textile, these temperature-regulating properties can be tuned to the comfort of the human body. While these textiles weren't incorporated into any gloves flown on NASA missions, they formed the basis for a new product, sold under the name Outlast.

Outlast has since become one of the most widely distributed temperature-regulating fabrics, found in products such as bedding, loungewear, and office chairs (Spinoff 2024, 2023, 2022, and more). It has seen especially extensive use in activewear, ranging from jogging clothes to professional sports gear.

Founded in 2001 and based in Fréjus, France, the company Ekoï makes clothing and accessories for cyclists, particularly those who bike competitively. The company sponsors athletes and uses their feedback to tailor products to their needs.

"We started sponsoring because our DNA is that we develop the product with pro athletes and then we sell it directly to the customers on the website," said Sylvain Georges, U.S. export manager for Ekoï.

The company first encountered Outlast at the Performance Days fabric trade fair in Munich and was impressed with its capabilities, as well as its NASA heritage.

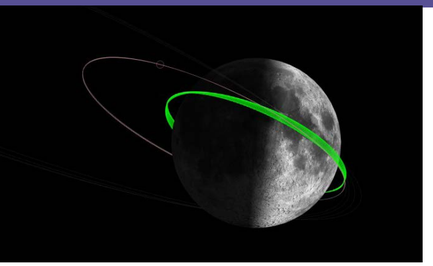
"We were there to meet different suppliers for fabric technologies. We saw their booth and there was a big astronaut displayed there," said Celine Milan, director of textiles at Ekoï. "It was pretty clear that it was interesting for NASA, so we thought it would be interesting for us."

Officially launched in July 2022 during the Tour de France, Ekoï's Outlast line is worn by the Israel-Premier Tech and Arkéa-B&B Hotels racing teams. Over the course of that race, the company found it improved cyclists' performance in the event's mountain stages, where elevation changes mean wide swings in temperature. It also improved athletes' aerodynamics, as their jerseys could stay closed in warmer environments, rather than opening them to let in wind.

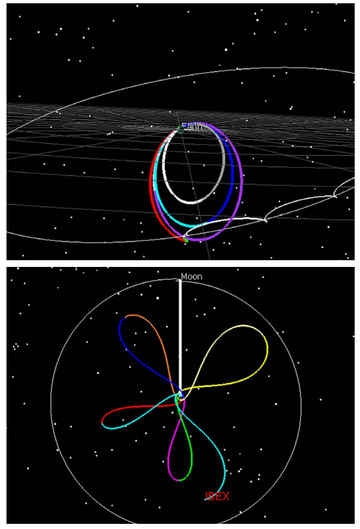
Today, Ekoï sells 12 products that incorporate Outlast materials, including jerseys, gloves, and socks. The company plans to expand the product line soon, with a helmet featuring Outlast padding. While Ekoï primarily sells in Europe, it has intercontinental reach, and the product's NASA heritage makes it appealing to athletes.

"When you say NASA, it's always impressive." Milan said. "At the beginning we were even saying here in our offices, 'Wow, this technology was funded by NASA.' It's not some technology used by anyone, it's on another level." ●

Old-School Software Enables New Missions



An Astrogator-enabled view from Earth of the trajectory of the Lunar Atmosphere and Dust Environment Explorer, a spacecraft that orbited — and, in 2014, deliberately impacted — the Moon to gather information about the lunar atmosphere, conditions near the surface, and the environmental influences on lunar dust. *Credit: Space Exploration Engineering LLC*



Ansys' STK Astrogator is commercial software that supports trajectory design and visualization. It grew out of code NASA commissioned in the late 1980s. The images compiled here are actual trajectories from missions over the years. *Credit: Space Exploration Engineering LLC*

Trajectory software NASA commissioned decades ago has grown into a tool for all

Trajectory modeling software that has evolved from code NASA first commissioned in the late 1980s is now used commercially, internationally, and by NASA.

Called Astrogator, the capability is a component of the Systems Tool Kit, or STK, a mission-engineering package from Canonsburg, Pennsylvania-based Ansys Inc. The software was developed by Analytical Graphics Inc. (AGI), which has been an Ansys company since 2020.

Astrogator supports missions from preliminary design to higher-fidelity solutions, where the aim is to get as close as possible to a digital twin of the mission trajectory, said Cody Short, principal astrodynamicist at Ansys AGI.

"You can start with low-fidelity models and then bring pieces in and build up your solution as you go, adding constraints along the way," Short said.

Cheryl Gramling, who now works in the Space Communications and Navigation program office at NASA Headquarters in Washington, was, back in the 1980s, working at the agency's Goddard Space Flight Center in Greenbelt, Maryland, as flight dynamics lead for several missions. They employed lunar gravity assists, using the Moon's gravity to alter spacecrafts' flight paths or speeds.

"When designing trajectories in multi-body gravity regimes, I was hand-plotting different views of the trajectories," she said. "This was arduous. New graphics processing workstations had reached the market, and it was an opportune time to apply that graphics technology to trajectory design."

Gramling came up with the concept for a trajectory design and visualization software and arranged for NASA to develop what became known as SWINGBY through a contract with Computer Sciences Corporation (CSC).

In 1994, CSC began selling the code, rebranded as a software package called Navigator, in cooperation with AGI, according to John Carrico, who worked on the software at CSC and then AGI. Carrico, now CTO and owner of Space Exploration Engineering, still uses Astrogator as a customer.

In 1996, AGI bought Navigator from CSC and also secured the rights to incorporate the SWINGBY code into the company's Satellite Took Kit, rebranding the capability STK/Astrogator and continuing to develop it, Carrico said. Now, as an Ansys offering, the STK stands for Systems Tool Kit, and Astrogator anchors the STK Premium (Space) product.

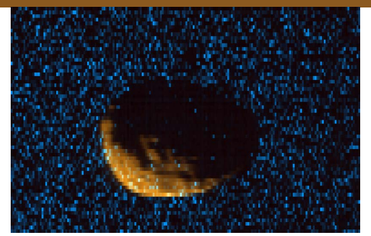
NASA has used the software for numerous missions, from satellite trajectories orbiting Earth to the deepest space probes. Among these are the James Webb Space Telescope, the most powerful telescope in space, and New Horizons, which launched in 2006 and is currently approaching the edge of our solar system, twice as far from Earth as the dwarf planet Pluto.

The software is used internationally, including by government space programs in Europe and Asia. Customers include the "big primes" — large aerospace companies that are often prime contractors on government projects — as well as startup satellite and smaller space companies. Astrogator has been used in several missions overseen by NASA's Commercial Lunar Payload Services, an initiative to contract out lunar missions to private companies to achieve research goals and spur the commercial space industry at the same time.

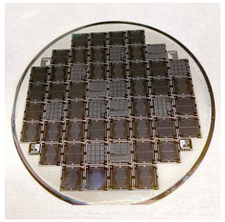
"We're continually developing Astrogator," Ansys' Short said.

In the 1990s, Carrico observed, trajectory design and mission and maneuver planning were only possible for the largest organizations, like NASA and companies that worked closely with the space agency. "Now there are hundreds and really thousands of people who can do what only the government used to be able to do." ●

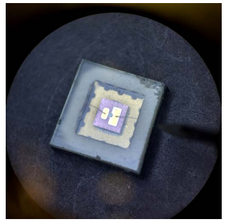
A Planetary Sensor's Earthly Applications



NASA uses ultraviolet spectrographs to investigate conditions on celestial bodies like the Martian moon Phobos, pictured here. In this image, orange shows mid-ultraviolet sunlight reflected from the surface, exposing the moon's irregular shape and many craters. *Credit: Colorado University and NASA*



CoolCAD photodiode technology, which is made with the semiconducting material silicon carbide, is small, lightweight, robust in extreme conditions, and highly sensitive in part of the ultraviolet spectrum. *Credit: CoolCAD Electronics Inc.*



While CoolCAD engineers understand the physics of silicon carbide and how to build photodiodes with it, they also work with NASA to ensure the components fit with the agency's spectrographs and other instruments. *Credit: CoolCAD Electronics Inc.*

NASA-funded technology detects fires, shale, and more

Technology NASA uses to study gases and rocks on other planets is helping companies identify and monitor conditions on Earth — like the location of shale for fracking and whether a fire has started on an airplane.

Used in spectrometers and other instrumentation, silicon carbide photodiodes from Greenbelt, Maryland-based CoolCAD Electronics Inc. detect ultraviolet, or UV, light in both space and terrestrial applications.

"Our diodes are very sensitive," said Dr. Zeynep Dilli, CoolCAD's director of engineering. "They don't need filters to block out visible light as other off-the-shelf UV photodiodes do, so we can make detector systems smaller and more efficient."

Photodiodes convert light energy into an electric signal — the opposite of an LED, or light-emitting diode, which converts electrical energy into light.

Traditional photodiodes detect both UV and visible light, so isolating UV ranges requires filtering out visible light with bulky filters, adding mass and losing transmission. But CoolCAD technology, made with the semiconducting material silicon carbide, doesn't require filters because it is sensitive only to part of the UV range.

Dr. Shahid Aslam, a research space scientist at NASA's Goddard Space Flight Center in Greenbelt, Maryland, who has worked with CoolCAD, said silicon carbide is an optimal material for the fabrication of UV-sensitive photodiodes that need to operate in harsh space environments with high radiation levels and extreme temperatures.

"These photodiodes are designed to be insensitive to visible light, making them ideal for applications where you want to detect only the UV light with high sensitivity," he said.

For NASA, UV photodiode technology has many applications in both planetary and Earth sciences. It can be integrated into spectrometers that can distinguish different gases in planetary atmospheres, as well as aerosols and pollutants.

Because silicon carbide photodiodes can operate in harsh environments, they are ideal for detecting radiation on planetary surfaces, including cosmic rays, charged particles, and more, Aslam said.

Aslam also noted that UV observations are key to understanding how galaxies and stars evolve, as well as the composition and structure of exoplanet atmospheres, providing insights into their habitability potential by identifying biosignatures.

NASA has supported CoolCAD's photodiode development with multiple contracts through its Small Business Innovation Research program. Additionally, the company is building NASA highly sensitive detectors for instrumentation small enough to fit into a 1U CubeSat — a cubic satellite with 4-inch sides.

On Earth, CoolCAD's silicon carbide photodiodes are used in early fire warning systems on aircraft and ships because of their ability to detect flames regardless of ambient conditions, according to Dilli.

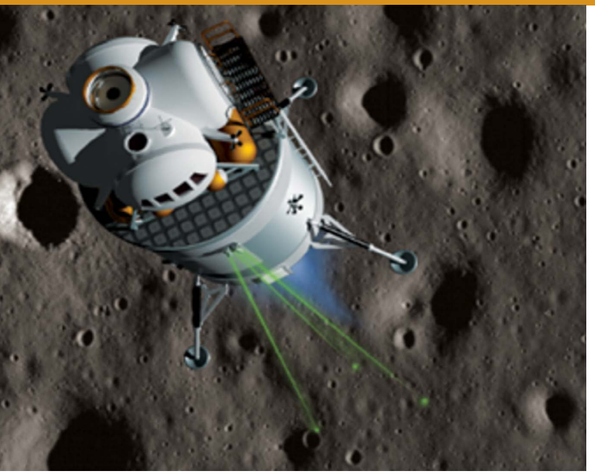
The silicon carbide photodiodes are also used in downhole applications for fracking. They can detect radiation levels, indicating the presence of frackable, gas-rich shale rock.

"To find the background radiation underground, people use optical sensors, and traditionally they use photomultiplier tubes, which are kind of big and fragile," Dilli said. "Using a semiconductor like silicon carbide is more reliable and much smaller."

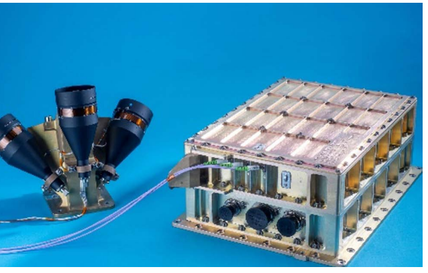
NASA's Aslam said CoolCAD, which was founded in 2009, has been a good partner for the space agency.

"They not only understand the physics of silicon carbide devices, but they also know how to fabricate them," he said. "They also work with us to make sure the detectors they deliver integrate into our instrumentation." ●

Softer Moon Landings for Companies



Navigation Doppler Lidar devices send out laser beams that bounce off planetary surfaces, revealing information about a lander's altitude and velocity. The technique is similar to Doppler radar but based on light instead of microwaves. *Credit: NASA*



Navigation Doppler Lidar was invented at NASA's Langley Research Center before the agency licensed it to Psionic of Hampton, Virginia. *Credit: NASA*

NASA helps private sector soar with better navigation technology

After NASA patented a laser-based technology to enable more precise Moon and Mars landings, the space agency licensed the innovation in 2016 to Psionic Inc. of Hampton, Virginia, which has continued to advance it with NASA support.

Psionic was founded by former NASA employees who had worked on the technology at the agency's Langley Research Center, also located in Hampton. The company identified Earth-based applications (Spinoff 2020) for the technology, which is called Navigation Doppler Lidar, or NDL, while at the same time improving its space navigation and landing capabilities for both NASA and commercial missions.

NASA has continued to work with Psionic on the technology under Space Act Agreements and has also bolstered the company's efforts through multiple Small Business Innovation Research contracts and Game Changing Development program projects.

NDL determines the precise position and speed of a spacecraft using a technique similar to Doppler radar but based on light instead of microwaves. The device emits multiple laser beams at different angles toward a planetary surface that bounce back to the sensor, with variations in frequency and timing providing measurements of both altitude and velocity.

The technology was part of the first commercial lunar landing, a 2024 mission by the company Intuitive Machines through NASA's Commercial Lunar Payload Services, or CLPS, initiative. That program contracts out lunar missions to private companies to achieve research goals and spur the commercial space industry at the same time.

The NDL used in the Intuitive Machines mission was built by NASA, but Psionic built the same device, under its license, to be the primary altimeter for another CLPS mission, Astrobotic's Griffin lander, slated for a late 2025 launch.

Psionic has also further developed navigation doppler lidar with its own version of the device, PNDL for Psionic NDL, which is less than half the size and weight of the current NDL, expands the operating range, decreases power requirements, and adds other improvements.

PNDL's scanning capabilities can assist autonomous docking, for instance with a space station or other spacecraft. The technology is being integrated into Axiom Space's commercial space station, which is currently under construction.

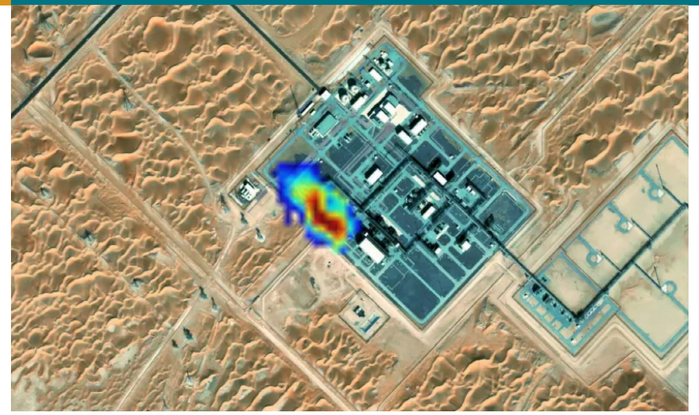
PNDL's scanning functions also facilitate surface navigation, enabling lunar rovers, for instance, to avoid boulders or craters. Psionic said it is working with several companies that are building lunar rovers.

Farzin Amzajerdian, the senior scientist at NASA Langley who led the team that invented NDL, said transferring licenses to companies like Psionic helps the space agency achieve its goals. "We actively try to transfer our technology," he said. "It's actually a bragging point for NASA. It's an accomplishment each year to say how many technologies have been transferred to industry."

NDL, which was coinvented by Diego Pierrottet, who is now Psionic's chief engineer, won NASA's 2022 Invention of the Year award in the commercial category.

"We're not only reaping the benefits of this technology transfer," said William Cook, senior vice president of space operations at Psionic. "We're helping NASA and commercial partners navigate with greater confidence than ever before." ●

Spotting Invisible Gas Leaks



In this satellite image of an oil field in the United Arab Emirates, Momentick's technology was able to detect a methane plume of more than 4,250 pounds per hour. *Credit: Momentick Ltd.*

Offshore oil and gas operations are often among the biggest emitters of methane, yet their plumes are the hardest to spot. This is because techniques for identifying escaped methane rely on reflected sunlight, and oceans absorb most light. Landsat, however, offers certain advantages in light exposure and bandwidths. *Credit: Getty Images*

Processed satellite imagery helps companies identify and contain methane losses

About 3% of the natural gas that's captured by producers is lost through leaks before it can be used, according to Momentick Ltd. of Tel Aviv, Israel. That represents an industry-wide loss of about $60 billion per year. Now that company is using satellite imagery to spot those methane plumes and help companies stem their losses.

Momentick relies on several different Earth-imaging satellites, especially the joint NASA-U.S. Geological Survey Landsat satellites, as well as ESA's (European Space Agency) Sentinel constellation, because both programs' imagery is frequently updated and free of charge. Goddard Space Flight Center in Greenbelt, Maryland, oversees NASA's portion of the Landsat program.

Methane, the main component of natural gas, is not visible to the naked eye. The company uses proprietary image-processing algorithms that utilize the short-wave infrared wavelengths, which are affected by methane, along with other wavelengths that are not. It takes a few hours of processing to reveal the methane signature, which shows not only the presence of the gas but also its concentration and emission rate, CEO and cofounder Daniel Kashmir explained.

The technique can accurately measure plumes as slow as about 2,400 pounds per hour, but Momentick's system is tailored to detect the presence of plumes below that level and report them along with a level of confidence. A plume of that size might be normal for a gas field or oil pad — oil drilling often releases natural gases — but these are dwarfed by the sort of leaks that can pour out of offshore rigs, said Omer Shenhar, the company's vice president of product.

This is where the Landsat satellites present a particular advantage. Though offshore rigs might emit plumes of hundreds of thousands of pounds per hour, they're difficult to detect. Readings rely on reflected light, and deep water absorbs most of the Sun's light. While the Sentinel constellation has better spatial resolution than Landsat, the latter has its advantages when it comes to light exposure and bandwidths, explained Dr. Adam Eshel, Momentick's chief technology officer.

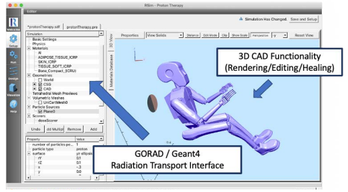
The company's services should pay for themselves by eliminating product losses, said company spokesperson Mira Marcus. She noted that they also help companies avoid fines as regulations on emissions become stricter around the world. For example, the European Union is now putting emissions limits on oil and gas importers. Because the biggest players by now have their own methane trackers, it's the small and mid-size companies that are turning to Momentick, Marcus said. And pipeline operators especially stand to benefit, she added, as it's difficult and expensive to monitor hundreds of miles of pipeline manually or with drones.

Other customers include insurers that serve the oil and gas industry and need to assess their risks, as well as governments looking to enforce regulations and base policies on current data, she said. In the future, the company plans to serve the waste management industry, measuring emissions from landfills and dumpsites. Agriculture is another possible market.

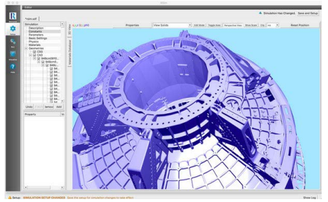
Momentick employs about 20 people. Landsat has been important to the company's business model, Marcus said. "Thanks to using Landsat and it being free, we're able to lower our pricing to make it more appealing and cost-effective to companies." ●

Simulations That Are Positively Radiant

Astronauts aboard future trips to the Moon will need to wear special detectors to make sure they aren't getting too high a dose of radiation, but NASA needs to make sure those detectors will work before they are built. These efforts resulted in the creation of RSim. *Credit: NASA*



This screenshot of RSim shows a simulation of proton therapy, a form of cancer treatment that uses a beam of targeted radiation. Assisting the design of these medical devices is a key market for RSim. *Credit: Tech-X Corp.*



Radiation simulation software helps keep astronauts and patients safe

With the Artemis program sending astronauts beyond the relative protection of low Earth orbit, spaceflight requires assurances that the many forms of radiation out in space, whether cosmic rays or solar wind, won't harm astronauts.

Tech-X Corp., based in Boulder, Colorado, produces simulation software to help projects with high-level engineering needs. Now a division of Silvaco, the company's flagship software includes VSim, for simulating plasma and vacuum electronics, and RSim, which can trace its origins to NASA needs.

RSim is designed to simulate radiation. Built upon the open-source Geant4 system developed by the European Organization for Nuclear Research (CERN), and plugged into a configurable graphical user interface, RSim can accurately model how radiation moves through space in all dimensions.

NASA's Johnson Space Center in Houston needed ways to test radiation sensors that would be aboard satellites or spacecraft designed to ferry humans to space — before the sensors were built. The only way to do that was through simulations, combined with standard computer-aided design software to allow quickly repeated design cycles.

"We have a lot of computational power, we have supercomputing capabilities at Johnson, so we want to be able to leverage that, but we don't want to rely entirely on brute force," said Diego Laramore, a research scientist with the Radiation Analysis Group at Johnson.

According to Laramore, there are two ways that radiation tends to behave. Some particles, such as protons or ions, are "deterministic" and can be calculated with relative ease if you know where they started from. Other types of radiation, like gamma rays, are "stochastic" and are much harder to predict over large spaces. Through Small Business Innovation Research (SBIR) funding from NASA, with additional funding from the Department of Energy, Tech-X developed a method of approximating how this stochastic radiation would behave in a vehicle the size of Orion, the capsule slated to take astronauts to the Moon. By focusing on a very small section of the vehicle being simulated, scientists could see how it would behave in the area around a crew member's seat, as opposed to an area less important for the specific test.

Since the company's initial NASA SBIR funding in 2018, RSim has been used in the development of commercial satellites and other vehicles sent to space. The user-friendly developments Tech-X made for NASA now benefit the company's commercial customers.

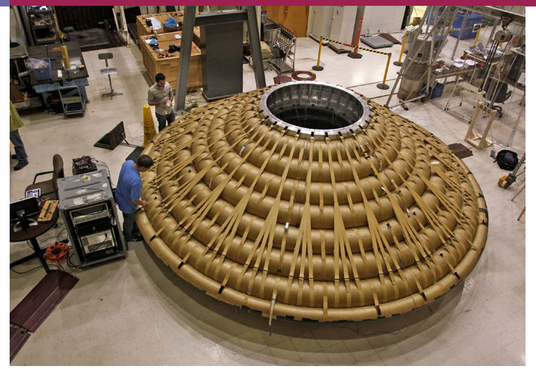
"Usually when people use Geant4, they have to write their own code," said David Alexander, vice president of user experience at Tech-X. "But in our product, the RSim interface helps them get simulations right with buttons and menus that are easy to use."

RSim is used not only in the realm of space but also in industrial and medical manufacturing. Because radio waves are a form of radiation, RSim can aid in designing a signal-shielded room for testing radio and cellphone equipment. Machines for treating cancer with particle beams use directed radiation to hit only tumors, so manufacturers can use RSim to see if any particles wind up places they shouldn't. Ultimately, Tech-X credits NASA with being instrumental in the software's development.

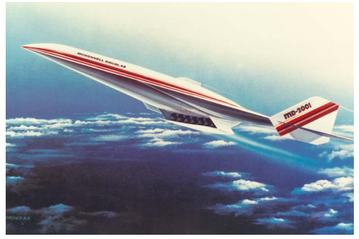
"A functional prototype came out of the initial NASA work, and we've improved it into a substantial product," Alexander said. "There would not be an RSim without that original NASA project. It was foundational." ●

RSim integrates with standard computer-aided design software to enable changes to quickly determine how different designs affect how radiation moves around an environment. *Credit: Tech-X Corp.*

Beat the 'Heet' at 400,000 Feet



Assisting NASA's research into inflatable heat shields for spacecraft is one of the more recent collaborations for Heetshield, which has had several Small Business Innovation Research (SBIR) contracts with Langley Research Center. *Credit: NASA*



The National Aero-Space Plane (NASP) project was a NASA effort to develop a fully reusable space vehicle. Research into thermal protection systems for the NASP were some of the first SBIR contracts that Steve Miller had with NASA, which led to the formation of the company Heetshield. *Credit: NASA*

NASA funding helps high-tech insulation take flight

How does a space plane stand up to extreme heat that builds up when it's traveling at several times the speed of sound?

This question is the origin of Steve Miller's entire career.

In the 1980s, the National Aero-Space Plane project was intended to be the future of spaceflight, and potentially air travel. In a State of the Union speech, Ronald Reagan promised it would enable passengers to rocket from Washington to Tokyo in two hours. To support this effort, NASA requested Small Business Innovation Research (SBIR) proposals for the required technologies.

"I'd met some researchers who'd been working on thermal protection systems for the space shuttle, and they invited me to submit an SBIR proposal to collaborate with them," Miller said.

Miller explored advancing high-temperature multi-layer insulation, a method for reflecting radiant heat with metal-coated reflective films separated by thin, non-thermally conductive spacers like felts or polyester netting. It's a method that works particularly well in the vacuum of space. By the mid-1990s, the space plane project hadn't made it past the concept stage. But Miller's developments in the field of multi-layer insulation showed promise, which inspired further work with the space agency. Funded by both NASA and the U.S. Air Force, one of his early improvements was adding small particles called "opacifiers" to felt spacer layers to scatter and block radiant heat.

Another idea he tested was the incorporation of aerogel into felts, first as spacer layers in multilayer insulation and then as standalone insulation. Aerogel is a substance renowned for its heat-insulating properties, a result of it being almost entirely made of air.

"In some cases, insulation is up to 98% porous, so we use aerogels to fill in those gaps," said Elora Kurz, who manages one of Miller's current SBIR contracts at NASA's Langley Research Center in Hampton, Virginia. "And you can use different sizes of aerogels. Steve likes to relate the various sizes of aerogels to filling those gaps with beach balls and ping pong-sized balls to reduce conduction of heat transfer."

"It's been this 30- to 40-year collaboration. We would come up with ideas, and then through the smart people at NASA, we could test them," Miller said. In 2004, he founded a nonprofit research foundation to work on insulating materials for NASA, the military, and others.

In 2020, Miller's Flagstaff, Arizona-based company reorganized into Miller Scientific Inc., which operates under the name Heetshield. Shortly after, Heetshield received Phase III SBIR funding to build in-house production capabilities for its aerogel-embedded thermal protection system solutions. Now with the ability to produce this insulation at scale, and further aerogel technology licensed from NASA's Glenn Research Center in Cleveland, the company began shopping its thermal protection solutions to the private market. Miller says Heetshield has sold its aerogel thermal protection solutions to small engineering companies and startups like Radian Aerospace, which is looking to build its own fully reusable spaceplane. The company's latest SBIR contracts, including the one Kurz is managing, have focused on improving the felts needed for the Hypersonic Inflatable Aerodynamic Decelerator technology NASA is exploring. In the future, Miller hopes to produce more consumer-focused insulation, such as curtains or window treatments, based on the developments he made with help from NASA.

"I love being the dumbest guy in the room," Miller said. "When the other people in the room have tested these thermal insulations for their whole careers, you get to pick their brains about how to improve the material or better test it or something like that. That collaboration has given me the opportunity over my entire career to make something useful out of these ideas." ●

Search for Life Helps the Search for Oil

The Scanning Habitable Environments with Raman and Luminescence for Organics and Chemicals (SHERLOC) instrument is helping the Perseverance rover search for signs of past life on Mars. Pablo Sobron was involved with its development and used that experience to develop more instruments at Impossible Sensing. *Credit: NASA*

NASA's search for life signs on Mars is a boon for oil and gas production on Earth

Whether exploring the depths of the universe or the depths of our own planet, scientists often turn to spectroscopy — a method of determining what things are made of using varieties of light. Depending on the wavelengths a sample absorbs or reflects, it can indicate which elements or chemicals are present. For NASA, it's a key tool for making discoveries in space, particularly in seeking evidence of extraterrestrial life.

As a contractor at NASA's Jet Propulsion Laboratory in Southern California, Pablo Sobron works on the SHERLOC (Scanning Habitable Environments with Raman and Luminescence for Organics and Chemicals) instrument on the Perseverance rover currently exploring Mars. SHERLOC uses an ultraviolet laser to determine the makeup of surface materials and see whether any have signs of ancient life. Making tools capable enough to perform this research on Earth is difficult enough, but constructing one that can do everything off-world is even more challenging.

"As we're searching for life out there, we're looking at trace amounts of amino acids, proteins, or DNA, if we're very lucky," Sobron said. "We're looking at parts per billion or per trillion sometimes, which is really something that today you can only do with a few instruments around the world. We have to figure out how to put that on a robot on another planet."

While working on SHERLOC and other spaceflight projects, Sobron founded St. Louis-based Impossible Sensing LLC in 2016 to continue improving spectroscopy tools. The company has had multiple Small Business Innovation Research (SBIR) projects with the space agency, notably at NASA's Ames Research Center in Silicon Valley, California, regarding development of similar sensors. One, known as PERISCOPE (Probe for Exploring Regolith and Ice by Subsurface Classification of Organics, PAHs, and Elements) was developed over multiple contracts into an even more sensitive method to measure traces of organic elements.

On Impossible Sensing Energy's factory floor, three Flow sensors are tested. The technology has a direct link to Small Business Innovation Research awards that Impossible Sensing carried out with Ames Research Center. *Credit: Impossible Sensing Energy Inc.*

In 2019, Sobron met Ariel Torre, a veteran engineer who saw a new market for the technology Impossible Sensing was developing — oil exploration. When extracting oil, two substances usually come out along with it: natural gas and water. Typically, well output is measured by pumping all three into a tank and waiting for them to separate, then measuring each one individually. The company's multi-phase flow meters, on the other hand, can be placed right at the wellhead and use spectroscopy to determine the makeup of the mixture while it's being extracted. Torre said that by using these NASA-derived sensors, monitoring could be done in real time and at one-tenth of the cost of comparable $250,000 sensors. And with the remote nature of many oil wells, the sensor's engineering for longevity and reliability is a bonus.

Impossible Sensing Energy's Flow sensor is deployed at a drill site, attached to an oil well and detecting what materials are being pulled from deep below Earth's surface. *Credit: Tundra Oil & Gas Ltd.*

"There are a lot of parallels to design requirements that, for NASA, are a given," said Torre. "When you build something to go to Mars, it's designed to just work. It's designed so that no one has to fix it because no one can. The oil and gas industry aspires to that level of design and reliability."

In 2021, Impossible Sensing spun off a Canadian company called Impossible Sensing Energy, based in Calgary, Alberta, to market its spectroscopic sensors to oil and gas companies. Marketed under the brand name Flow, the devices' initial sales were to companies operating in Canada. The oil producer Veren has purchased 20 units, and a second producer, Tundra Oil & Gas, has also placed an order, while several other companies are currently testing Impossible sensors at their own well sites. ●

Greens Grow in Circles

Anu's rotary aeroponics system uses small containers full of seeds and nutrients, much like single-serving coffee pods, to make growing plants easy. *Credit: Heliponix LLC*

NASA-funded research inspires home indoor farming tech

Keeping an edible garden at home is a common hobby, but it can be a tough one. Between pulling weeds and keeping pests from eating your crops, not to mention the need for a lawn or plot of land, it's a lot of work for a piece of fruit or a leafy vegetable. But what if you could grow greens, herbs, and some fruits indoors?

NASA has been a pioneer in the field of indoor farming for decades and collaborates often with outside institutions. For more than 40 years, Purdue University in Indiana has received funding from and collaborated with NASA's Ames Research Center in Silicon Valley, California, as part of the agency's Specialized Center of Research and Training program to explore methods of growing plants under electric light.

One of the NASA-funded projects at Purdue is a system called Minitron. Active since the 1980s, Minitron is the university's indoor agriculture test bench, consisting of several small plant-growth chambers to optimize resources and energy usage to produce highly nutritious crops.

"We've learned a lot from that research, and they've learned a lot from NASA research," said Gioia Massa, who currently leads NASA's space crop investigations at the space agency's Kennedy Space Center in Florida and was involved in the development of Minitron while a postdoctoral researcher at Purdue. "Minitron is essentially a scaled-down version of the Biomass Production Chamber that was at Kennedy."

Scott Massey also became fascinated with the capabilities of indoor farming while an undergraduate student at Purdue. Coming from a background in petroleum production, he had experience in hydraulic engineering. A fellow student, Ivan Ball, brought expertise in electronics and automated systems. Using what they learned from working on experiments with Minitron, they began exploring ways to further scale indoor horticulture down to the point where a growth chamber could be a home appliance.

The team's primary development was "rotary aeroponics." Their system uses pre-measured containers of seeds and nutrients resembling single-serving coffee pods, which are inserted into ports on a rotating column, inside an enclosed environment optimizing hydration, air flow, and humidity for plant growth. Plants emerging from the compostable seed pods rotate past an LED light source, optimizing space within the chamber and saving energy.

"This started as a hobby. I thought if I patented it, somebody down the line will have the wherewithal to commercialize it, and maybe I can play a small part in helping them," said Massey. "But I learned very quickly that the excitement of entrepreneurship is wonderful." Massey and Ball established Heliponix LLC in Evansville, Indiana, in 2016.

Purdue University students remove plants from an Anu growth column. The company's technology forms a platform for agricultural education, as well as industry. *Credit: Heliponix LLC*

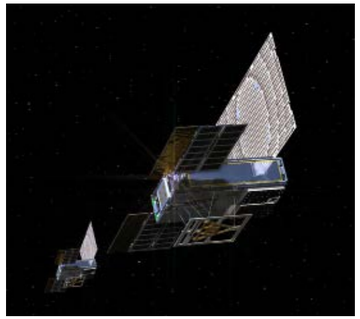
Originally marketing its product under the name Gropod, the company would soon do business under the name Anu. In its first two years, Anu sold 40 units to consumers. As of 2024, the company licenses its technology to major players within the hardware manufacturing industry. The Anu team has developed a modular container farm that is available for commercial growers with a focus on healthcare applications, education programs, and entrepreneurs seeking to eliminate local food deserts.

Massey credits his work with Minitron and the NASA-funded studies at Purdue for helping him grasp the intricacies of indoor agriculture. Massey is currently expanding Anu's global reach, including into Saudi Arabia, which has expressed interest in the technology for its agricultural goals.

"The best design for a vertical farm was optimized millions of years ago when trees began to grow," said Massey. "We think we're catching up to nature." ●

Probe Deeper with Better Space Receivers

The Deep Space Network is how NASA missions to other planets report back to Earth. Sending smaller spacecraft outside of Earth's orbit requires a small but capable radio, which comes in the form the Universal Space Transponder Lite, or UST-Lite. *Credit: NASA*



The Mars Cube One spacecraft were the first CubeSats to fly to Mars. To support future exploration efforts with small spacecraft, the Jet Propulsion Laboratory developed the UST-Lite radio to allow them to go even further into deep space. *Credit: NASA*

Argotec's version of UST-Lite can be integrated with the company's HAWK satellite platform and used for satellite missions both near and far. *Credit: Argotec S.r.l.*

Software-defined radios give adaptability to satellite operators

When sending probes to deep space, adaptability is the name of the game.

The communications radios aboard spacecraft must be reliable and reconfigurable. In 2023, when Voyager 1 was sending back garbled data, NASA engineers were able to upload a fix to the computer more than 40 years after it was originally launched because its processors were so flexible.

Technology has advanced considerably since the 1970s, and the future of satellite communications might come from a company that cut its space technology chops on everything from spacecraft witnessing asteroid impacts to a high-tech coffee maker.

Argotec Group, based in Turin, Italy, with offices in Melbourne, Florida, is no stranger to manufacturing specialized hardware for space exploration. Its LICIACube and ArgoMoon satellites were used to document critical stages in the Artemis I and Double Asteroid Redirection Test missions. After building an espresso machine that would function in the weightless environment aboard the International Space Station, the ISSPresso, the company shifted its primary business to small satellites and the components that enable their operations. In search of high-quality communication devices, Argotec went to NASA's Jet Propulsion Laboratory in Southern California, which had been making advancements in space radios.

JPL manages the Deep Space Network, which communicates with NASA spacecraft beyond Earth orbit. While the network's three ground stations provide substantial "ears" for listening to deep signals, the spacecraft need powerful radios too, for transmitting back to Earth. Among the most recent is the Universal Space Transponder (UST), developed in 2017 for future missions to Mars. As smaller spacecraft are sent further into space, even smaller high-quality radios are needed, leading to a new JPL project: UST-Lite.

While much smaller than JPL's prior work, the UST-Lite transponder is more capable than other radios its size. An important aspect of these radios is that they are "software-defined," meaning they can be reconfigured on the fly, with all aspects of the technology adjustable through use of a field-programmable gate array processor.

"Where the UST-Lite stands out is that it's a very flexible platform," said Dennis Ogbe, signal analysis engineer at JPL's Reprogrammable Signal Reprocessing Group. "It inherits our software-defined radio capabilities, and it supercharges them in a way that makes it even more flexible."

UST-Lite's primary advantage comes from its four radio channels, which let it communicate on multiple wavelengths simultaneously, allowing a higher rate of data transmission from farther away. This, and the ability to remotely adjust it via software, is why Argotec was interested in the technology.

"There's a real need out there among companies for a radiation-hardened, deep space, multi-frequency, software-defined radio that can support all their requirements in a small package," said Corbett Hoenninger, U.S. general manager at Argotec.

In 2023, Argotec licensed the UST-Lite radio from JPL and began incorporating it into its product lines. Argotec's HAWK satellite platform can be integrated with UST-Lite. HAWK forms the backbone of the Italian IRIDE network of Earth-observation satellites, and Argotec is selling the platform to commercial satellite operators. The radio's configurability means it works well for space communications both near and far from Earth. A standalone version of UST-Lite for non-HAWK spacecraft was released in 2025.

"We designed UST-Lite to be a high-reliability deep space radio," said Ogbe. "But it's agile in frequency and configurability. This is a radio that that can be deployed in in low Earth orbit as well, because it's so flexible and programmable." ●

Weaving Data Fabric with AI

Greg Deeds looks out the window of a helicopter flying over Arizona during a test of Autonomy Association International's data fabric technology in collaboration with NASA. Through multiple evaluations above Phoenix, the testing proved the capabilities of the company's Digital Infrastructure Platform. *Credit: Autonomy Association International Inc.*

NASA's research into the field of advanced air mobility looks to enable autonomous aircraft with complex capabilities such as carrying cargo or providing medical aid. The Data and Reasoning Fabric project out of Ames Research Center tested delivery of programs and information to these kinds of vehicles. *Credit: NASA*

In testing of the data fabric platform, a helicopter stood in for the air taxis and autonomous vehicles that would use this technology. *Credit: NASA*

Air taxis and drones navigate different zones with NASA-inspired system

One of the biggest goals for companies in the field of artificial intelligence (AI) is developing "agentic" systems. These metaphorical agents can perform tasks without a guiding human hand. This parallels the goals of the emerging urban air mobility industry, which hopes to bring autonomous flying vehicles to cities around the world. One company wants to do both, and it got a head start with some help from NASA.

Autonomy Association International Inc. (AAI), founded by Greg and Jennifer Deeds in 2021, is a public benefit corporation based in Mountain View, California, near NASA's Ames Research Center in California's Silicon Valley. The AAI team has deep roots in the area, supporting the Silicon Valley Autonomy Association to stage meetings and events among experts in AI and autonomous vehicles.

In 2022, AAI signed a Space Act Agreement with Ames to support the agency's Data and Reasoning Fabric (DRF) project, which aimed to enable the transportation of people and cargo to areas previously unserved or underserved by aviation, and to provide reliable, accurate, and current data for aeronautic decision-making. Much the way clothing fabric is made of intertwined threads, a data fabric comprises intertwined data sources. While a data fabric built by a tech company may include data from a few different cloud services providers, NASA's DRF also can use information provided by local governments and other service providers. By viewing airspace as a large data fabric, an autonomous vehicle can take in data and requests from the cities and towns it flies over and prioritize responses between them.

"The goal of the work was to develop a system that facilitates the exchange of information among numerous systems and enables the application of machine learning and artificial intelligence for aeronautics problems," said Ken Freeman, principal investigator of the project at Ames.

In the air over Arizona, AAI and NASA performed four testing evolutions of the data fabric technology. Using hardware and software developed by AAI, the flights tested advanced air mobility passenger flights and the use of a drone for rapid delivery of medical supplies from urban to rural areas and back, while sending new tasks to the aircraft in flight. A helicopter stood in for the drone and air taxi, flying over towns, universities, tribal lands, and the airspace around Phoenix Sky Harbor airport, and obtaining data and programs given to it from different places.

"We're focusing on the digital infrastructure building blocks of smart cities and regions of the future," said Jennifer Deeds, chief operating officer of AAI.

In the years since the original NASA project, the company has cultivated relationships and customers abroad. Released in 2024, the company's Digital Infrastructure Platform uses the same technology originally designed for the NASA flight test. A new, "agentic" version followed not long after, able to retrieve necessary AI programs with minimal interaction. Jennifer says customers using the AAI platform include companies in the fields of agriculture, real estate development, and industrial food production using it to aggregate and manage data.

"Inspiration to lean into data fabric to solve certain complexities came from our NASA partnership," said AAI cofounder and the project's industry principal investigator Greg Deeds. "Working on this project was a great experience — to work with NASA engineers and leaders, like Ken Freeman, gave us experience that we'll carry forward in all of our products." ●

Data Analysis Goes to the Dogs

NASA's workforce of several thousand civil servants and contractors forms one of the largest knowledge bases in government. A knowledge graph helped NASA ensure the right people could be asked the right questions. *Credit: NASA*

Knowledge graphs originally designed for NASA help make unseen connections

Analyzing huge amounts of data can be tough work. Computers can help in this process, but a computer lacks a key human component — intuition. Stardog Union Inc. is a company that specializes in using artificial intelligence (AI) to tackle data analysis, and the company's path to the market has been intertwined with NASA.

"We've been partnering continuously with NASA since 2006," said Kendall Clark, cofounder and CEO of Stardog. "In fact, the first thing we did as a company was build a system for NASA."

In the mid-2000s, Clark and his cofounders were working in the artificial intelligence lab at the University of Maryland when they were approached by the chief information officer of NASA Headquarters in Washington to create a solution for the agency.

In the wake of the space shuttle Columbia accident, NASA needed a way to find specific expertise among its workforce to report issues and solve problems that arise, and it needed database insights to quickly identify the right expert for each question.

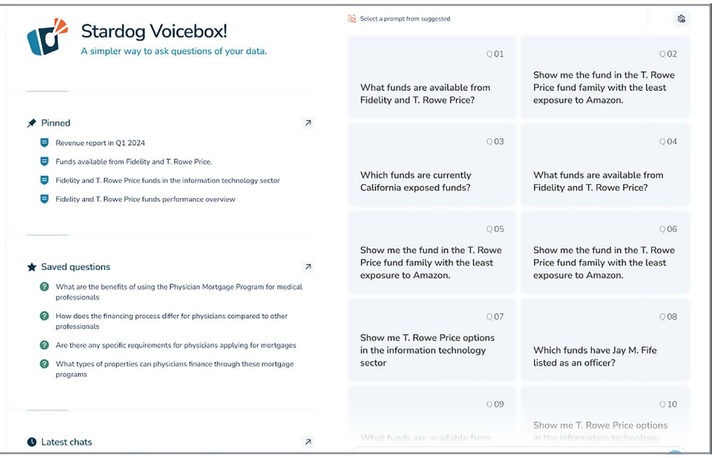
"It's a needle-in-the-haystack problem, which means it's a data integration problem," said Clark. "Each data source was a piece of that puzzle."

To solve this puzzle, the team built a form of AI called a knowledge graph. Knowledge graphs work by comparing sets of data and forming patterns between them, then telling the users what the important links are. This work resulted in a system called People, Organizations, Products, and Skills (POPS), which could find any expert at NASA by referencing the knowledge graph built on information about the agency's workforce. Clark's company was founded that same year. Although the company was originally called "Clark and Parsia" after the founders' last names, the software it developed out of POPS was nicknamed Stardog, which became the name of the Arlington, Virginia-based company in 2016.

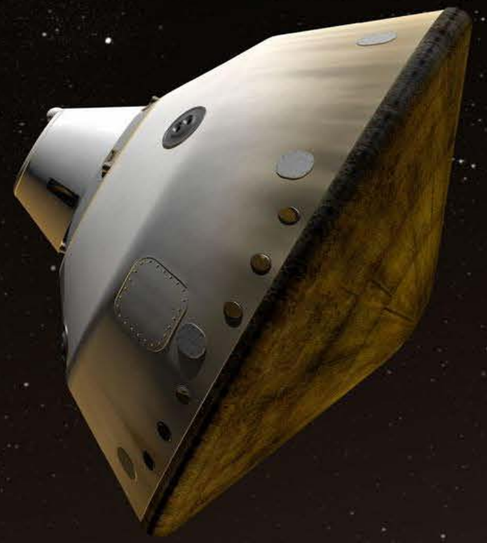
"A picture of an astronaut dog is good for branding," said Clark. "But it's a kind of quiet homage to our NASA background."

While Stardog's software is still based on knowledge graphs, the advent of generative AI has boosted the company's portfolio of services, enabling a chat function that lets users ask direct questions about the data they've unleashed Stardog on. Unlike the AI chat programs from big companies that consumers use every day, which are trained on all the content their creators can find on the internet, Stardog's system only looks at what's local to the databases being examined. This makes Stardog's AI "hallucination-free" and trusted to explain its data analysis. Today, Stardog is widely used across several industries to gain insights by making connections in data, and Clark says he owes it all to NASA.

"The platform we now sell to banks, manufacturers, and pharmaceutical producers globally is the grownup version of that thing we built in 2006 with NASA." ●



Stardog's Voicebox software is a knowledge graph, paired with a generative AI chat client that allows users to ask questions directly to their data. The company's software can trace a direct lineage to work done for NASA Headquarters. *Credit: Stardog Union Inc.*



This is an artist concept of NASA's Mars Science Laboratory aeroshell capsule as it enters the Martian atmosphere. The Curiosity rover and the spacecraft descent stage are safely tucked inside the aeroshell at this point. Credit: *NASA/JPL-Caltech*

SPINOFF Features

Some of the challenges NASA scientists and technologists need to resolve for successful space exploration and Earth observation are similar to those we face every day. Growing food in a hostile environment, quickly accessing satellite data, and staying healthy are just a few of these. The agency serves as the nation's research and development lab by figuring out how to address all that and more, and then sharing the technology, data, and lessons learned with the private sector.

Feeding People Through Disasters

Washington-based World Central Kitchen uses data from satellites in low Earth orbit to build maps supporting staff and volunteers distributing food and water in disaster areas. The nonprofit gets the data through NASA's Earth Observing System, which has its Project Science Office at Goddard Space Flight Center.

NASA satellite data helps build maps for first responders, including chefs and other food support

In the aftermath of a disaster, whether it's a bombing or a hurricane, a flood or a wildfire, people still need to eat. So when access to food and water becomes difficult or impossible, chefs from around the world mobilize to provide free meals. World Central Kitchen, a nonprofit organization "providing meals in response to humanitarian, climate, and community crises," orchestrates the work of preparing fresh food and providing drinking water. Offering support to those hard-hit communities often requires a map that relies on NASA satellite data.

Advance teams coordinate logistics, including security and communications, so they need to know the terrain, where resources are located, and the damage done to infrastructure. Online maps allow a user to zoom in and out to view any part of a community, and different layers of information can be added or removed based on the data needed, according to Ali Sharman, former mapping specialist for World Central Kitchen. Details such as population centers, restaurant locations, food pickup locations, and the travel routes to reach isolated pockets of people are just a few of those layers. Logistics teams on the ground also provide a constant flow of information about conditions that's continually added to the data warehouse the organization maintains to develop up-to-date maps throughout an event.

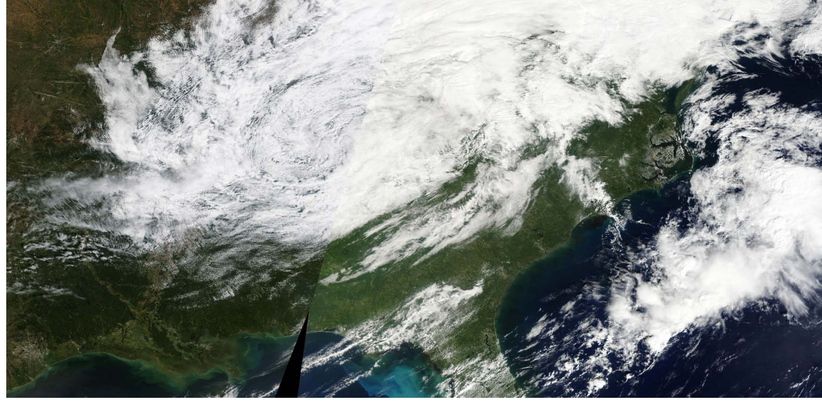
World Central Kitchen (WCK), a global nonprofit, mobilizes local chefs and resources to serve free hot meals during disasters like the wildfires in Southern California in 2024 and 2025. *Credit: World Central Kitchen*

"NASA makes itself very available, both in terms of personal contact and data," said Sharman. "Open data is what allowed me to do my work quickly. NASA has done a great job making their data very accessible and easy to find and use."

To create electronic and even paper maps, one of the first places World Central Kitchen turns for regional data is NASA's Disasters Response Coordination System, an agencywide initiative with its program office at NASA's Langley Research Center in Hampton, Virginia.

In addition to the most comprehensive long-term view of Earth's surface, provided by the Landsat satellites, multiple sensors on satellites in low Earth orbit provide near-real-time data during and after disasters. Anyone can access that data from NASA's website, or users can request assistance for specific events. The Disasters Mapping Portal is open-access, and most of the information can be downloaded.

"Our role is to connect the scientists at each center or the subject matter experts — people who generate the actual science and datasets — to the response agencies or organizations such as World Central Kitchen," said Rachel Vershel, disaster response coordinator for NASA's Goddard Space Flight Center in Greenbelt, Maryland. Launched in June 2024, the Disasters Response Coordination System brings together a wealth of NASA's Earth science information from across the agency, continuing a decades-long effort to make data available.



The Moderate Resolution Imaging Spectroradiometer on NASA's Terra satellite is one of the data sources WCK uses to build area maps for staff working in disaster areas like North Carolina, where the remnants of Hurricane Helene, pictured here, caused historic flooding in 2024. *Credit: NASA*

'A Visual Language'

Working alongside local chefs in Haiti after an earthquake in 2010, chef José Andrés saw an unmet need for nutritious and comforting food as people were trying to rebuild their lives. Along with his wife, he created World Central Kitchen to feed survivors, first responders, and anyone in need after a disaster. Whether the catastrophe is caused by humans or nature, a worldwide network of staff and volunteers responds in the immediate aftermath. Based in Washington, the organization builds partnerships with local chefs, restaurants, food trucks, food suppliers, and others to prepare and distribute meals while supporting the local economy.

The belief that food is a human right powers World Central Kitchen's staff and volunteers. Coordinating the logistics of getting food to people depends on accurate and continual data updates. For example, food safety can be tricky.

"When you work with hot meals, you have a four-hour window to deliver that meal at a certain temperature before you hit a food safety issue.

Meals prepared by WCK staff and volunteers in a central kitchen are served cafeteria-style when a facility is available, but often meals are packaged for distribution or for people to pick up, as in this location in Southern California. *Credit: World Central Kitchen*

"A map is a universal language, it's a visual language."

Ali Sharman, World Central Kitchen

The timing is very important to our team, in terms of where we can safely deliver food," said Sharman, noting that the maps also serve as an orienteering tool.

Even if internet access and GPS service aren't available, regional electronic maps containing saved wayfinding datapoints provide a base map to which saved data can be added. Once internet access is available, World Central Kitchen's online portal also allows staff and volunteers to share, view, and download real-time data. But frequently, Sharman received requests for large paper maps for use in the field.

These can often serve a function that online maps don't, she said, as proved to be the case in 2023 during the aftermath of an earthquake in a mountainous region of Morocco that destroyed buildings and caused rockslides, making roads impassable. Just finding the people who needed food was a challenge. Then there was the language barrier in a country where not all the staff and volunteers spoke the local dialect.

"When I was in Morocco, I was sitting outside a kitchen with a large map laid out," said Sharman. "Suddenly all of the drivers surrounded me and started pointing at the map and telling me where their villages were. A map is a universal language, it's a visual language."

'The Very Best in People'

In advance of Hurricane Helene's 2024 landfall in Florida, Rapid Response Field Kitchens developed by World Central Kitchen were positioned for delivery to places like Big Bend, where volunteers delivered the food to residents on foot and by offroad vehicles.

In the wake of the same storm in North Carolina, World Central Kitchen used helicopters to deliver sandwiches, water, and baby formula to mountain communities isolated by washed-out roads. Local food trucks were hired in Georgia and Tennessee to distribute meals to people far from the larger distribution centers and restaurants in cities. Throughout, NASA data supported these efforts to bring together the comfort of food and community, said Sharman.

"You see people in their very worst moments, and yet it seems to bring out the very best in people. It's a beautiful thing that happens amid tragedy," she said. Sharman sees the same generosity of spirit in the effort NASA puts into preparing and providing the satellite imagery and data that enable the maps aid workers require.

Just a few of those resources include the Fire Information for Resource Management System, which provides active fire data from the Moderate Resolution Imaging Spectroradiometer instruments aboard the Aqua and Terra satellites and the Visible Infrared Imaging Radiometer Suite (VIIRS) instruments aboard three other satellites. Aqua and Terra also generate flood data, and VIIRS contributes climate information. The website and mobile app make it easy to download and incorporate NASA data into mapping programs like the one World Central Kitchen uses.

Setting up field kitchens in the wake of a disaster like Hurricane Fiona in Puerto Rico is one way WCK prepares food for distribution to the devastated community. *Credit: World Central Kitchen*

Local chefs who know the food preferences of a geographic area guide menus designed to bring food and comfort to communities. WCK also hires local food trucks to reach as many people as possible. *Credit: World Central Kitchen*

Because each disaster is different, the information World Central Kitchen and other organizations need is ever changing. Dedicated NASA staff maintain relationships with businesses, nongovernmental organizations, and government entities such as the Federal Emergency Management Agency to be ready for a quick response when those emergencies arise.

The Black Marble

Some of the relief efforts NASA has supported include the 2022 volcanic eruptions in Hawaii, the 2020 chemical explosion in Beirut, and multiple landslides around the world. The most frequently requested data is for cyclones or hurricanes, flooding, and wildfires, but event-specific datasets remain available in NASA's Disasters Mapping Portal. Agency teams only stop adding new information when they confirm the work on the ground has transitioned to recovery and rebuilding is underway.

However, not all the data ends there.

"The Black Marble is a power-outage product that's used long into the recovery phase," said Vershel. "You start seeing nighttime lights come back on and what areas likely still don't have power. That's really important." This kind of information helps government entities and those working in the area track the recovery process.

Agency expertise in compiling and sharing data makes a difficult situation more manageable, according to Sharman.

"Things like digital elevation models that NASA has been publishing for a really long time carefully piece together satellite data about the structure of Earth's surface," she said. "When I need something specific, I can email someone at NASA, and they'll email back very quickly and be able to tell me exactly what I need to know." ●

When physical barriers or transportation issues prevent people from getting to food distribution sites, volunteers take food directly to people — by helicopter, offroad vehicles, or foot. *Credit: World Central Kitchen*

"NASA has done a great job making their data very accessible and easy to find and use."

Ali Sharman, World Central Kitchen

In addition to providing meals, WCK also trucks in drinking water and offers a biweekly farmer's market to provide fresh fruits and vegetables at no cost. Local produce and other ingredients are purchased whenever possible to support the local economy in a time of crisis. *Credit: World Central Kitchen*

Extraterrestrial Medical Diagnostics

Miniature laboratory technology tested by NASA returns fast blood test results

A portable device made by Boston-based 1Drop Diagnostics US can test a single drop of blood for numerous medical conditions. Glenn Research Center prepared the technology for testing on the International Space Station, and it now supports medical research on Earth.

A delay of weeks or even days to get the results of blood work can mean an agonizing wait for diagnosis and treatment. But technology exists that delivers quick diagnoses, and NASA has helped improve it. Astronauts on Mars will be millions of miles away from a lab, making it impossible for them to access diagnostic tools on Earth. Due in part to NASA's support for the development of portable testing technology for use on other worlds, it's now possible to identify a host of medical problems on Earth from a single drop of blood. Miniaturized hardware and sophisticated software tested by a U.S. astronaut on the International Space Station are now being used by pharmaceutical companies and hospitals conducting clinical research.

The 1DROP Health Monitoring Platform only requires a drop of blood and about 15 minutes to analyze samples for diabetes and cardiovascular, kidney, and thyroid disease. *Credit: 1Drop Diagnostics US Inc.*

"We're in the business of spaceflight. We're not in the business of making really great medical devices. There are companies out there that can do that much more effectively," said Courtney Schkurko. A project manager with the Mars Campaign Office Exploration Medical Integrated Product Team at NASA's Glenn Research Center in Cleveland, Schkurko described the technology as a "portable compact lab." This kind of point-of-care medical diagnostic device generates swift and accurate test results on Earth, performing preliminary analysis necessary for medical treatment.

The 1DROP Health Reader from 1Drop Diagnostics US Inc. uses a disposable microchip designed to look for specific molecules, called analytes, in blood. An analyte is any chemical being subjected to analysis. Some of those tests are a top priority for the space agency to safeguard human health. Here on Earth, the Boston-based company currently supports the detection of diabetes risk, kidney function, cardiovascular disease, and hormone function. And more capabilities are in development.

'Above the Clouds'

The Food and Drug Administration granted permission in early 2024 for use of the 1DROP Health Reader for research purposes only. Pharmaceutical companies, researchers, and hospitals, including Massachusetts General Hospital, Harvard Medical School, and Baylor College of Medicine, are working with the company to collect data about the technology's performance, as well as their own research. Using it alongside slower, established diagnostic tools, researchers screen participants in clinal trials for compatibility with an autoimmune disease drug, an anticoagulant, and a medication for chronic kidney disease.

Blood tests normally require a vial or two of blood from the patient and a complicated process with multiple steps. To ensure accurate results, a trained professional working in a laboratory or physician's office must oversee the testing. However, advancements in miniaturized technology have allowed 1Drop to pack all of the requisite technology onto a disposable microfluidic chip and automate the entire process.

Instead of collecting vials of blood to send to Earth for testing, as astronauts Alexander Gerst and Serena Auñón-Chancellor are doing here, people on the Moon will need a way to do their own tests. The 1DROP Health Reader proved it can do that just as well in space as it performs on Earth. *Credit: NASA*

"Each chip contains miniature filters, sample collectors, valves, channels, reaction chambers, and pumps," said Luc Gervais, CEO of 1Drop. A single drop of blood extracted from a fingertip is dropped into the chip, which is then inserted into the reader.

An approach called multiplexing identifies different types of analytes by examining the separation of the cells in each test. Fluorescent light is directed onto the sample, and filters identify the intensity of the light reflected back — each analyte reflects light in a different way. The reader has built-in light, lenses, image sensors, and all of the electronics to identify the molecules. That data is analyzed by the algorithms and artificial intelligence programmed into the reader to measure the concentration of specific biomarkers.

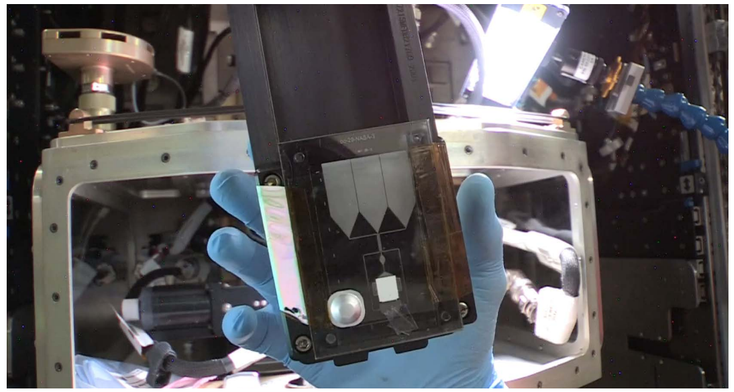
The analysis only takes a few minutes. "You get that concentration on the screen of the reader. Then the data goes to a cloud-based infrastructure to synchronize that data and send it to the smartphone of the patient or the physician," said Gervais. A custom app allows the user to access and store results over time.

"We're in the business of spaceflight."

Courtney Schkurko, Glenn Research Center

The flight demonstration of the 1DROP device on the space station included tests prioritized by the agency for long-duration missions and proved the technology worked as required in zero gravity. But there was one problem, according to Schkurko.

"Commercial devices have some type of cloud application behind them, and we fly above all clouds, pun intended." So the technology must make it easy to manipulate the data and transfer it between computer systems, she said. Using recognized data-sharing standards to safely transmit the information to NASA computers, 1Drop created a custom interface to download, share, and store results to each astronaut's health record.



Aboard the International Space Station, Captain Christopher Cassidy tests the 1DROP chip created by 1Drop Diagnostics. Successfully counting blood cells and measuring protein-based biomarkers in microgravity means it might diagnose medical conditions on long-duration missions. *Credit: 1Drop Diagnostics US Inc.*

Mitigating Biohazards

Because liquids behave differently in space, drawing blood is incredibly risky. All bodily fluids are biohazards, so any molecules that might escape during a procedure pose a threat to the health of the entire crew. A sample could also get contaminated because the environment isn't sterile, potentially leading to inaccurate results. And there's the issue related to thoroughly cleaning the device for future use and disposing of test-related material. Some of these challenges are easier to address in low Earth orbit than they will be in deep space.

Blood samples are currently returned from orbit to NASA for terrestrial processing. A consultation with a flight surgeon and other medical professionals is unaffected by the communication delays and lapses associated with deep space. On the space station, the containment and removal of bio-waste is relatively simple compared to long-duration missions, where recycling and reuse of materials will be essential.

"Trash and waste management are critical to NASA missions," said Schkurko. "From a medical perspective, we don't want any type of contamination that would get back into the human body or that could potentially make anyone else sick." To ensure against contamination of both the environment and the sample, 1DROP devised a self-contained system of capillary wicking pumps and valves that keep the fluid from escaping and let nothing else into the chamber. Now it confers the same benefits on Earth.

Astronauts Kate Rubins (left) and Andre Douglas practice Moon-walking operations in preparation for Artemis III. NASA is preparing for long-term, deep space missions in part by testing portable health diagnostic tools to ensure a quick medical diagnosis for astronauts. *Credit: NASA*

'Good Enough for Astronauts'

Creating a user-friendly, self-administered test to replace a complex process that takes highly specialized equipment has taken many years. Gervais appreciated the unexpected contributions NASA made to improving the technology, including modifying the equipment to withstand the force of a rocket launch. That effort will make it possible for anyone anywhere to use the 1DROP Health Reader.

"It could be used in the Arctic or in the desert or in the developing world and places where there's no access to a lab or a controlled environment. Working with NASA was not something that we ever really imagined, but it has ruggedized the device and the technology," said Gervais. Whether used in the field by first responders in disaster-recovery situations or by a pharmacist supporting patients with chronic conditions, quick and accurate results can alleviate some of the stress of diagnosis and treatment.

Experience with NASA's Human Research Program and sponsorship of the company's participation in the U.S. National Laboratory initiative to miniaturize diagnostics testing for health assessment in deep space also helped the company to advance the technology. A significant outcome was developing tests for biomarkers related to liver and kidney function, high-priority analytes for NASA deep space missions that can also be used in terrestrial medicine.

"It's been great working with these commercial entities to help them understand what the challenges for operations in space might be and what NASA-specific needs might be," said Schkurko. "Working with them to modify that core technology to meet our needs gives us the best of both worlds, where we can bring some of that spaceflight expertise and they can bring the medical and the technology expertise so that everybody can benefit." ●

"Working with NASA was not something that we ever really imagined."

Luc Gervais, 1Drop

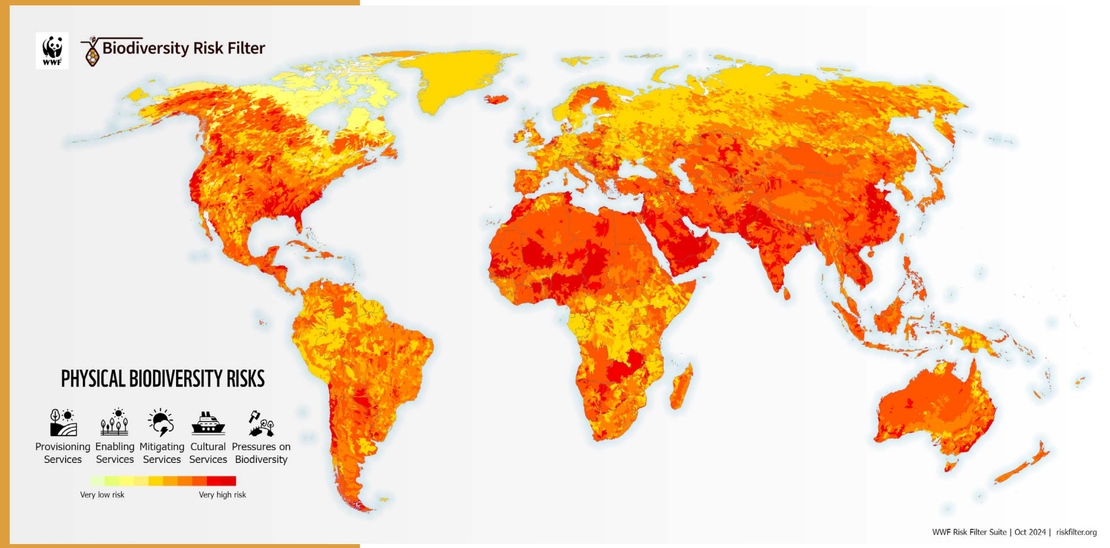
Filtering Out Risk

Environmental stewardship for businesses begins with NASA data

The World Wide Fund for Nature, whose U.S. headquarters is in Washington, uses Earth-observation data managed by Goddard Space Flight Center in its Risk Filter Suite. The platform informs businesses' understanding of the natural resources they require and tracks risks to those resources.

One environmental factor affects everything from clothing, food, and pharmaceuticals to fresh water availability and wildfires. That's biodiversity — the variety of plants, animals, and ecosystems that provide the vital resources all life requires. Humans are part of Earth's ecosystems, but understanding that interconnectedness is challenging. NASA-built Earth-observing satellites provide a wealth of environmental information, and it's easy to access and use that data, thanks to the World Wide Fund for Nature (WWF). The organization's Risk Filter Suite consolidates global data to help businesses understand their risks related to both biodiversity and fresh water.

There's a lot at stake. The natural world supports $44 trillion in products and services globally each year, or about half of the total global gross domestic product, according to a 2020 report by the World Economic Forum. That organization considers loss of biodiversity and ecosystem collapse one of the five top risks of the 2020s. But it takes a lot of data to maintain an accurate picture of local and global environments. Scientists constantly track diverse aspects of ecosystems, such as mineral deposits, wildlife, and plants, in addition to human activity like mining, cultivation, and infrastructure. But most



In this map of physical risk to biodiversity, red indicates "very high" risk. The World Wide Fund (WWF) for Nature shows businesses how the natural resources they depend on can be put in jeopardy by natural disasters and human activity such as exploitation. *Credit: World Wide Fund for Nature*

businesses don't have the ability to access this data and use it to evaluate their operations.

"It is extremely difficult for companies to find their way through that data jungle because they're not scientists or ecosystem engineers," said Maria Walsh, science manager for WWF's Risk Filter Suite. That's why the organization long known for its work in wildlife conservation is helping businesses identify the ways in which they rely on natural resources and how their activities impact biodiversity.

WWF is an independent conservation organization active in nearly 100 countries, whose U.S. headquarters is in Washington, where it's still known as the World Wildlife Fund. Its open-source platform includes the Biodiversity Risk Filter and the Water Risk Filter. After a user enters a company location — this could also include offices and suppliers across multiple countries — along with other data, the Risk Filter Suite identifies water- and biodiversity-related risks to help inform a nature-positive business model.

Multiple datasets from NASA combined with the most up-to-date information from other space agencies, academic institutions, and researchers around the world support a comprehensive picture of the biodiversity connections to numerous market sectors. WWF aggregates the information into a risk score between 1 and 5.

"It's basically bridging this gap between the incredible scientific work being done and the companies that it ultimately needs to reach," said Walsh. With over 2 million uploads and 17,000 active users, WWF is just getting started.

Weather events like hurricanes damage ecosystems and harm water quality. After Hurricane Irene drenched New England in late August 2011, the Connecticut River spewed muddy sediment into Long Island Sound, damaging coastal fisheries and other businesses. *Credit: NASA*

Translating Data

The most significant contributors to biodiversity loss are human-driven changes to land, fresh water, and seas, followed by overexploitation, invasive species, pollution, and environmental changes, according to the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services. Approximately 75% of Earth's land surface has been dramatically altered by human activity, including an 85% loss of wetlands. Those alterations contributed to an average 73% decline of mammal, bird, amphibian, and reptile populations between 1970 and 2016, according to WWF.

"Companies have a huge amount of power and a huge network that touches every aspect of life and every landscape on our planet," said Walsh. "Engaging with companies on these issues is an incredible multiplier to bring biodiversity-positive action into this world."

Three modules — Inform, Explore, and Assess — help users learn about biodiversity as they identify the natural resources their operations require and potential issues now and into the future. For example, crop farming is "extremely" vulnerable to water scarcity and extreme heat while often having a "very high" impact on land and tree loss. An office building depends less on water but also can have a "high" impact on land and tree loss.

Increasingly, customers and stakeholders are demanding disclosure about risks and opportunities related to the impact corporate activities have on the environment. The Task Force on Nature-Related Financial Disclosures and European Sustainability Reporting Standards are just two of a growing number of standards forcing businesses to take a critical look at their practices. The Risk Filter Suite provides the data needed for that accountability.

Earth: Then and Now

NASA datasets included in the filters are generated, in part, by Landsat and other Earth-observing satellites. Multiple sensors, including the Moderate Resolution Imaging Spectroradiometer aboard the Aqua and Terra satellites, provide views of Earth's entire surface every one to two days. And the Visible Infrared Imaging Radiometer Suite instruments aboard the Joint Polar Satellite System satellites, which NASA operates jointly with the National Oceanic and Atmospheric Administration, provide visible and infrared imagery of the land, oceans, atmosphere, and cryosphere.

To show how much has changed over time, Landsat provides decades of data.

"The satellites were designed to systematically monitor Earth's surface for the purpose of surveying, monitoring, and managing natural resources for better management of those resources," said Bruce Cook, Landsat scientist at NASA's Goddard Space Flight Center in Greenbelt, Maryland.

By looking at a range of light, from the bands visible to the human eye to colors in the infrared and ultraviolet regions, scientists can learn a lot about the surface of the planet. Cook explained that plant species contain different light-absorbing pigments, so the colors they reflect are varied, revealing the diversity of vegetation in an area.

Some of Earth's surface characteristics that satellites measure include snowpack, minerals, and features like mountains and bodies of water. Meanwhile, thermal emissions reveal surface temperatures, which are important for things like understanding how much water is evaporating from plants and soil.

'Unprecedented Change'

Landsat contributions to the WWF database include information about tree cover, agricultural land, and urban sprawl and infrastructure. Other NASA contributions include the Fire Information for Resource Management System data related to fires and air quality and the Shuttle Radar Topography Mission data related to wind and storm surge forecasting. NASA's Socioeconomic Data and Applications Center adds data on population, human impact, ecosystem conditions, and water quality.

Some companies benefiting from all this information are working directly with WWF to make data-driven decisions about business operations. Understanding water risks is a top priority now that flooding and drought are more common.

One global pharmaceutical company used the Water Risk Filter to look at how physical climate-related risks could impact critical sites around the world. When the company shared flood-related data with on-site staff, a team in Japan found that elevated river levels in the area were unlikely to pose a problem for their facility. But having that conversation prompted the staff to look at local government hazard maps, and they discovered precipitation-induced landslides pose a future water-related risk.

The same company is also identifying high-risk raw materials in its supply chain and then mitigating some risks around those materials, such as palm oil and the chemical palladium.

A need to better understand water risks was one reason the H&M Group, a global clothing company, worked with WWF to provide its suppliers with insights and more in-depth data for a science-based approach to setting meaningful targets for water use. The textile industry requires a lot of water for cotton growing and processes such as dyeing and washing. Producing a single cotton T-shirt requires around 792 gallons — any reduction in usage could have a significant impact.

"We are in a time of unprecedented change, and that can inspire a lot of fear," said Walsh. "Leveraging the incredible work that scientists have been doing and translating that into terms that companies can understand is a work in progress."

Addressing Risks

WWF is committed to the costly undertaking of continually adding to and updating environmental data, ensuring that anyone at any time can review their procedures and database. The organization is developing a new module called Act that will provide companies with mitigation actions to address specific risks.

The Water Risk Filter currently identifies three risk types — physical, reputational, and regulatory, and the Biodiversity Risk Filter will soon include regulatory risk. WWF is also working on breaking down risks to the commodity level. Doing that could make the data more relevant to companies producing wheat, soybeans, potatoes, and other commodities, because their requirements are markedly different from those of other growers.

"This is a positive exercise for companies to consider. Looking at these risk aspects creates a chance to address them before they become a problem," said Walsh. ●

Wildfires inflict all sorts of damage, from destroying habitats and polluting water to damaging the infrastructure people rely on, like power lines and roads. The WWF Biodiversity Risk Filter helps individuals and businesses prepare. *Credit: Derrellwilliams, CC0*

Making Future Satellite Fuel Today

Non-toxic propellant is fueling safer propulsion systems thanks to NASA's efforts

With the help of a former Marshall Space Flight Center employee, Rubicon Space Systems created a new in-space propulsion system for satellites. The Huntsville, Alabama company employs a non-toxic fuel that's safer for ground crews during fueling and performs better than traditional fuels.

More than eight miles up, the air is too thin for most planes to fly. But even in low Earth orbit 300 miles from Earth's surface, there are enough air molecules to cause a slight drag on satellites. In time, this friction will pull them from orbit, and they'll burn up in the atmosphere. To guarantee a stable long-term orbit, a satellite needs a thruster.

Most satellite propulsion systems rely on propellants like hydrazine, which are highly toxic and require an onboard heater to keep them from freezing. So NASA and the Air Force Research Lab collaborated with industry to create a state-of-the-art propulsion system for satellites that uses a fuel called Advanced Spacecraft Energetic Non-Toxic (ASCENT) propellant. Originally developed by the Air Force, the fuel is both safe and more efficient than traditional satellite propellants.

Increased demand for cost-effective, reliable satellites makes this new propulsion technology a game changer with benefits that are attracting commercial and government customers alike.

Rubicon Space Systems, a division of Plasma Processes LLC, leveraged multiple Small Business Innovation Research awards from NASA to build a new propulsion system using ASCENT for a lunar mission. Now the Huntsville, Alabama-based company offers the alternative-fuel thrusters and propulsion systems for existing commercial satellite designs.

"Satellite manufacturers are learning they have reached the maximum capability of what they can do with hydrazine propellant without making the spacecraft larger, which limits what they can do," said Daniel Cavender, director of propulsion with Rubicon Space. Redesigning, testing, and qualifying a new satellite is costly and time-consuming, but replacing the propulsion technology with a more efficient system makes it possible to continue to use the flight-qualified models.

"This lower-toxicity propellant actually has higher performance than the existing technologies," said Cavender, noting that it gets about 50% better "mileage" than fuels like hydrazine.

"This lower-toxicity propellant actually has higher performance than the existing technologies."
Daniel Cavender, Rubicon Space Systems

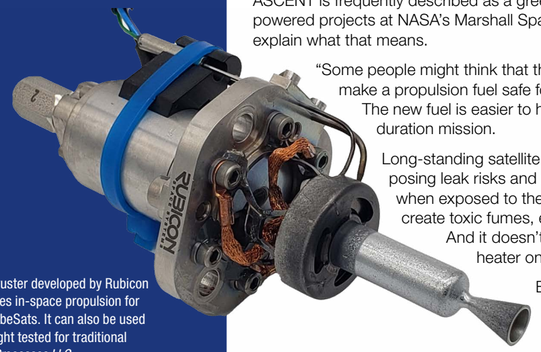
A Better Way to Boost

ASCENT is frequently described as a green fuel. Nehemiah Williams, who has managed ASCENT-powered projects at NASA's Marshall Space Flight Center in Huntsville, Alabama, frequently has to explain what that means.

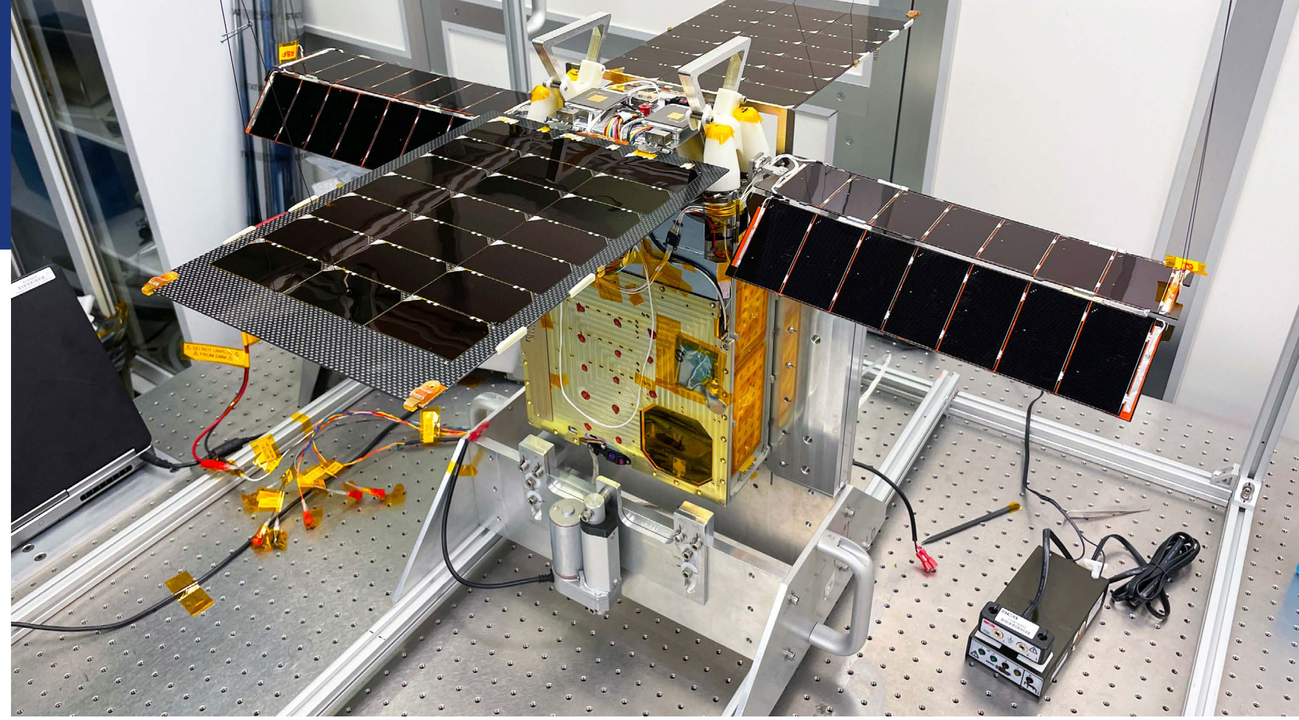
"Some people might think that the fuel is green in color, but it's more about the attempt to make a propulsion fuel safe for humans and safer for the environment," said Williams. The new fuel is easier to handle on the ground and easier to store in space for a long-duration mission.

Long-standing satellite propellants like hydrazine are corrosive to storage tanks, posing leak risks and requiring specialized containers, and they create toxic fumes when exposed to the air. By contrast, ASCENT is less corrosive and doesn't create toxic fumes, eliminating those hazards to people fueling the spacecraft. And it doesn't freeze, which frees up the power and space used by a heater on a satellite.

Before NASA got involved, a green propulsion system wasn't available. Cavender said there also wasn't a commercially produced non-toxic propellant in 2015, when NASA announced its Green Propellant Infusion Mission (GPIM). At the time, Cavender was the assistant chief engineer on GPIM at Marshall.



The 1 Newton nanothruster developed by Rubicon Space Systems provides in-space propulsion for small satellites like CubeSats. It can also be used in satellites already flight tested for traditional fuels. *Credit: Plasma Processes LLC*



Lunar Flashlight was a low-cost CubeSat designed to investigate the shadowy surface of the Moon's South Pole. It used a new green propulsion system that ran on Advanced Spacecraft Energetic Non-Toxic (ASCENT) fuel. *Credit: NASA*

"We went to industry to look at what was available," he said. "As it turned out, industry wasn't ready to provide a green chemical propulsion system that had the capability NASA needed." To change that, he helped set up the Green Propellant Working Group. The coalition of small businesses, academia, and federal agencies helped build a non-toxic propulsion system for spacecraft, and NASA is still working to make it widely available.

Satellite Snowflakes

GPIM proved the first ASCENT-powered satellite thrusters after its launch in 2019. At that point, NASA decided to use a similar system for a lunar satellite, dubbed Lunar Flashlight, intended to seek evidence of frozen water in the permanently shadowed craters of the Moon's South Pole. The agency selected Plasma Processes to manufacture parts for the propulsion system.

After launch, the 2022 flight demonstration failed to reach lunar orbit because it encountered a problem. Debris from the 3D printed parts was likely the cause of clogged fuel lines that ultimately shut down the thrusters. However, the flight data NASA obtained before that happened demonstrated the system did work as designed. Plasma Processes created Rubicon Space, with Cavender at the helm, to commercialize ASCENT propulsion systems, and the Lunar Flashlight flight provided important lessons that went into improving the technology. These included new standards for filtration and stricter contamination control for 3D printed parts.

The Sprite propulsion system built by Rubicon Space uses valves that were developed and tested by NASA for the green propulsion demonstration. Work done under a Space Act Agreement at Marshall made it possible

to incorporate the technology in Sprite's 1N HT thruster. This new propulsion system is now being incorporated into existing satellites originally designed to use traditional toxic fuels. The company can also customize the systems to meet individual mission requirements, offering system design testing its customers can't do in-house.

"Everybody wants to move around in a special way to enable whatever the mission is, whether it's science or national security. So every propulsion system risks ending up being its own little special snowflake," said Cavender. But Rubicon Space is taking an approach that allows some customization to a standard template without returning to the drawing board for each customer.

Learning New Tricks

Chemical thrusters generally have high thrust but aren't usually as efficient as electric thrusters. While electric thrusters are highly efficient for long-duration propulsion, they produce little thrust. ASCENT can power both types of thrusters, so Rubicon Space is developing a new chemical-electric hybrid propulsion system.

The company has had multiple Space Act Agreements with Marshall supporting its latest efforts, including one that led to the new valve that was incorporated into the Rubicon Space propulsion system. Describing the NASA staff as "the best in the world," Cavender said he believes the collaboration will help the company achieve "the Holy Grail of propulsion," a universal off-the-shelf, dual-mode propulsion system.

NASA continues to develop non-toxic propulsion technologies, sharing its data and experience in an effort to spur more commercial space activity. The ongoing collaboration between NASA and Rubicon Space in particular is benefiting numerous customers as well as the space agency.

"Rubicon has been a really good technical partner for us," said Williams. "They've included NASA standards for hardware and systems and are applying them to the development of their new unit to show that they meet our standards and requirements overall." Now that the hardware necessary for using ASCENT and other green fuels is available, a new generation of propulsion can begin.

"If we keep doing things the same way, we're going to miss opportunities to develop technologies in ways that we didn't think that we could do. I would love to see green propulsion expand with an emphasis on design around this technology, because you just don't know what you'll learn until you try something different," said Williams. ●

The Sprite propulsion system built by Rubicon Space was developed with NASA to use ASCENT fuel. It's both safer and more efficient than conventional fuel like hydrazine. *Credit: Plasma Processes LLC*

Long-standing satellite propellants like hydrazine are so toxic to humans that workers handling them require a protective suit like this one worn by crew preparing the Mercury Surface, Space Environment, Geochemistry, and Ranging spacecraft. *Credit: NASA*

"You just don't know what you'll learn until you try something different."

Nehemiah Williams, Marshall Space Flight Center

Boosting Bone Health

Using NASA data, new technology promotes strong bones

Because astronauts can lose bone density on long-duration missions, Johnson Space Center conducts research on bone loss. Data provided by NASA-funded research helped Osteoboost Health of Redwood City, California, develop Osteoboost, a new FDA-approved device that treats early-stage bone loss.

Recovering from a broken bone can be a long, painful experience — even life-threatening for the elderly.

The risk of a fracture when thousands of miles away from medical care is one reason NASA studies bone health in astronauts. Weightlessness in space and even low gravity on the Moon or Mars can weaken human bones over time. NASA-funded research into options for combating that bone loss has included a study attempting to understand whether vibrations might trigger bone cells to create new tissue. The answer was yes for the test animals, and that effort also determined the ideal vibration intensity and frequency for humans. Now a new technology is using that information to help prevent the most common fractures in hips and the lower spine for Earth-bound patients.

ESA (European Space Agency) astronaut Samantha Cristoforetti uses the treadmill on the International Space Station to help maintain her muscle and bone health while in microgravity. *Credit: ESA/NASA*

Approved by the Food and Drug Administration (FDA) as a Class II prescription medical device for patients with osteopenia, Osteoboost was created to help prevent bone loss. Osteopenia is loss of bone density that occurs prior to osteoporosis, and both conditions significantly increase the risk of fractures, according to Laura Yecies, CEO of Osteoboost Health Inc.

"Hip fractures are deadly, with 20% to 30% mortality in the first year after a fracture. Patients who survive are highly likely to lose their independence," said Yecies. "And debilitating vertebral compression fractures are the most common osteoporotic fracture." This is why the Redwood City, California-based company developed a technology that can be worn like a belt, concentrating the vibrations at the vulnerable areas of hips and lower spine.

Good Vibrations

The research funded by NASA's Johnson Space Center in Houston failed to demonstrate that whole-body vibration would benefit the entire human skeleton. But it did find a level of vibration that people could tolerate, and it proved vibration stimulated bone cell growth in several different animal groups. Victor Schneider, medical research officer for NASA, explained that a variety of external stimuli can be beneficial for internal functions.

"You can stimulate bone cells through the skin. Magnetic forces do this. Electrical forces do this, and both of those are also FDA approved for stimulating new bone cells to make new bone," he said. "This technology fits into that category."

“Hip fractures are deadly, with 20% to 30% mortality in the first year.”

Laura Yecies, Osteoboost Health

The best frequency and level of vibration to stimulate the growth of bone cells, as identified by NASA-funded research, helps Osteoboost transmit the appropriate dose to the lower back of the wearer. *Credit: Osteoboost Health Inc.*

NASA focuses on many aspects of astronaut health to ensure that time in space doesn’t have a detrimental effect. The agency’s Human Research Program has been collecting data for over 50 years and learned quite a bit about bone health. For example, astronauts in space on short-term missions of just two or three months experience minimal bone loss, while long durations in space can have a detrimental effect.

That’s because the human body evolved in an environment with gravity. That force causes bone cells to generate the additional tissue necessary to maintain density and strength to do their job. When any extra force is added by activities such as weightlifting or running, our bones recognize that added stress and automatically start generating new cells to make them stronger. Just the act of walking on Earth helps keep legs, hips, and spinal bones healthy, but in space there is no weight-bearing stress to trigger the production of new cells.

That lack of force signals that strong bones are no longer required. They adapt to weightlessness by breaking down and releasing calcium, collagen, and minerals that are no longer needed to support the full weight of an astronaut. To help combat those losses, the Bone and Mineral Laboratory monitors astronauts’ bone health. Substitutions for gravity on long-duration missions include equipment like a specially designed treadmill and a weightlifting machine on the International Space Station, and it’s paying off. Astronauts experience only minor short-term bone loss in space, according to Schneider.

Preventing Fractures

People begin losing bone density in their 30s, and that accelerates with aging and age-related conditions like menopause. Some drug therapies such as chemotherapy and steroids can also degrade bones. The most common fractures occur in hips and the L1 and T12 vertebrae. And early intervention is important, according to Yecies.

“Osteopenia is like many chronic conditions. If you don’t intervene early, it’s very difficult to recover,” she said. While there are some medications available to treat osteoporosis, they have limitations. One is the short-term duration of use because side effects can be severe, and benefits decrease over time.

Hip-fracture mortality has halved in the last 50 years. Although the fracture rate has gone down minimally, the increase in the aging population has led to dramatic increases in numbers of fractures, according to Yecies. Osteoboost Health would like to help reverse that trend.

The Osteoboost vibration belt is a non-toxic alternative. A doctor can offer this treatment to patients with osteopenia as a way to improve their bone strength and bone density. Clinical trials revealed no serious adverse side effects, so it can be used as long as needed.

A pressure sensor at the back automatically senses the appropriate pressure to transmit vibration to the skeleton. An accelerometer — a sensor that measures acceleration — is positioned over the hip bone and gauges the vibration intensity. Calibration adjustments are automatic and made for every 30-minute session. If the vibration is inadequate, the strength is raised. If it’s too strong, it’s lowered.

“The distribution of muscle and fat around the lower back might be different, so a slightly different vibration will be required,” said Yecies. “Or one day you’re wearing running shorts, another day you’re wearing sweatpants. The device always ensures the right dose of vibration.”

“NASA funding of basic science is so important and has been critical for us.”

Laura Yecies, Osteoboost Health

Noting that different frequencies and intensities during vibration studies resulted in different degrees of efficacy, Yecies credits the NASA-funded research with identifying the optimal frequency and intensity to benefit humans.

“NASA funding of basic science is so important and has been critical for us. It is exciting that research conducted on behalf of young, healthy astronauts will have benefits for frail, elderly people,” said Yecies. ●

Gravity is essential for maintaining strong bones. So specially designed exercise machines were created for the space station, such as the Advanced Resistive Exercise Device, a weightlifting machine that mimics lifting free weights on Earth. Astronauts, including Nick Hague of NASA, typically work out for two hours daily. *Credit: NASA*

Aerogel Art Attracts Attention

Comet-catching NASA technology enables exotic works of art

Lessons learned during visits to an aerogel lab at the Jet Propulsion Laboratory helped Ioannis Michaloudis of Limassol, Cyprus, build a career as an aerogel artist. The material is difficult to work with but has many unusual and striking qualities.

Artist Ioannis Michaloudis must have seemed like an unusual choice of speaker at first. Much of his talk before the scientists, engineers, and entrepreneurs gathered in Dallas for the 2024 summit of the Advanced Research Projects-Energy agency was abstract. He spoke of the sky as the planet's protective garment, floated the idea of making shade clouds from space junk, and characterized his artwork as "biomimicry of the sky."

But as the world's best insulator, the translucent, ethereal silica aerogel material Michaloudis works with has concrete energy applications. He finished his talk by proving this with a video of his aerogel Coperni AirSwipe bag, which had caused a sensation at its debut months earlier, being filled with molten brass.

Artist Ioannis Michaloudis shows the crowd at the Advanced Research Projects-Energy 2024 summit the ingot that was formed by pouring molten brass into the aerogel AirSwipe bag he made for Coperni, held here by model Emily Hutchison. *Credit: 2024 ARPA-E Energy Innovation Summit*

"It was amazing because they were like, you know, an artist is speaking, OK, he's making beautiful things," recalled the Greek artist, researcher, and professor. "And then lava inside this bag that had gone viral all over the world."

Michaloudis, now based in Limassol, Cyprus, is probably the world's only artist molding sculptures and fashion accessories from this striking material, mainly because it's extremely hard to do. He was able to invent his own recipe and process only due to a nearly obsessive drive to create a three-dimensional cloud. It was a quest that took him to the Massachusetts Institute of Technology (MIT) in Cambridge, Massachusetts; Shivaji University in Maharashtra, India; and NASA's Jet Propulsion Laboratory in Southern California.

The impulse that propelled him to the Coperni collection debut and, subsequently, a slew of speaking engagements, took hold when he was completing his Ph.D. in 1998. In one of a series of photos he had taken, he noticed a cloud shaped like a hook. That was all it took. "I say to myself, if this cloud it looks like a hook, if nature can make this kind of shapes, why not to make a cubic cloud?"

From the start, he had a hunch NASA could help, but the agency didn't respond initially, so he went to do post-doctoral work at MIT. There, he attempted to use lasers to manipulate steam, but it required too much electricity. Then in 2001, a researcher at the university approached him asking, "You are the guy who wants to make a cubic cloud?" The man claimed to have a piece of cloud right in his office. It turned out to be a small sphere of silica aerogel.

At about 99% air, aerogel is the world's lightest solid. It's made by combining a polymer — typically silica-based — with a solvent to create a gel that is then flash-dried under pressure. This leaves a solid, dry structure filled with microscopic pores. Many aerogels hardly even look solid. Smokey blue, sometimes tinged with orange, their edges seem to blur.

Origins in Stardust

One of NASA's most successful commercial spinoffs has been a method for incorporating aerogels into insulating blankets (Spinoff 2022, 2020, 2018, and more). But NASA has also used chunks of pure aerogel for other purposes — such as trapping dust from the tail of a comet.

Steve Jones was hired by JPL in 1996 to develop an aerogel for the Stardust mission. The idea was that a probe with an exposed, porous surface could capture particles while flying behind a comet. But that "stardust" is traveling so fast that even a foam would vaporize it on impact. After extensive testing, aerogel had been identified as the substance that could catch and preserve it.

"They knew how to make an aerogel, but it wasn't consistent or flight quality," said Jones, who spent the next two years developing an aerogel that was up to the task.

The Stardust spacecraft did eventually drop its sample return capsule into a Utah desert, containing comet particles and interstellar dust that revealed a wide range of organic compounds.

By the time Stardust launched in 1999, other NASA researchers were interested in aerogels for insulation, and Jones won funding to set up a new aerogel lab. He went on to use aerogel to insulate electronics boxes for the Spirit and Opportunity Mars rovers and the heat source in the Mars Oxygen In-Situ Resource Utilization Experiment on the Perseverance Mars rover, among other projects.

Among Michaloudis' creations are wispy nymphs captured in jars of aerogel. The artist's drive to produce aerogel art began with the idea of making a three-dimensional cloud. *Credit: Ioannis Michaloudis*

In the early 2000s, Michaloudis heard about Stardust and reached out to JPL. By then he had done some work with an aerogel company but was still exploring methods and recipes. Jones invited him to the lab. "He visited two or three times," Jones recalled. "I went through the primer on aerogel with him, the different kinds you could make and their different properties."

> *"I went through the primer on aerogel with him, the different kinds you could make and their different properties."*
>
> *Steve Jones, Jet Propulsion Laboratory, retired*

Michaloudis said he was especially impressed at the size of the 50-liter reactor in Jones' lab. The company he'd been working with had a single-liter reactor. Thanks to NASA, he said, he decided to equip his own lab with a 20-liter reactor, allowing for large sculptures.

He started sending over molds that Jones made sculptures from, but some of them cracked. In the end, Michaloudis said, NASA's aerogel recipe wasn't ideal for making large, three-dimensional objects. But he left with some important takeaways, he said. In addition to tips on working with this rare class of materials and the inspiration to go large on his own apparatus, he said Jones taught him about safety. "He explained to me that if you go for big volumes, you have big risks." To avoid explosions, a large reactor needs emergency release valves known as burst discs, he learned.

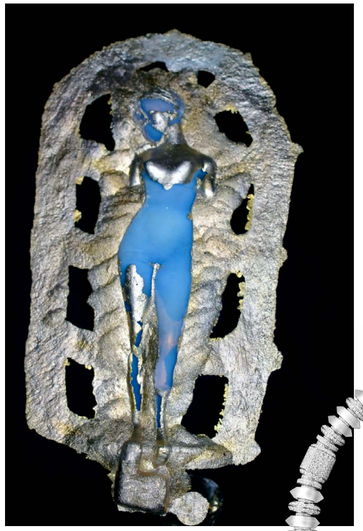
The Sky in a Bottle, Then on the Catwalk

With his JPL experience in tow, Michaloudis traveled to India, where he learned to use methanol as the solvent, resulting in aerogels better suited to making large objects. This was also where he learned they could stand up to molten metals, after he convinced a foundry worker to submerge a sample in liquid brass. "We had lava surrounding sky. It was amazing," he said. "I was crying like a baby."

The Jet Propulsion Laboratory perfected aerogel for the Stardust mission. Under Stardust, bricks of aerogel covered panels on a spacecraft that flew behind a comet, with the microporous material "soft catching" any particles that might strike it and preserving them for return to Earth. *Credit: NASA*

Michaloudis had his first solo exhibition in 2006 and has had a dozen more since. "My general vision about silica aerogel is that it is the personification of the sky, which is in danger at this moment on our Earth," he said. "Because it is blue and orange at the same time, I say it is like a piece of sky. So it's like molding the sky."

His works include reinterpretations of ancient sculptures, wispy nymphs suspended in blue cylinders, translucent masks, jewelry with aerogel



Some of Michaloudis' works are new takes on classical sculptures. To create "Veria Girl," he partially encased the aerogel sculpture in melted brass. *Credit: Ioannis Michaloudis*

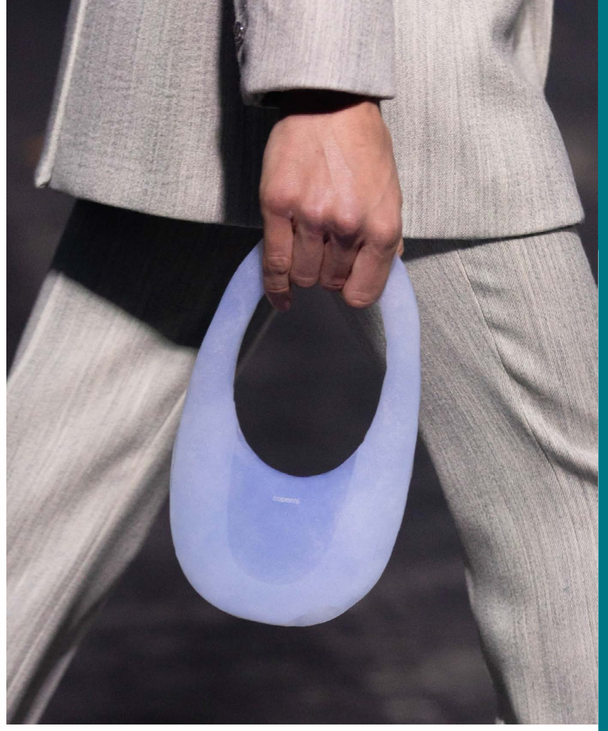
Goutte de Ciel, or Drop of Sky, was the centerpiece for Boucheron's High Jewelry Carte Blanche "Contemplation" 2020 collection debut. Michaloudis collaborated with the luxury jewelry and watch house to create this ice-blue pendant of aerogel suspended in rock crystal and surrounded by white gold paved with diamonds. *Credit: Boucheron*

baubles encased in glass. He also sells bottled clouds, Sky Cubes with suspended clouds of magnetized metal filings, "nebulas" of phosphorous floating in aerogel discs, and much more.

In 2020, he brought aerogel into high fashion when the French luxury jewelry and watch house Boucheron collaborated with him to create the centerpiece of its collection for that year, a big, ice-blue pendant of aerogel encased in quartz and surrounded by white gold and thousands of tiny diamonds. The piece, titled Goutte de Ciel, or Drop of Sky, ended up selling for half a million dollars.

"We had lava surrounding sky. It was amazing. I was crying like a baby."

Ioannis Michaloudis, artist



The aerogel AirSwipe bag Michaloudis created for Coperni's 2024 fall collection debut appears almost luminous in its model's hand. The bag immediately captured the world's attention. *Credit: Coperni Sas*

But none of his creations have captured the world's attention like the Coperni AirSwipe bag unveiled at that company's 2024 fall collection debut. Seeming to glow a translucent blue in its model's hand, "it had millions of immediate 'likes' on the catwalk," Michaloudis said. "For about 48 hours, it was in the media all over the world." Since the AirSwipe appeared, he has received continuous requests for speaking engagements and products, he said. "I have requests for anything that you can imagine. A chair out of aerogel, glasses out of aerogel, whatever you want."

His next collaboration is with Mercedes-Benz, though he can't say more about it.

Michaloudis credits his tutelage at JPL as an essential step on his path to developing aerogel as art. "If Stardust wasn't there, we wouldn't be having this conversation," he said. "I am what I am, and we made what we made thanks to the Stardust project." ●

NASA 'Arms' Astronauts, Industry with Robotic Intelligence

To free up astronauts, NASA tackles complexity of controlling robotic arms

"I like to see it as a way to maximize the value of the money we spend on getting humans to the lunar surface."

Shaun Azimi, Johnson Space Center

In the Integrated Mobile Evaluation Testbed for Robotics Operations facility at Johnson Space Center, PickNik robotic control software proved its prowess in tasks like passing cargo transfer bags through a hatch and placing them in storage bins, in anticipation of work NASA would like robots to carry out during the later Artemis missions. *Credit: NASA*

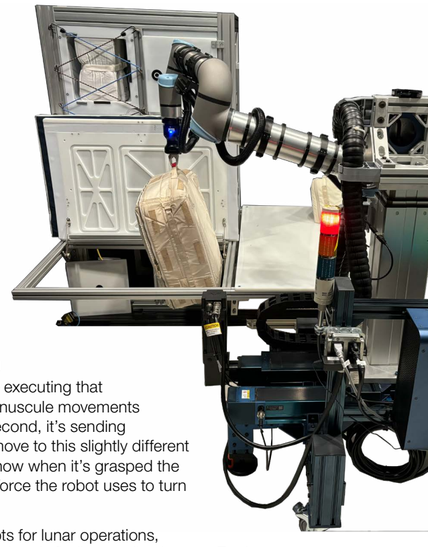
With help from SBIR funding from Johnson Space Center, PickNik Robotics of Boulder, Colorado, developed and refined its MoveIt Pro robotic automation software and then worked with roboticists in Johnson's Integrated Mobile Evaluation Testbed for Robotics Operations facility to prove the software's functionality.

Being an astronaut isn't always glamorous.

Crewmembers on the space station spend about a third of their time just hauling in cargo from resupply capsules and carrying trash bags back out, said Shaun Azimi, who leads the Dexterous Robotics team at NASA's Johnson Space Center in Houston. And that's with a full-time crew of seven.

As NASA plans extended astronaut stays on and around the Moon in the later Artemis missions, the agency wants robots to take over some of these menial jobs, freeing up crewmembers to do more of the science and exploration they're there for. The problem is, while robots in science fiction can often pass for human, developing real-world robots — which would more likely resemble mobile six-jointed arms — to carry out even the simplest human tasks is exceedingly complicated.

"Robotic manipulation historically is like a big arm in a factory moving the chassis of a car from one conveyor belt to another," said Ezra Brooks, principal software engineer at PickNik Inc., noting that no intelligence is needed to repeat this preprogrammed set of actions over and over.



Getting a robot to recognize an object in an unstructured environment, approach it, and carry out some operation with it is an entirely different and far more difficult job. This is the challenge Boulder, Colorado-based PickNik is overcoming, with help from the space agency.

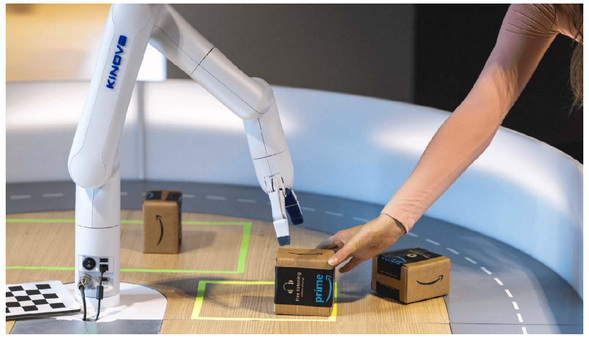
For instance, the company worked with roboticists at Johnson to prove out software that enabled a robot to recognize a hatch on a spacecraft — including its latch, handle, and hinges — then turn the latch, grasp the handle, and open the door.

Just planning the motion from a given starting configuration of the joints in a robot arm to an ending configuration that sets it up for the next action "takes some very clever math and a lot of CPU horsepower," Brooks said. "Then once you're actually executing that trajectory, the software is telling the robot all of the minuscule movements it needs to make. Maybe upwards of 1,000 times a second, it's sending commands saying, move this joint at this velocity or move to this slightly different position." A force feedback algorithm lets the robot know when it's grasped the latch, and a control algorithm determines how much force the robot uses to turn it.

While much work remains to be done to prepare robots for lunar operations, software PickNik developed with the help of NASA is already finding applications on Earth.

"Working with NASA is really rewarding from the perspective of being able to dive into the deep end of really difficult problems that almost no one else is running into yet."

Ezra Brooks, PickNik Robotics



PickNik's MoveIt Pro, developed in part with funding and help from NASA, automates robotic arm demonstrations in the lobbies of two Amazon Web Services learning centers. *Credit: PickNik Inc.*

Robotic Baggage Handlers

The work at Johnson, funded under the Small Business Innovation Research (SBIR) program, was carried out in the center's new Integrated Mobile Evaluation Testbed for Robotics Operations (iMETRO). There, the team also proved the software's ability to make the arm lift cargo transfer bags of the sort used on the International Space Station in and out of the hatch and a storage bin, in anticipation of future robots' Artemis assignments.

The software PickNik tested with Azimi, now known as MoveIt Pro, had been developed under SBIR funding from NASA and the Space Force, and further NASA SBIR contracts have helped refine its user interface and improve its autonomy and ability to recover from failure.

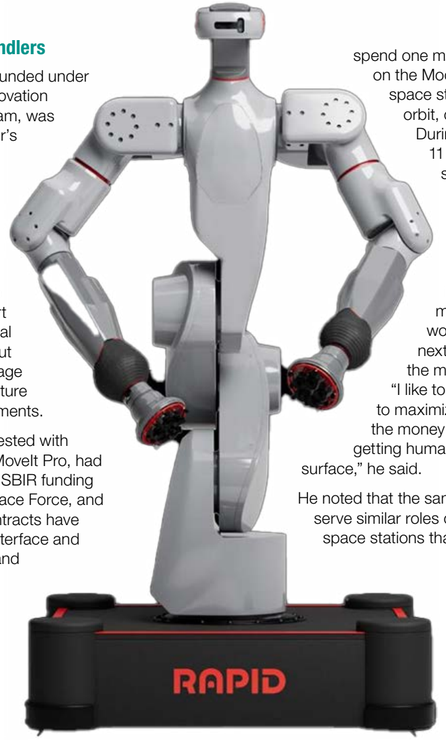
Early Artemis missions will be short, but eventually, crews of four or so might spend one month per year on the Moon and in a space station in lunar orbit, called Gateway. During the other 11 months, Azimi said, robots could load and unload supplies and carry out simple inspection and maintenance work, allowing the next crew to make the most of its stay. "I like to see it as a way to maximize the value of the money we spend on getting humans to the lunar surface," he said.

He noted that the same robots could serve similar roles on commercial space stations that a handful of companies are now building for low Earth orbit, which also would likely only be crewed part-time.

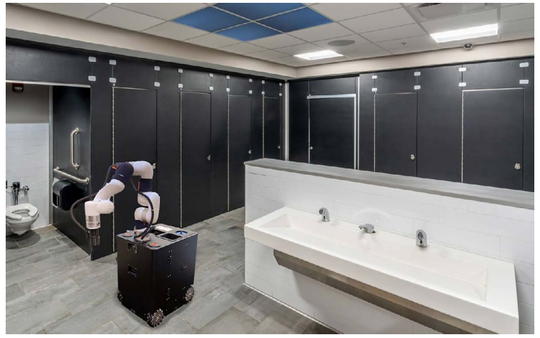
For now, Azimi said, PickNik is building a commercial customer base on Earth, which helps fund product development and make it sustainable. "So our development through NASA SBIRs focuses on the gaps between that terrestrial use case and the in-space use case." For example, inconsistent communication between Earth and the Moon will require more independent robots. And the ability to remotely fix any problems that arise will be much more important when human operators are 240,000 miles away. But all of these capabilities come in handy on Earth too.

Brooks said the 35-person company might not have developed a commercial product without early funding from NASA. In robotics, he said, "you have to do years and years of research and iterative development on trying to refine algorithms and doing serious science to get to a point where you even would have a distinct product you could sell." NASA funded much of that foundational work.

And, he said, it helps to be working with one of the world's premier robotics organizations. "Working with NASA is really rewarding from the perspective of being able to dive into the deep end of really difficult problems that almost no one else is running into yet."



PickNik's MoveIt Pro software enables a single Rapid 3PRO, a two-armed industrial robot from Rapid Robotics, to perform dozens of different tasks, and new capabilities can be added quickly. *Credit: PickNik Inc.*



Hivebotics in Singapore is using a custom version of MoveIt Pro to automate its flagship product, a restroom-cleaning robot named Abluo. *Credit: PickNik Inc.*

In fact, Brooks ran up against some of those problems as a NASA contractor working on the agency's On-Orbit Servicing, Assembly, and Manufacturing 1 mission, an ambitious robotics project that ended up cancelled a couple of years after he left for PickNik. He said the work helped him foresee and address challenges the MoveIt team would come up against.

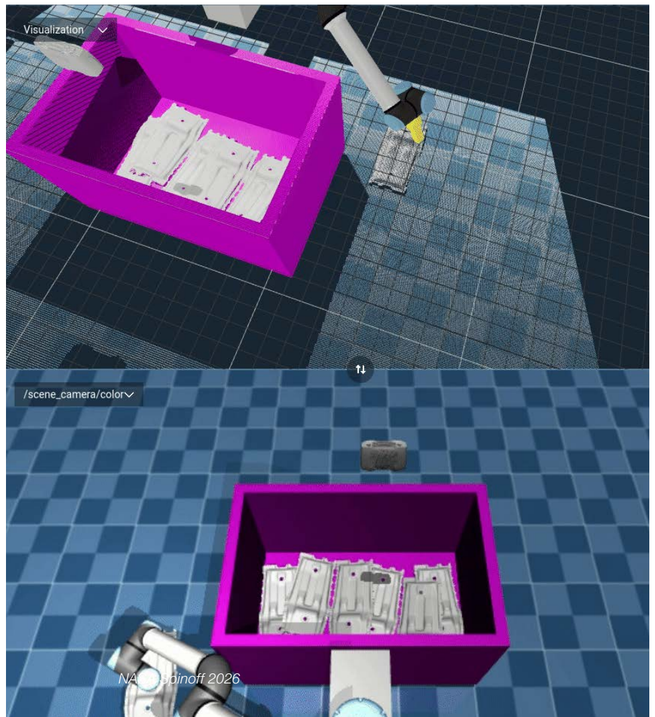
Automated Housekeeping, from Restrooms to the Moon

All of the software development funded by NASA has already been folded into MoveIt Pro, the company's flagship product, Brooks said. Released in 2023, the software has found a significant customer base. BMW is using it to bring more intelligence to its robotic assembly lines, and it automates robotic arm demonstrations in the lobbies of two Amazon Web Services learning centers.

A company called Lightspeed is using MoveIt Pro to program huge robotic arms that build "panels" of walls, roofs, and floors in an attempt to address the nationwide shortage of affordable housing. And PickNik customized the software to help Hivebotics of Singapore automate its flagship product, a restroom-cleaning robot named Abluo.

For MoveIt Pro to one day automate robots in space, though, Brooks said engineers and space agencies will need to do a lot of work to build confidence in robotic intelligence for space missions. "It's far more complicated than really any other software that's ever been flown to space."

But Azimi said the payoff will be worth the effort. Robots capable of logistical work could probably do facility maintenance and even keep science experiments running while the crew is away, he said. "Anything robots can do in those 11 months, you're ahead of where you would be if you didn't have that capability at all." ●



The user interface for PickNik Robotics' MoveIt Pro robotic control software shows work the company did with automaker BMW to make assembly line robots more capable of dealing with unexpected situations. *Credit: PickNik Inc.*

Keeping Cool, Containing Flame

New fire-retardant insulation enhances battery safety and more

Funding from the Astronaut Scholarship Foundation helped launch the Oros outdoor clothing line that incorporates aerogel insulation. Lessons about aerogel created by Kennedy Space Center led to a new non-toxic, fire-retardant formula. Now Portland, Oregon-based Solarcore has spun off from Oros to offer industry an ultra-thin insulation.

The batteries that power hybrid and electric cars today are more efficient and powerful than ever. But the most common type, lithium-ion batteries, can on rare occasions catch fire, posing a serious safety risk. Insulation can help manage that, but only if it's fire-retardant and will fit into very narrow spaces. Solarcore Inc. introduced Sc_Foam_FR in 2024 to do just that. The thin, flexible, fire-retardant foam insulation that uses aerogel developed with NASA funding is making electric vehicles safer. And it's finding new applications in a number of industries that need efficient performance in extreme temperatures and also have heightened safety requirements.

Building codes include fire-retardant standards for insulation. A new aerogel insulation meets those requirements while providing sound-dampening. Solarcore created the new aerogel formula that insulates heating and cooling systems like the one made by AIIR, shown in this dorm room. *Credit: AIIR Products Inc.*

After launching the Oros clothing brand that employs a similar high-performance insulation (Spinoff 2018), Michael Markesbery, CEO of Solarcore, wanted to use what his teams learned about insulation to revolutionize the insulation industry as a whole.

"We started selling Solarcore Foam to other consumer clothing brands like Cabela's, LL Bean, and others," said Markesbery. "But we wanted to go broader, support more industrial applications — HVAC, batteries, automotive, and the like."

He first learned about aerogel technology after winning a scholarship from the Astronaut Scholarship Foundation for his undergraduate research.

That was the start of Solarcore's proprietary insulation, made using silica aerogel, a substance invented almost a century ago. The original aerogels were brittle and broke apart easily. So NASA's Kennedy Space Center in Florida worked with a company called Aspen Systems under Small Business Innovation Research contracts to create a flexible material that would meet aerospace needs, including insulating cryogenic fuels stored on a launchpad. Aspen ended up spinning off a new company, Aspen Aerogels.

Aerogel is made by creating a gel and then removing all the liquid through a process called supercritical drying. What's left is a solid so porous it's 95% air or more. When made with silica or fused with quartz, aerogel contains pores less than one-ten-thousandth the diameter of a human hair, or just a few nanometers. That nanoporous structure means aerogel contains more air than any known solid, which makes it an excellent insulator and extremely lightweight. It's also highly fire-resistant.

> *"NASA's been able to create some pretty amazing technologies that have had some amazing commercial applications."*
>
> *Michael Markesbery, Solarcore*

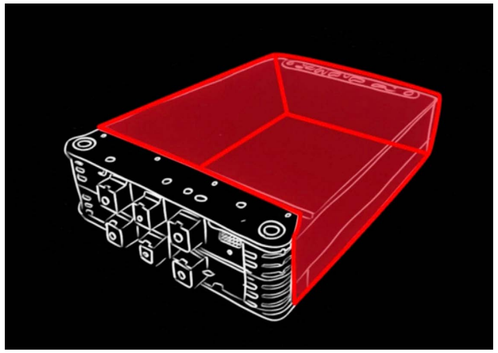
Solarcore infuses this version of aerogel into a polymer composite, fabricating insulation as thin as 2 millimeters.

Non-Toxic Insulation

Different industries have different fire-safety standards, so creating an off-the-shelf product that any company could use would mean meeting the most stringent requirements. While creating and testing formulas to accomplish that, Solarcore worked with a variety of ingredients and learned about their properties, including toxicity. If a fire does break out, what chemicals might be released when flames reach the insulation?

Previous experience in the clothing industry proved helpful for developing a formula that would not discharge toxins. "There's a lot of concern around what people are putting on their bodies," said Markesbery. "The most prevalent test methodology for safe clothing is called OEKO-TEX Standard 100. It tests for over 300 different chemicals and concerns. So we've made sure that we achieve that standard for Solarcore Foam used in consumer products." The new fire-retardant insulation was independently tested, allowing the Solarcore brand to meet the European Union Restriction of Hazardous Substances Directive requirements to limit the amount of hazardous chemicals in electronics.

For lithium-ion batteries used in cars, this is an added safety feature employed by several automotive customers in commercial cars and trucks. A battery pack contains multiple cells. One of those cells can malfunction and catch fire, and that fire can easily spread due to the proximity of other cells. That's called thermal runaway. A thin layer of this fire-retardant insulation packed between the cells can prevent that problem. If it ever becomes necessary to evacuate a vehicle when a battery cell fails, people have time to get out safely without the added risk of toxic fumes.



Solarcore aerogel in electric car batteries insulates against cold-weather impacts and adds a layer of safety by containing any thermal runaway event long enough for safe evacuation of the vehicle. *Credit: Solarcore Inc.*

Fire and Ice

Whether containing heat or maintaining a cool interior temperature, insulation no longer must be dense or require a lot of space to be effective, thanks to aerogel and thanks to NASA, said Markesbery.

"NASA's been able to create some pretty amazing technologies that have had some amazing commercial applications," he said. "We're one of many companies that had the benefit of being able to access that technology for the betterment of the commercial consumer markets."

The unique combination of safety, flexibility, and effective insulation appeals to AIIR, a heating and cooling company that manufactures compact residential HVAC units for homes and hotels. Lining the interior of the cabinet housing increases performance as well as dampening mechanical sounds. The units more easily meet building safety requirements.

Commercial airline customers are also addressing multiple needs in their airplanes. The insulation and acoustic properties help make the passenger cabin more comfortable. The same material can be used to insulate and isolate onboard appliances packed into a compact galley kitchen. As a result, the heat generated by running a microwave, coffee maker, and refrigerator poses less of a fire risk, and the lightweight solution reduces weight and makes the plane more fuel-efficient.

Recreational vehicle manufacturer Remote Vans is also using Solarcore insulation in its vehicles for similar reasons.

"The less you have to run your battery for heating or cooling, the longer you can go off-grid," said Markesbery. "Ultimately, that comes back to effective insulation throughout the cabin. The advantage of Solarcore foam is you're going to get far more thermal insulation at a fraction of the thickness of fiberglass or mineral wool insulations."

Less weight also improves the vehicle fuel efficiency.

The company is happy to customize the insulation to meet specific customer requirements. To date, the standard rolls of 3-, 5-, and 12-millimeter material have met all customer needs, ranging from commercial space to cold chain packaging for temperature-sensitive items like pharmaceuticals.

The original formula for Solarcore Foam, now called Sc_Foam, is also non-toxic and can be adapted. Customers like Alfa, a Norwegian footwear brand that uses Solarcore in a cross-country ski boot, are benefiting from the increased thermal performance and slimmer profile of the standard Sc_Foam. ●

"You're going to get far more thermal insulation at a fraction of the thickness of fiberglass or mineral wool."

Michael Markesbery, Solarcore

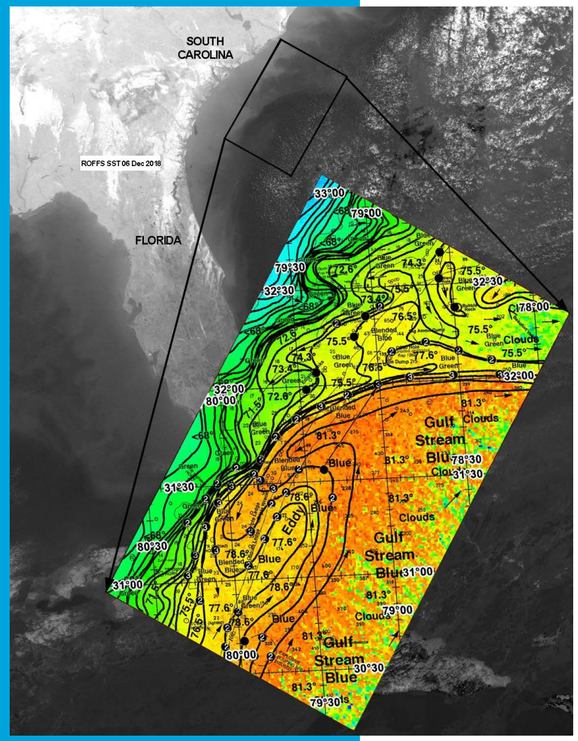
Insulation helps maintain the internal temperature of a recreational vehicle, making going off the grid more energy-efficient. That's why Remote Vans uses Solarcore to insulate its Aegis Series models such as the one shown here. The insulation adds little overall weight and supports effective heating and cooling. *Credit: Remote Vans LLC*

Forecasting Fish from Space

For four decades, company has used satellite data to guide sportfishing

Roffer's Ocean Fishing Forecasting Service, or ROFFS, of West Melbourne, Florida, uses data about ocean color and surface temperature, gathered by Earth-observation satellites and made available through Goddard Space Flight Center, to forecast the presence of big game fish for anglers.

Data from Earth-observing satellites is nothing if not versatile. Among other uses, these eyes in the sky help us look into the future to predict everything from the weather to worldwide crop yields to the behavior of sea ice. And for close to 40 years, satellite data has allowed one company to monitor and predict the movements and concentrations of game fish for sportfishing.



This example shows a forecast from Roffer's Ocean Fishing Forecasting Service (ROFFS) for the presence of big game fish in an area off the coast of South Carolina and Georgia. *Credit: Roffer's Ocean Fishing Forecasting Service Inc.*

In fact, in the early 1980s, NASA helped pioneer the concept, carrying out the two-year Fisheries Demonstration Program with the National Oceanic and Atmospheric Administration (NOAA) and other partners. They demonstrated that information on sea surface temperatures, combined with other data, particularly science-grade ocean color data — at the time from NASA's Nimbus 7 oceanographic and meteorological satellite — could support five-day forecasts that improved anglers' success rates.

In 1987, oceanographer Mitchell Roffer founded Roffer's Ocean Fishing Forecasting Service Inc. (ROFFS) (Spinoff 1988), using satellite data to provide real-time estimates of the preferred habitat locations and bait concentrations for marlin, tuna, sailfish, swordfish, and other game species, as well as both short-term and seasonal forecasts of their movements. He also made customized forecasts for boat racers and the shipping industry.

Today ROFFS has grown to a 10-person team led by owner and President Matt Upton, a longtime employee until he bought the company from Roffer in 2018. A lot has changed for the West Melbourne, Florida-based business since it was founded, especially the technology. Whereas Roffer, in the early days, hand-drew his indications on printed maps and distributed them largely by fax machine, the company's products today are all digital.

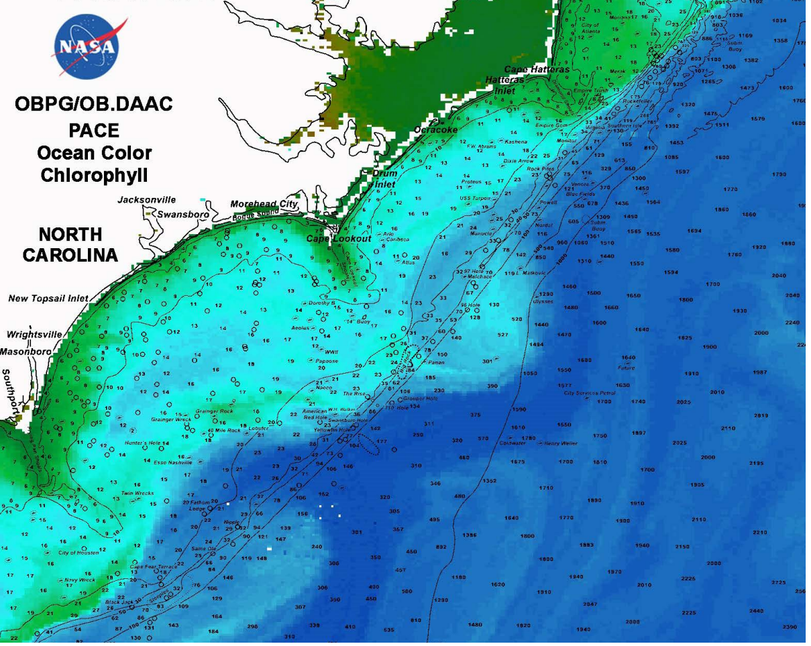
And ROFFS had to rely entirely on sea surface temperature data in its early years. The Coastal Zone Color Scanner on Nimbus-7 died the year before the company was founded, and the next ocean color-observing instrument didn't launch until 1997. By the early 2000s, there were enough instruments in space to start relying on ocean color data. Today there are a host of sophisticated instruments observing the oceans from orbit.

Both color and temperature data can reveal frontal boundaries where two distinct water masses meet. These fronts "provide convergence zones for life — phytoplankton, zooplankton, then bait fish that feed on them, and then that's where you find these larger pelagic fish that we help our clients find, like marlin, tuna, wahoo, dolphin fish," said Upton. "They're going to be where bait is."

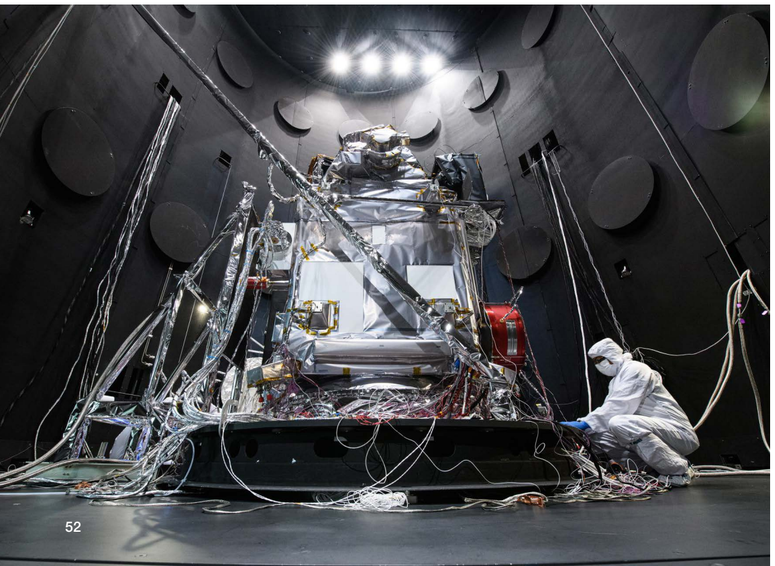
Water clarity can also affect the presence of some game fish, and knowing the ocean bottom structure and topography is important too, he said. Depending on the currents, large structures like ledges, canyons, reefs, and even shipwrecks can cause upwellings that carry nutrients to the surface, allowing phytoplankton — microscopic plant-like organisms — to flourish.

Collecting Oceans of Data

One of the main sources of data ROFFS relies on now is the Ocean Biology Distributed Active Archive Center (OB.DAAC) at NASA's Goddard Space Flight Center in Greenbelt, Maryland. The archive, which was created in 2004, continually pulls in global ocean color and surface temperature data from several



Ocean color data from NASA's new Plankton, Aerosol, Cloud, Ocean Ecosystem (PACE) satellite, shown here for an area along the shores of North and South Carolina, now helps ROFFS predict where algae will draw the small fish that bring in the big fish anglers like to pursue. *Credit: Roffer's Ocean Fishing Forecasting Service Inc.*



The PACE Observatory rests inside the Space Environment Simulator thermal vacuuum chamber at NASA's Goddard Space Flight Center before undergoing thermal environmental testing in June of 2023. Following its launch in early 2024, PACE became a valuable source of data for fishing predictions from ROFFS. *Credit: NASA*

Earth-observing satellites.

"We get all this data, and we make it available to the public for whatever use they want," said Sean Bailey, the oceanographer who manages OB.DAAC at Goddard. "Primarily, our focus is on scientists, but we do support these commercial communities as well."

Some of the data comes from the Moderate Resolution Imaging Spectroradiometer (MODIS) instruments on NASA's Terra and Aqua satellites, which launched in 1999 and 2002, respectively. The Visible Infrared Imaging Radiometer Suite (VIIRS) instruments aboard the three satellites in the Joint Polar Satellite System, a joint NASA, NOAA, and Air Force program intended as a follow-up to MODIS, are major contributors. And the center incorporates data from the Ocean and Land Color Instruments on two of ESA's (European Space Agency) Earth-observing Sentinel satellites.

Recently, ocean observers got a more refined tool when data from the new Plankton, Aerosol, Cloud, Ocean Ecosystem (PACE) mission became public. Whereas the MODIS instruments gather data in 36 spectral bands, and VIIRS in 22, the Ocean Color Instrument on PACE operates in 286 very narrow bands of wavelengths.

Ocean color is important to ROFFS mainly because it helps identify and verify frontal boundaries that tend to concentrate life, and it also can show the presence of chlorophyll, which indicates phytoplankton, the foundation of the marine food chain. PACE has such high spectral resolution that it can both detect the presence and concentration of phytoplankton and also differentiate between classes and species of them, Bailey said.

"It's nice and crisp and seems to be accurate," Upton said a few months after the company began working PACE data into its products. He also noted that data from the aging MODIS instruments has become less reliable with time. "So the introduction of PACE has really helped us out in the past few months."

Free Data Drives Economic Ecosystem

Bailey said ROFFS is one of about 1,500 entities and individuals around the world that use OB.DAAC's free subscription service. "Any user can say, 'I'm interested in this part of the ocean, so I would like you to save a copy of the data for that region and send it to me,'" he said. "So every time a satellite goes over the region of interest, the data are extracted and staged for the user to grab from us."

ROFFS then applies its own knowledge and in-house processing to the data to create its customized products.

Upton said predicting game fish locations for sports and recreational fishing makes up about 80 percent of the company's business. Most of that activity is on the East Coast from Massachusetts to the Bahamas and from Florida to Mexico. The company also supports fishing tournaments around Bermuda and Cabo San Lucas, Mexico. Upton estimated ROFFS has about 2,500 regular users in the United States.

"It'll blow your mind how much of the economy, especially on the East Coast, in the Gulf, and really anywhere, how many resources and jobs fishing brings," he said. "Even big fishing tournaments draw crowds and boost the local economy, everyone from boat builders to restaurants."

But predicting fish involves monitoring and predicting currents, and there's a market for that information too. Oil and gas companies need to monitor and foresee ocean conditions around their offshore rigs to manage underwater operations, and ROFFS also occasionally helps them find favorable currents for ship routing when they move a platform to a new location.

The company has also helped the government and universities identify bluefin tuna spawning waters, track contaminated runoff plumes after hurricanes, and monitor oil spills.

Upton noted that ROFFS is one of many entities that depend on Earth-observation data from satellites. "It's important to researchers, it's important to industry, probably more than people know," he said. "There are other companies like mine, and they rely on these satellites also. It's free data, and we want to keep it free and keep the data flowing and improving, and NASA does a great job at that. That's important."

Bailey said the advent of PACE and its ability to identify types of algae will allow new products. Already the high-resolution Sentinel instruments have enabled a system warning of toxic cyanobacteria in inland waters. "The spacecraft wasn't put up there to do that, but because we are measuring a variable that can be turned into a product, that can be used to support human health," he said. "These are the kind of things that come out of the science that we do. So it's important to look at Earth. We live here. We want to know what's going on and how best to plan for the future." ●

"It's important to look at Earth. We live here. We want to know what's going on and how best to plan for the future."

Sean Bailey, Goddard Space Flight Center

Big game fishing is more fun where the big fish are. ROFFS combines data from Earth-observation satellites with its own proprietary methods to predict where anglers will most likely find fish like marlin, tuna, swordfish, wahoo, and the mahi-mahi seen here. *Credit: Getty Images*

A Better Seat for the Seated

Experience meeting NASA requirements helped design innovative wheelchair cushion

Kalogon was founded in Melbourne, Florida, by a former NASA contractor, who used experience working on the Commercial Crew Program based at Kennedy Space Center to design a wheelchair seat that helps prevent blood clots and deep vein thrombosis.

Whether seated atop a rocket waiting to go to space or deskbound at work, sitting all day tends to not be good for the body. However, there are those who have no choice in the matter. According to the National Institutes of Health, people who need wheelchairs to move have a higher incidence of blood clots and deep vein thrombosis in the legs and lower body than others, due in part to pressure from wheelchair seats.

"We need to offload that pressure, but in a way that you don't have to move." said Tim Balz, founder and CEO of Kalogon Inc.

Kalogon manufactures specialized cushions designed to alleviate pressure. Balz became passionate about assistive technology in high school, where he started a nonprofit that would refurbish used wheelchairs and give them away to those who needed them. During college, he kept working on designs for a "smart" wheelchair, and soon after graduation, he accepted an offer to work at SpaceX.

SpaceX is one of the most prominent NASA contractors, especially in its role as part of the Commercial Crew Program. Balz worked at SpaceX's facility near NASA's Kennedy Space Center in Florida and helped to ensure the Dragon capsule met NASA's requirements for commercial human spaceflight, which were originally set in 2005 and have been consistently updated since.

"There are human factors, and there are performance factors. These are all things that have to be factored into the design of a vehicle," said David Francisco, technical fellow for human spaceflight standards at NASA's Johnson Space Center in Houston. "How much strength does it take to open a door? How much lighting is required? How long does it take to egress the vehicle?"

At SpaceX, Balz shuffled through multiple teams, covering all the different engineering needs for sending a rocket full of people to space. At the same time, he was working on what would become Kalogon's cushion. SpaceX had an open data policy, and while Balz was working on one project, he would

The Orbiter wheelchair seat was designed to help those in wheelchairs be more active. The blue cushion uses air bladders to improve blood flow and reduce sores. *Credit: Kalogon Inc.*

"Theoretically, we were trying to solve a lot of the problems that NASA was having with their spacesuits … Through that, I learned a good deal about making soft goods, and a wheelchair cushion has a lot of soft goods."

Tim Balz, Kalogon

see how the company was approaching others, particularly when it came to meeting NASA's requirements for the Commercial Crew Program, including spacesuits.

"The material the suits are made of has to be durable enough to hold the pressure but still maintain the flexibility to move. And whenever you talk about pressurizing something, you're always looking at how it's stitched," said Francisco. "At the same time, you don't want it to be so inflated that you can't move your hands or manipulate controls."

The spacesuits required by the Commercial Crew Program are only needed for "intravehicle" activity, meaning they're only exposed to a vacuum in an emergency. At the same time, these suits still had to provide protection for several situations, presenting the suit designers with many challenges to meet NASA's standards.

"I would go look up things and try to learn some of the creative techniques they were using at that point. Theoretically, we were trying to solve a lot of the problems that NASA was having with their spacesuits," said Balz. "Through that, I learned a good deal about making soft goods, and a wheelchair cushion has a lot of soft goods."

Not long after his departure from SpaceX in 2020, Balz founded Kalogon, based in Melbourne, Florida. Speaking with local customers about the issues they face being wheelchair-bound, Balz found that preventing sores and improving circulation was a much-needed benefit that a high-tech cushion could provide. Much like a spacesuit, which manages air pressure around an astronaut, Kalogon's cushion works by managing air pressure around a user's bottom. Inside the cushion, a half dozen air cells are inflated and deflated to constantly change where pressure is applied to the body. This pressure difference flexes blood vessels in the thighs and keeps blood flowing while the user is sedentary. Balz's research into how the spacesuits were built, how they manage pressure, and how the suits perform when astronauts have a rough landing have all played a part in designing Kalogon's technology.

Kalogon's "smart cushions" can be found in both homes and hospitals. The company's flagship product line is called Orbiter. And because it can quickly and easily change its shape, Balz says Orbiter offers flexibility that normal wheelchair cushions don't provide.

"We sit very differently when we're driving, versus when we're typing, versus when we're eating, versus when we're relaxing. If you use a normal wheelchair cushion, you get to pick one posture and it has to be your posture for everything," said Balz.

To fulfil NASA's requirements for Commercial Crew missions to the International Space Station, SpaceX had to design spacesuits that would be able to go to space and hold air in case the capsule lost pressure. These spacesuit designs would go on to inform the development of Kalogon's smart cushion. *Credit: NASA*

"With our product, people can click a button on an app and have the cushion change shape, allowing them to go do activities that otherwise would have been difficult.

In addition to the Classic edition, there is also Orbiter Med, which is molded specifically for individual users with special needs, allowing it to be covered by Medicare as a necessary assistance device. And Booster is a smart pump that maintains or adjusts the pressure in wheelchair air cushions in conjunction with the Kalogon app. As of late 2024, the company has sold thousands of units across its product lineup.

While the primary market for the cushion is wheelchair users, Kalogon is looking to expand to a wider audience. The company has received multiple Phase II Small Business Innovation Research contracts from the Air Force for a product called Orbiter Ace, which adapts its tech for B-52 and E-4B aircrews and is exploring options with the wider commercial aviation industry. In the future, Balz sees airline pilots and long-haul truck drivers using Kalogon cushions to keep their blood flowing. While pressure from seating isn't an issue for weightless astronauts, Kalogon is one more example of solutions for the many difficulties of space travel finding unexpected uses here on Earth. ●

Orbiter is designed to fit any wheelchair and is easy to install and control. *Credit: Kalogon Inc.*

"With our product, people can click a button on an app and have the cushion change shape, allowing them to go do activities that otherwise would have been difficult."

Tim Balz, Kalogon

The Orbiter Med is one of Kalogon's best-selling products. Its design can be molded to an individual's exact measurements, and its companion app lets users adjust the seat for various activities. *Credit: Kalogon Inc.*

For Battery Safety, KULR Heads Prevail

KULR Technology Group, based in Webster, Texas, has leveraged technology licensed from Johnson Space Center, earlier work done for the agency, and the long NASA experience of its chief technology officer to develop products and testing services around lithium-ion battery safety.

Company's work with NASA improves lithium-ion battery manufacturing, testing, packaging

About 15 minutes after takeoff on a January morning in 2013, a smoke alarm and an unusual smell caused a Japanese All Nippon Airways flight bound for Tokyo to divert for an emergency landing. The cause was traced to a short circuit in one of the eight lithium-ion cells in the Boeing 787 Dreamliner's main battery, which had triggered a "thermal runaway" incident. Heat from the cell had apparently melted insulation and let it contact a brace bar, unleashing currents through the battery box that overheated and short-circuited other cells.

Just days earlier, the lithium-ion auxiliary battery on another 787 parked at a gate at Boston Logan International Airport had spontaneously combusted shortly after passengers and crew had disembarked.

The Dreamliner was the first commercial aircraft to make extensive use of lithium-ion batteries. Following the two incidents early in its second year of service, the entire fleet — then 50 planes — was grounded pending investigation.

"This is a really good example of a NASA invention benefiting the entire battery industry."

Michael Mo, KULR Technology Group

The SafeCASE Sleeve, which incorporates Thermal Runaway Shield technology that KULR developed while working with NASA, is one of several products the company offers for safe storage and transportation of lithium-ion battery packs. *Credit: KULR Technology Group*

Since their first commercialization in the early 1990s, lithium-ion batteries have become increasingly important, first for powering consumer devices, then hybrid and electric vehicles, as well as aeronautic and defense applications. Now they're being eyed for powering flight in small passenger aircraft.

Affordable, packing a lot of energy into low mass and volume, and able to survive countless recharge cycles, lithium-ion batteries offer distinct advantages. But with flammable electrolytes that can ignite when things go wrong, they present a safety challenge that becomes even more dangerous in flight.

One company rising to that challenge is KULR Technology Group, headquartered in Webster, Texas. KULR is using several NASA technologies licensed through the agency's Technology Transfer program to consolidate its position at the forefront of lithium-ion battery safety.

The KULR ONE Space 400 series is the largest in a line of batteries KULR offers for space applications, based on NASA best practices and principles, as well as technology the company developed with the space agency. *Credit: KULR Technology Group*

Starting Thermal Runaway to Stop Thermal Runaway

By the time of the Dreamliner battery malfunctions, NASA too was using lithium-ion batteries. The agency was invited to join an investigation into the incidents and came away with its own concerns. The NASA Engineering and Safety Center (NESC) began looking for ways to stop thermal runaway from propagating from cell to cell within a battery. But it found there was no way to reliably model the phenomenon, which could be unpredictable.

"The thermal models kept indicating that if you trigger this cell into thermal runaway, all the other cells are going to propagate," said Will Walker. "But then they would run an experiment, and propagation wouldn't happen."

A video of a thermal runaway event exposed the reason: "A lot of the energy gets spewed out," Walker said. "So you've got to understand not just the total energy but the fraction — how much stays put, and how much gets ejected away?"

With funding from NESC, Walker, then a battery thermal engineer at NASA's Johnson Space Center in Houston, became one of the inventors of fractional thermal runaway calorimetry (FTRC). KULR, where Walker is now chief technology officer, has now licensed that technology from Johnson.

KULR also has an exclusive license for another technology developed at Johnson — the internal short circuit (ISC) device, which triggers thermal runaway for testing purposes.

When a company wants to prove a battery pack's safety, Walker said, the ISC can put it to the test. "You intentionally put a cell in there with an ISC device inserted so you can trigger thermal runaway quickly." Other methods to trigger a cell, like puncturing or heating it, bias it toward or against propagating to other cells, he said, whereas an ISC device mimics thermal runaway in the field.

KULR works with battery manufacturers around the world to get its ISC devices inserted into their cells to create trigger cells. The company then sells these to other companies or uses them in-house for testing as a service.

For in-house testing, the FTRC technology has become popular. KULR shares a NASA license for FTRC testing on small batteries and holds an exclusive license from the space agency for a large-format version of the testing. In both cases, the technique is used to determine the total energy released from a given lithium-ion cell during thermal runaway, the fraction of that energy that's transferred through the cell casing, and how much is ejected from the cell. That information is used to design and test battery assemblies that will stop thermal runaway from spreading.

Among the products KULR offers are lithium-ion cells screened in accordance with NASA Work Instruction 37A, which is in place to ensure reliability and safety for space missions. *Credit: KULR Technology Group*

Safety Standards Sell Cells

FTRC testing can also help inform and improve some of KULR's own products, such as the Thermal Runaway Shield (TRS), which wraps cells in lightweight carbon fiber and phase-change materials to draw heat from batteries and contain it. By 2017, the company was using this concept, developed with NASA and the Defense Department, in assemblies for lithium-ion battery packs (Spinoff 2020). It has now incorporated TRS into its SafeCASE product line — soft containers for safe transportation and storage of lithium-ion battery packs. Hybrid and electric car manufacturers, battery recyclers, and others are using the SafeCASE line to store battery packs.

One of KULR's newest product lines is the KULR ONE Space battery family. Previously, the market for space-worthy lithium-ion batteries was dominated by very high-end, multi-million-dollar custom units and lower-end, off-the-shelf varieties that may not meet rigorous standards. "With the emerging space economy, all of these startups with new satellites and probes going into space every year, there's a need for a new mid-tier battery," Walker said. "So the KULR ONE Space was meant to take all of NASA's best practices, principles, and strategies for designing a safe battery and to package it up into commercially viable options."

These range from a 100-watt-hour CubeSat battery to the 1- and 2-kilowatt-hour packs the company is making for one company's asteroid-mining probe.

KULR ONE batteries for electric aircraft and defense are also in development. These draw less on the company's space heritage, but one thing all KULR batteries have in common is that their cells are screened in accordance with NASA standards, which require every cell to be inspected for defects or inconsistencies.

The company recently set up an automated screening line to meet this standard, known as NASA Work Instruction 37A, at high volume, and the screening is applied to all cells used in KULR batteries. And the company also sells screened cells to other companies or screens other companies' batteries as a service.

And almost all the cells KULR sells or uses in its products come from a shipment that underwent initial spot-check screening by NASA. "That was a strategic procurement we made a few years ago, and then those are the cells we use in 90% of our batteries," Walker said.

All this work on safety and reliability has made KULR's products popular across the aerospace, defense, and automotive industries. CEO Michael Mo noted that the SafeCASE line has been quick to take off. "We're serving General Motors with that product, we're serving battery recyclers for storage, we've got a Department of Transportation special permit, and we're working with UPS," Mo said.

KULR's Thermal Runaway Shield technology (left), developed during work with NASA, uses lightweight carbon fiber and phase-change materials to contain the heat if a lithium-ion cell goes into thermal runaway. *Credit: KULR Technology Group*

"In terms of the internal short circuit device, it's used by over 80 customers now," he added. "We've got SpaceX, Tesla, Toyota, Volkswagen, all those companies, they're all using this product. All those are also customers for the FTRC test."

And Mo noted that FTRC testing to characterize thermal runaway behavior didn't even exist until NASA invented it. "This is a really good example of a NASA invention benefiting the entire battery industry," he said. "Something to test a battery going to space is now going to test for automotive batteries, defense batteries, electric aviation, you name it." ●

"The KULR ONE Space was meant to take all of NASA's best practices, principles, and strategies for designing a safe battery and to package it up into commercially viable options."

Will Walker, KULR Technology Group

Sparks fly after KULR technicians short-circuit a lithium-ion battery for testing. From NASA, the company licenses both internal short circuit devices to trigger thermal runaway and fractional thermal runaway calorimetry technology to measure and characterize the ensuing energy release. *Credit: KULR Technology Group*

Robots in the Operating Room

Small, minimally invasive, portable surgical robot developed with NASA support

Virtual Incision of Lincoln, Nebraska, used funding from Johnson Space Center to develop a mini surgical robot that's now authorized for colectomies. A version of the device designed for space successfully performed a demonstration on the International Space Station.

When surgeons on Earth remotely controlled a miniature robot in space to perform a series of snips, the surgical technology had come full circle.

Research that started decades ago with NASA funding led to an innovative set of devices for Earth-based surgeries, the MIRA Surgical System, before further customization made it ready for space. The U.S Army also helped fund the miniature system.

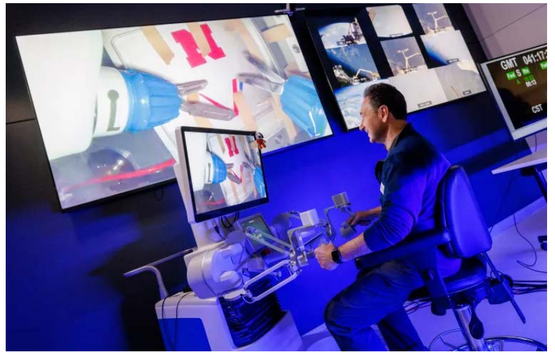
"Both NASA and the Army are interested in doing surgery in crazy places, and small lends itself to that," said Shane Farritor, cofounder and chief technology officer of Lincoln, Nebraska-based Virtual Incision Corp., which makes both MIRA devices.

Virtual Incision's MIRA Surgical System enables minimally invasive surgeries and can easily be transferred between operating rooms in a hospital or other surgery site. A surgeon controls the device from a console that's a few feet away or, potentially, much farther. *Credit: Virtual Incision Corp.*

Less than two weeks after the spaceMIRA demonstration on the International Space Station, which was in February 2024, the Earth-based MIRA system received marketing authorization from the Food and Drug Administration for colectomies — operations to remove part or all of the colon.

The commercial MIRA system — which stands for Miniaturized In Vivo Robotic Assistant — enables minimally invasive surgeries and can easily be transferred between operating rooms in a hospital or other surgery site.

"What we're pushing is simplicity," Farritor said.



Michael Jobst, a colorectal surgery specialist, makes the first surgical robotic cuts in space from Virtual Incision's offices in Lincoln, Nebraska. For the demonstration on February 13, 2024, surgeons cut rubber bands to mimic surgery inside a payload box on the International Space Station. *Credit: Virtual Incision Corp.*

NASA astronaut Loral O'Hara displays spaceMIRA on the space station. The device, a version of the terrestrial surgical system adapted for space, tested techniques for performing robotic surgery in microgravity in February 2024. *Credit: NASA*

"Our device is a lot simpler than other surgical approaches in a lot of ways, including that it's very small and transportable and easy to set up. It's also sterilized as it is, so there's no draping," he said, referring to the process of placing sterile plastic cloth over a device during surgery to prevent contamination and infection.

At 24 inches, the MIRA surgical device weighs about 2 pounds. The company described it as "substantially smaller" than any other mainframe systems on the market and said it contains some of the smallest motion control electronics that have ever been put in a medical device. The industry standard for surgical robots weighs well over a thousand pounds.

The MIRA contracts for insertion and then expands as needed, with two small arms that hug into the centerline and an integrated camera. The system also includes a companion cart and a console.

Surgeons control the instrument arms and camera from the console, which is equipped with "joysticks" and a screen that is usually a few feet from the operation. In the future, it may be possible to perform the procedure remotely — miles away, a continent away, or from Earth to space. Robot-assisted surgeries in general, compared to traditional procedures, reduce the number and size of insertions, which usually means less pain during recovery, a smaller chance of infection, and smaller scars, as well as potentially more precise movements.

In addition to the approved colectomy application, the MIRA device has been used in clinical tests for gynecological procedures, including hysterectomies. Virtual Incision is also looking to develop customized MIRA devices for other kinds of surgeries, such as gallbladder procedures, weight-loss surgery, and hernia repair, all of which could benefit from a smaller surgical system and smaller incisions.

"Both NASA and the Army are interested in doing surgery in crazy places, and small lends itself to that."

Shane Farritor, Virtual Incision

"It is a drastically different form factor than other kinds of surgical robots," said Baraquiel Reyna, who manages the Science Integration Office in NASA's Human Research Program at Johnson Space Center in Houston and has worked with Farritor for decades.

NASA supported MIRA through grants, mostly to the University of Nebraska, where Farritor is a professor of engineering. Virtual Incision, which was founded in 2006, has maintained its close partnership with the university.

NASA also supported the further customizations for spaceMIRA, including through grants from the Established Program to Stimulate Competitive Research, which aims to boost research capacity in certain states and regions.

"As we go further from Earth, we are going to have reduced communication, reduced materials, and reduced everything," NASA's Reyna said. "Medical conditions that require surgery during a mission would be extremely rare, but they are still a possibility, so tools like this could be an asset. There may also be other space opportunities for this small, dexterous robot that is capable of very micro manipulations."

Farritor said working toward NASA's various constraints helped define the MIRA Surgical System. "Trying to minimize volume, mass, and power really led us to this concept," he said. On Earth, keeping the device small allows hospitals to move it between operating rooms and could allow for surgeries in remote areas that don't have a dedicated surgeon – rural areas, perhaps, or the sites of wars or disasters.

For any space-bound system, keeping volume and mass at a minimum are top of mind, and Reyna said it's exciting to see those concepts translated into a completely different domain.

He noted that the Human Research Program's purpose is to promote astronaut health. "If we can benefit Earth at the exact same time, that's just kind of fantastic," he said. ●

Lunar Gardening Device Grows Health, Beauty Ingredients

Cosmetics industry leaders turn to planting system designed for space

It started as a farming system for the Moon or Mars. Now it's cultivating plant ingredients on Earth for cosmetics, nutritional supplements, and more.

The BioPod, a 17-foot-long, 8-foot-tall precision agriculture device, was developed by Interstellar Lab Inc. to hone the molecular composition of plants, isolating and enhancing particular nutrients or essences.

Interstellar sells the devices outright and also uses them to grow plants for companies.

Barbara Belvisi founded Interstellar Lab, whose U.S. office is in Merritt Island, Florida, while consulting with experts at Ames Research Center. Her early designs became the Earth-based BioPod for precision agriculture, before going on to inform NuCLEUS, in-space farming tech that won NASA's Deep Space Food Challenge.

"Recently we've been doing a lot of flowers for a contract with a large perfumer," Interstellar CEO Barbara Belvisi said. "Our warehouse smells beautiful."

Interstellar Lab has recently been growing flowers, like the rose-scented geranium pictured here, for a large perfumer. *Credit: Interstellar Lab Inc.*

'If We're Going to Live on Mars …'

Belvisi founded Interstellar in 2018, around the time she was working at NASA's Ames Research Center in Silicon Valley, California, as a guest of the Space Portal team, an ad hoc group that aims to promote commercial space and collaborations.

Belvisi was researching how to integrate a bioregenerative life support system into a planetary space station.

"If we're going to live on the Moon and if we're going to live on Mars," she thought, "how can we build a system that will produce the food we need and also recycle the water, produce the oxygen, and capture the CO_2?"

Belvisi, who said her company would not exist without the support of NASA, designed a network of pods for the Moon and Mars, with drawings based on the space agency's engineering and calculations for planetary greenhouses, and that plan became the basis for the Earth-based BioPod, Interstellar's first spinoff.

Mutual Benefits

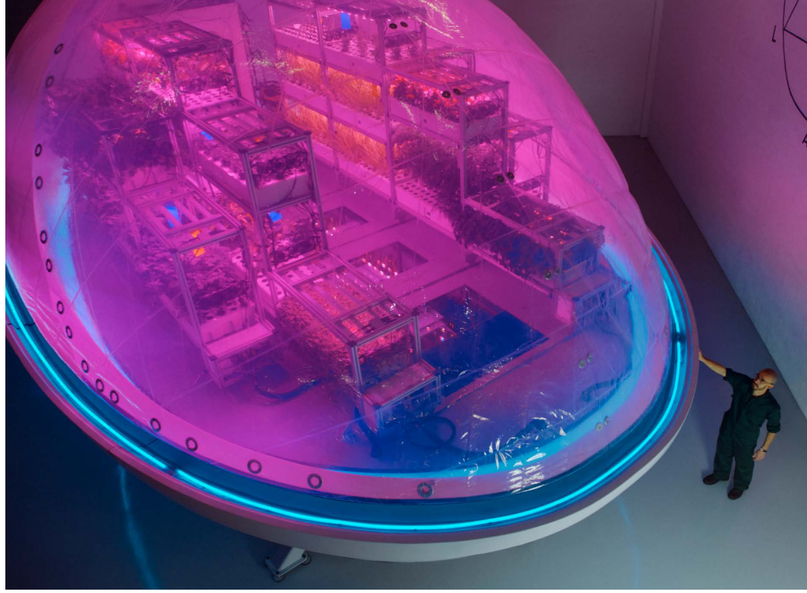
Dan Rasky and his colleagues at Ames who formed the Space Portal group some 20 years ago try to make NASA resources available to commercial endeavors that are aligned with the space agency's goals.

"NASA benefits from the commercial activities, and the commercial activities benefit from NASA's programmatic support," he said, explaining the thinking that resulted in multiple successes, including the first commercial spacecraft cargo delivery to the International Space Station in 2012.

"Interstellar Lab actually plays right into that," said Rasky, who worked with Belvisi through the Space Portal group. "She's doing things that are obviously on a business side, on a commercial side, but they're aligned with what NASA is trying to do, and it can clearly benefit NASA programs."

Rasky introduced Belvisi to scientists and others at Ames to discuss NASA's interests and requirements — exchanges that guided her own designs.

"We were impressed with the thoroughness of the work she was doing," he said. "She had a solid technical and business foundation for what she was proposing to do."



The BioPod, a 17-foot-long, 8-foot-tall precision agriculture device pictured here, was developed by Interstellar Lab to hone the molecular composition of plants, isolating and enhancing particular nutrients or essences. *Credit: Interstellar Lab Inc.*

Extracting Molecules

Plants produce two types of molecules: primary metabolites, which the plant needs simply to be alive and grow, and secondary metabolites, which help it adapt to its environment.

Pharmaceuticals, cosmetics, and the food supplement industry extract these secondary metabolites for their specific properties and characteristics, such as vitamin C taken from acerola, a red, cherry-like fruit.

Plants may increase their production of secondary metabolites as a reaction to environmental factors like less water, more light, or changes in temperature or humidity.

"That's what we do in our system," Belvisi said. "We look first at what kind of climates will trigger the production of the specific molecule, and then we recreate those environments inside our system to accelerate the growth of the plant and to make sure it is producing the alcohol or vitamin or nutrient that we are targeting."

Built with the constraints of space travel in mind, BioPods use 99% less water than traditional agriculture, eliminating waste and runoff, according to the company. They also collect and analyze data along the way.

Interstellar is currently using the device to grow plants for the cosmetics company L'Oréal, which aims by 2030 to bio-source nearly all of its ingredients from abundant minerals or circular processes.

Other customers include DSM, a large Dutch ingredient company that makes nutrition and beauty products; the Robertet Group, which develops raw materials and fragrances; and others.

“It’s kind of a thing at Interstellar to start with a space product and then move directly into Earth applications.”

Barbara Belvisi, Interstellar Lab

Another Spinoff

Interstellar, with headquarters in the Paris suburb of Ivry-sur-Seine and a U.S. office in Merritt Island, Florida, went on to adapt the concept back to an actual in-space device it calls NuCLEUS, or Nutritional Closed-Loop Eco-Unit System, which is a series of cubes that can fit on a space station or other small, off-Earth environment.

“Each cube has a different climate,” Belvisi said, “so we can grow different types of species in controlled environments and really optimize the growth of the plants inside our system.”

Belvisi said NuCLEUS is powered by the same technology as the BioPod.

“It’s a different form factor, but the same combination of hardware and artificial intelligence to autonomously recreate climates to grow plants,” she said.

Interstellar entered NuCLEUS in the Deep Space Food Challenge, which NASA held in collaboration with the Canadian Space Agency. The company won the grand prize of $750,000 in 2024.

Ralph Fritsche, a senior project manager for space crop production at NASA’s Kennedy Space Center in Florida, served as the head judge of the food challenge.

“Several things elevated the NuCLEUS concept above the others,” he said, noting that Interstellar’s offering leveraged the decomposing power of insects on inedible plant waste, which provides carbon dioxide that plants use as an input for photosynthesis.

“The components of NuCLEUS were designed for easy maintenance and repair,” he said. “The system also contains multiple individual growth chambers that provide not only system redundancy but flexibility for simultaneously growing a range of pick-and-eat salad crops, microgreens, mushrooms, and even insects.”

While Interstellar is in talks with NASA about further collaborations involving NuCLEUS, Belvisi said the company also has agreements with private space companies.

NuCLEUS also formed the basis of another spinoff called Pleiades, a smaller, modular farming system Interstellar uses to conduct research on more precise growing strategies for companies on Earth. Unlike the BioPod, which is designed to cultivate specialty plants at scale, the NuCLEUS-like system allows even more precise control over and monitoring of growing conditions.

Cameras and sensors enable researchers to watch plant reactions to the environment.

“It’s kind of a thing at Interstellar to start with a space product and then move directly into Earth applications,” Belvisi said. “It’s something that you find in all our product lines.” ●

“We look first at what kind of climates will trigger the production of the specific molecule, and then we recreate those environments.”

Barbara Belvisi, Interstellar Lab

Interstellar Lab researches what climates will trigger production of a specific molecule and then recreates those conditions inside the BioPod to quickly produce the desired vitamin or nutrient. *Credit: Interstellar Lab Inc.*

Interstellar’s NuCLEUS device, or Nutritional Closed-Loop Eco-Unit System, is a series of cubes that can fit on a space station or other small, off-Earth environment. It won the 2024 Deep Space Food Challenge, a NASA-Canadian Space Agency contest. *Credit: Interstellar Lab Inc.*

The NuCLEUS space-based growing system formed the basis of a second spinoff called Pleiades, a smaller, modular farming system Interstellar uses to conduct research on more precise growing strategies for companies on Earth. *Credit: Interstellar Lab Inc.*

Mapping a World of Data

Easy access to NASA data helps businesses and individuals

Esri's Living Atlas offers a bird's-eye view of Earth by combining free Earth-observation data from Goddard Space Flight Center with other resources. Continual updates by the Redlands, California-based company feed into apps that monitor everything from air quality and wildfires to hurricanes and shipping traffic.

Choosing a hiking trail through the Grand Canyon is easier with a map that shows current ground temperatures and where vegetation will provide shade along the route. Urban planning decisions can also be reviewed and modeled with maps to show the potential impacts of new roads and parks on mitigating flooding and reducing urban heat islands over time. These maps and others can be created using the ArcGIS Living Atlas of the World website or apps.

Esri's Landsat Explorer app maps colorized surface temperatures, collected from Landsat and other satellites, for a portion of the Grand Canyon. The app allows users to build a map of data for any location around the world. Some popular locations like the Grand Canyon are packaged for easy access. *Credit: Esri Inc.*

"You don't have to be a data expert."

Sean Breyer, Esri

Technology known as a geographic information system (GIS) that helps identify, organize, and analyze useful data serves as the foundation for numerous Living Atlas apps. Geospatial data about a location can be used to create maps providing popular data about air quality, wildfires, drought conditions, and more. Data compiled from thousands of sources, including NASA, makes it possible to view a wealth of information about any location around the world.

These free apps can be accessed using a smartphone, tablet, or computer. The data they rely on is constantly updated thanks to the efforts of the GIS user community and Esri, formerly known as Environmental Systems Research Institute Inc., of Redlands, California. The company developed and owns the ArcGIS platform and built the cloud computing infrastructure that allows any data provider to add their dataset in any format.

Living Atlas relies heavily on images and sensor data from Landsat satellites managed for NASA by Goddard Space Flight Center in Greenbelt, Maryland. Other datasets prepared by NASA contribute to apps that provide information about atmospheric conditions, such as weather forecasting, predicting and monitoring severe weather, and air quality. Data provided about ground conditions that can only come from sensors orbiting the planet helps agriculture, shipping, and other businesses.

"We have over 300,000 organizations using our software from almost every industry, and it's used by most Fortune 500 companies," said Sean Breyer, engineering director for the Living Atlas with Esri. "It maps information to support decision making."

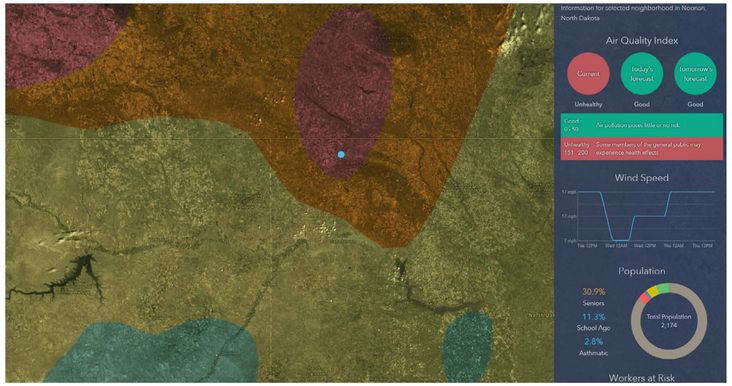
Esri doesn't control the information, but it maintains the infrastructure to support the spatial format, he said. The Living Atlas does help to curate the most popular geospatial data and organizes the information around specific topics for easy use. Esri's cloud-based ArcGIS infrastructure also provides computing power for users to perform their own analyses. Because the authoritative dataset creators retain control over their data, users can trust the accuracy and integrity of the results.

Data Expertise Not Required

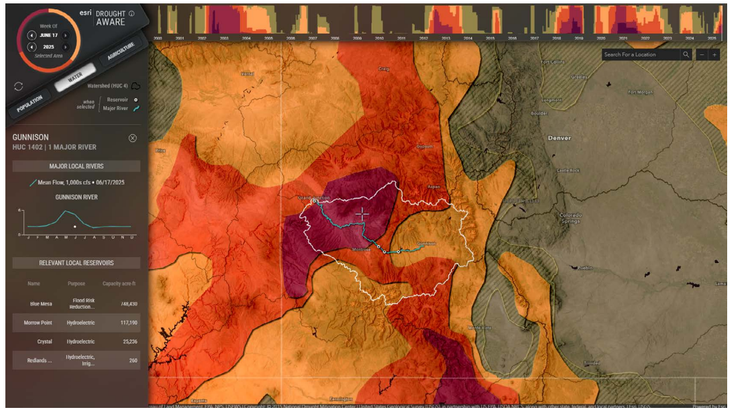
Numerous forms of data paid for with tax dollars are available to anyone. They are scattered across government agencies tracking things as varied as road networks by the Department of Transportation and demographics by the Census Bureau. Scientific information is just as dispersed, housed in institutions across multiple countries. And the companies that could benefit don't have the staff or computing power necessary to aggregate, sort, and analyze the information to extract only the pieces they need. "We take different datasets and roll them up into an app to make it really easy to use. You don't have to be a data expert," said Breyer.

The Living Atlas offers apps about some of the most common natural disasters, showing their impact on communities in the present and over time — Hurricane Aware, Wildfire Aware, and Drought Aware. Other apps provide different views of the Earth's surface — Historical Topo Map Explorer, World Imagery Wayback App, and Community Maps Editor. Some satellites with popular data have their own apps — Landsat Explorer, Sentinel-1 Explorer, and Sentinel-2 Explorer.

If a company is thinking about purchasing land for a new building, entering the address into the Drought Aware App displays decades of data that can help determine if an arid landscape plan is best or if an irrigation system will be necessary to maintain the grounds. Esri technology was used to create the "layers" powering these apps by training AI-powered deep learning models on petabytes of NASA and other data. The result is an app that quickly presents a satellite image of the address, graphs drought data, and offers related information about the area such as water sources, agriculture, and the population accessing that water. The Living Atlas includes roughly 10,000 layers of information providing insights and information resources curated from about 25 million data layers shared by universities, scientists, and other entities, including NASA.



Esri's Air Quality Aware app makes it possible for anyone to identify potential health risks. This map of Noonan, North Dakota, in June 2025 combines data from multiple sources, including NASA satellite data, to reveal the impact of smoke from wildfires burning in Canada. *Credit: Esri Inc.*

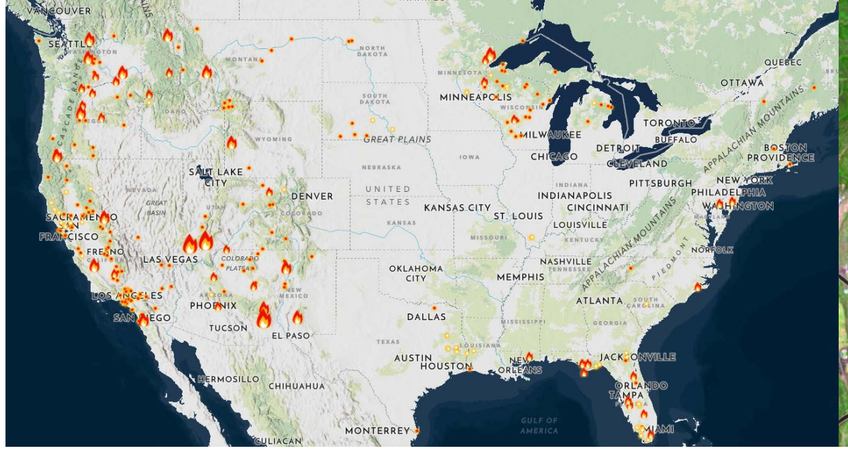


Does it seem like summers are drier than before? The Esri Drought Aware app compiles numerous sources of weather information with NASA satellite data to provide current information like this image of the Denver area along with local demographic data on the left and a long-term view of conditions across the top. *Credit: Esri Inc.*

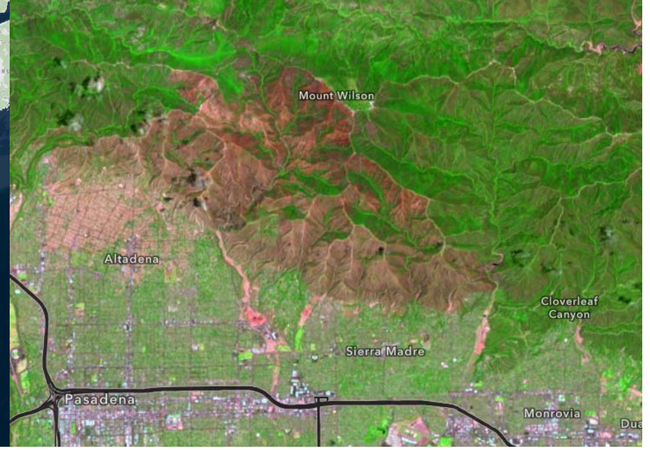
‘Amazing Stories’

Numerous satellites in low Earth orbit regularly transmit images and data collected by sensors updated daily or weekly. Some, like wildfire observations, are updated as often as every five minutes during the height of fire season. Esri has emergency management staff to help first responders and municipalities quickly access the local data they require. That’s because many of these organizations don’t have staff with data expertise to process the data NASA stores and prepares for use. The Earth Science mission includes helping end-users find what they need, said Katie Baynes, Earth data officer with NASA Headquarters in Washington.

“When we first started launching satellites and collecting information about Earth, we were primarily focusing on data for scientific research, study, and modeling by geophysical scientists,” she said. “But we realize that this data is also interesting to people who are building electrical grids or looking at infrastructure planning.”



Anyone can track the locations of all wildfires in the United States at any time. Statistics about each one, including data drawn from NASA satellites, are available in Esri’s Fire Aware app. *Credit: Esri Inc.*



Esri’s Wildlife Aware app maps the damage done by wildfires, called burn scars, using Landsat data. This image of the 2025 Eaton fire, which burned 14,021 acres just northeast of Los Angeles, shows the extent of the burn scar – the brown area on Mount Wilson and extending into the Altadena community. *Credit: Esri Inc.*

For companies coordinating marine shipping, Esri’s U.S. Vessel Tracking app provides invaluable data. NASA satellite data contributes to information about the movements of cargo, fishing, passenger, and other ships. *Credit: Esri Inc.*

“Content from NASA is an important foundational piece of what we do in Living Atlas.”

Sean Breyer, Esri

NASA has more than 130 petabytes of data housed at 12 archive sites, including some from the first satellites launched in the 1960s, that weren’t easy to access for non-technical users. So NASA partnered with Esri and other companies to move the most in-demand information to the cloud (Spinoff 2023). The company continues to share important insights about the ever-changing priorities of its users. Baynes is charged with overseeing and setting strategic direction for the 35-year-old science data systems program, and she’s particularly pleased about the effort to introduce younger generations to this resource.

In addition to supporting multiple NASA programs and projects to manage their GIS data initiatives, Esri collaborates with the educational website My NASA Data to provide the ArcGIS StoryMap Collection and related lesson plans for teachers and students. “These are just amazing stories about how to explore the data, explain how to evaluate data, teaching students the basics of scientific inquiry,” said Baynes.

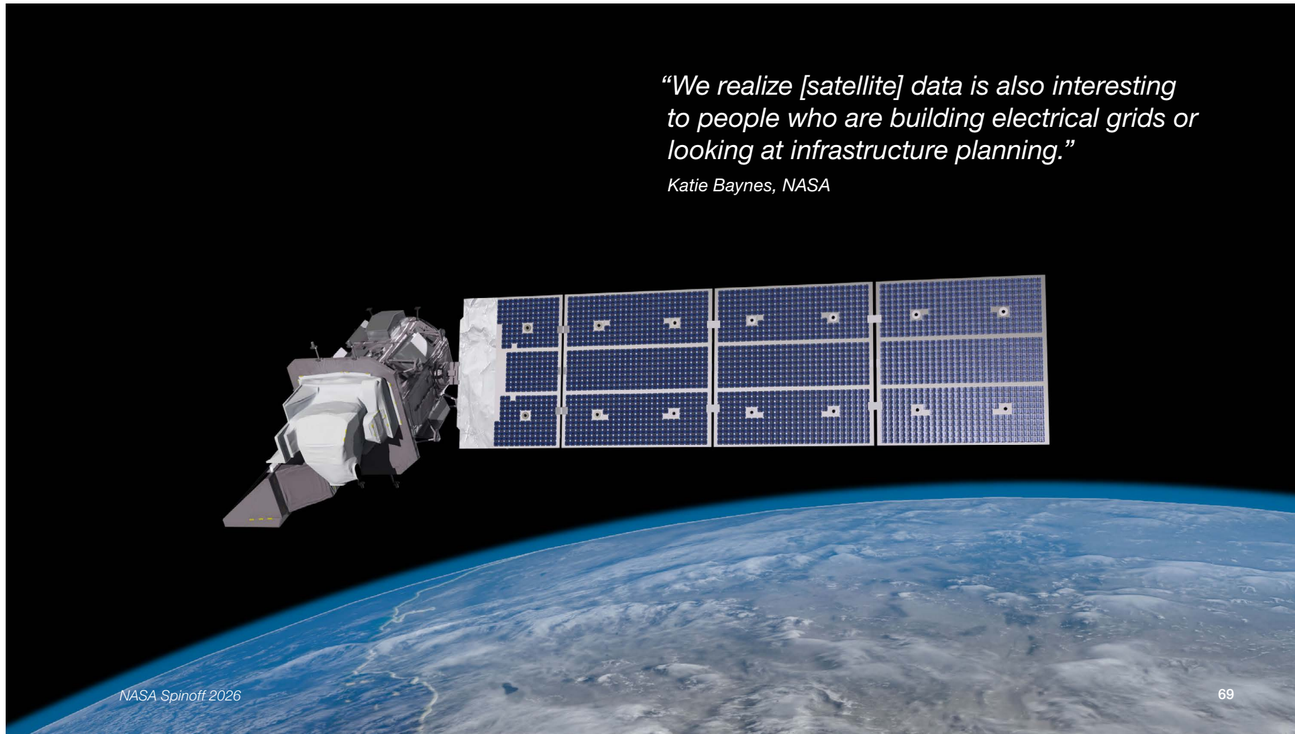
Counting Cars and Chlorophyll

A popular app Breyer highlighted uses satellite data to look for chlorophyll in the ocean as an indication of eutrophication, or lack of oxygen in the water, which impacts fishing practices, including recreational fishing. “We work specifically with people from the NASA biodiversity team to take the raw satellite data and process it into the useful chlorophyll thresholds around every country,” he said.

That data contained in the Living Atlas helps fisheries worldwide. Similarly, farmers can track moisture loss in fields and predict crop yields, while historic data about weather informs operations. Satellite data helps businesses count cars in a parking lot over time to identify shopping patterns and track weather to guide the placement of umbrellas or sunscreen near checkout lanes. Shipping companies can route goods and services based on the weather of the day and do long-term planning for shipping routes.

“It links directly back to NASA making that data available to our community in a ready-to-use format,” said Breyer. “Content from NASA is an important foundational piece of what we do in Living Atlas — sharing data in a way that is easy to use.” ●

The long-running Landsat Earth-observation program provides Esri with a wealth of historical data. Free of charge to anyone, the NASA data is easy to access and analyze using the company’s Living Atlas apps. *Credit: NASA*



Drone Company Makes It Rain Forests

Flying Forests cofounder builds on NASA science and technology experience

At Ames Research Center, Lauren Fletcher learned about building hardware around plant and animal biology. Later, he applied those lessons to create seedball-launching drones that are helping to reforest the planet, including at his latest company, Flying Forests of Reno, Nevada.

During a particularly rain-soaked week in Peru's Amazon jungle, not far from the city of Puerto Maldonado near the Bolivian border, 20 soldiers from the Peruvian Army helped Lauren Fletcher prepare ammunition for an upcoming operation. It was early December 2024, and the same alliance had conducted a similar mission a year prior, just up the Madre de Dios River.

With 20,000 rounds on hand, they waited for a break in the rain. When it finally came, the whole thing was over in an hour and a half.

All 20,000 seed balls, packed with seeds of the smooth Crotalaria plant, were deployed across 25 acres of barren, sandy soil, shot from a single drone equipped with a rapid-fire launcher, to combat environmental destruction in this important ecosystem.

This was the first step in reforesting the land, which had been stripped during gold mining operations. The Crotalaria, a hearty legume, would establish ground cover to allow the introduction of other native species.

Volunteers from the Peruvian Army and Wake Forest University's Center for Amazonian Scientific Innovation help to handmake thousands of seed balls to be launched by drone across 25 deforested acres in the Amazon jungle in late 2024. *Credit: Beta Earth LLC*

"You have to understand the biology first, and then you design the engineering to match the biology you're trying to support."

Lauren Fletcher, Flying Forests

This oyster toadfish was one of many living specimens flown to space in 1998 as part of NASA's Neurolab mission, which observed the effects of weightlessness on animals' central nervous systems. As a NASA employee, Lauren Fletcher helped design the Neurolab platforms that would experiment on various species in space. The Flying Forests founder later applied this experience of tailoring hardware to different biologies when he created drones capable of rapidly firing balls of different plant seeds. *Credit: NASA*

The soldiers were volunteers from a local military base, and Fletcher, thanks in part to his experience as a former NASA employee, had cofounded Beta Earth LLC, which does business as Flying Forests, the company that armed the drone and spearheaded the effort. Also on hand were several researchers from Wake Forest University's Center for Amazonian Scientific Innovation, which helped fund the operation.

Flying Forests, which Fletcher founded with Irina Fedorenko-Aula in Reno, Nevada, in 2020, is not the first company to use seed-launching drones to regrow forests. That would be the pair's first company, founded seven years prior.

Since Fletcher and Fedorenko-Aula created BioCarbon Engineering to harness what was then the very new power of drones for rapid, large-scale reforestation, several other companies have sprung up to do the same. But Flying Forests is the first to open up the technology for small-scale landholders.

From Animals in Space to Trees on Earth

At both companies, Fletcher leaned on his prior experience at NASA, at the intersection of technology and biology. As part of his 20-year NASA career, he worked in life sciences programs at the space agency's Ames Research Center in Silicon Valley, California. There, he qualified hardware for missions such as Neurolab, which studied the effects of weightlessness on the central nervous systems of animals of various species, and the Space Station Biological Research Program, which developed two major hardware suites for studying plants and animals in space.

"You have to understand the biology first, and then you design the engineering to match the biology you're trying to support," he said.

Later, while earning his Ph.D. under a paid NASA research program, he studied deforestation. When he tried looking into reforestation technology, he found that virtually none existed. "And I said, look, I work for NASA. We've got remote sensing, and we've got machine learning, and AI is coming along, and we've got robotic systems," he recalled. "There's got to be a way that we can combine these technologies to automate and accelerate reforestation."

When drone technology hit the market in 2013, he and Fedorenko-Aula started BioCarbon Engineering, and he built the first seed-flinging drone. "It immediately captured the world's attention," he said. Other companies followed suit.

While that company, now called Dendra Systems, has been successful, it and others in the field developed technology and business models that work at large scales but aren't cost-effective for smaller parcels of land. This locks about 80% of private forested landholders out of the conservation market, he said. "They're going to be the ones that are going to solve the majority of our reforestation problem around the world."

He designed a smaller, cheaper drone. Even more importantly, he said, Flying Forests operates on a franchise business model, equipping and employing local organizations that are already planting trees, with most of the funding that's generated going back to local workers.

Ancient Tech Meets High Tech

The drones don't launch individual seeds but rather seed balls, consisting of a clay-like base, plant food, and anti-predation materials such as garlic or cayenne pepper, with the seeds mixed in. Egyptians invented the concept thousands of years ago.

The technology to deploy the seed balls, on the other hand, builds on Fletcher's experience at NASA. It starts with a biology question, he said: "How do you get things to grow that you've basically thrown out the side of a drone?" Depending on soil biology, this might mean starting out by planting hearty ground cover to restore the soil, as was done in Peru.

Typically, several large datasets go into this decision-making, from hyperspectral satellite imagery and drone images of the area to ground surveys, to understand the local environment and what's needed for restoration. "The datasets are very large, and sometimes it's hard to understand what the relationships are. That's where the AI comes in," Fletcher said. Artificial intelligence can also help to create planting maps, considering factors like elevations and water distribution.

The species to be planted determines the size and nature of the seed ball, which must be as small as possible to maximize the payload.

"You start developing your science requirements wrapped around what's needed for restoration, which leads to your engineering requirements, and then you finally wrap in the operational requirements," Fletcher said. "You use that typical NASA hardware engineering development pathway. And then you develop the payload once you have all those requirements really understood."

His launching system is proprietary, but he says it's something along the lines of a spring-loaded catapult. It can launch 300 seed balls in a minute at an accuracy within about half a yard. He notes that others achieve even greater accuracy at the expense of speed. "My system goes for larger distribution, lower cost by boosting the planting rate."

Four drones could plant 40 million trees per year, enough to meet the demand from small-scale landholders in most countries, he said.

In its first five years, the company carried out demonstrations in Panama, Peru, and Kenya, planting a total of around 200,000 trees. Much larger projects are getting underway in Peru, Brazil, Indonesia, and the Bahamas, and the company is in discussions with several other potential partners, Fletcher said.

In June of 2024, volunteers with Flying Forests' reforestation efforts examine a formerly barren area in the Peruvian rainforest that they sowed with seedballs only the previous November. Now this crop of smooth Crotalaria provides ground cover to allow other native species to take root. *Credit: Beta Earth LLC*

Fletcher poses with the Flying Forests drone he outfitted with a rapid-fire launcher to carpet 25 acres of deforested Peruvian jungle with balls containing the seeds of a hearty legume species. *Credit: Beta Earth LLC*

Volunteers with Flying Forests' efforts to reforest the Peruvian jungle send up a drone laden with seed balls in December 2024. In an hour and a half, the little aircraft peppered 25 acres of deforested land with 20,000 balls containing the seeds of the hearty smooth Crotalaria plant, along with plant food and materials to deter predators. *Credit: Beta Earth LLC*

By late 2026, he said, he hopes to have rolled out full business operations in at least two countries. Under the company's franchise approach, this will mean working with organizations that already understand an area's ecology and have relationships with the local and federal governments. The company will hire and train local drone operators, technicians, remote sensing analysts, seed ball manufacturers, and managers. A revenue-sharing arrangement incentivizes forest maintenance after the planting is done.

Funding can come from various sources, including carbon credits, governments, foundations, landholders, and others.

Tree planting is often framed as carbon capture, but Fletcher thinks of it more as restoring "ecosystem services," the many benefits, direct and indirect, that ecosystems provide people. For example, loss of rain forest means less local precipitation. A degraded ecosystem doesn't support a healthy soil nutrient cycle. All this hurts local agriculture, and the effects are also felt offshore in fisheries, where less water is carrying fewer nutrients to sea, he said. Healthy forests are key to reversing those trends.

"At the end of the day, NASA's technology has been a centerpiece to helping us develop new technologies to manager our critical resources like fisheries, rivers, and forests," Fletcher said. ●

From Pluto to Farms and Pharmaceuticals

Water-finding filter for dwarf planet helps out on Earth

A filter technology used in numerous NASA spectrometers, including the one Goddard Space Flight Center built for the Pluto-exploring New Horizons probe, is at the heart of Chandler, Arizona-based VIAVI Solutions' MicroNIR, a handheld spectrometer that analyzes materials and ingredients on Earth.

A NASA spacecraft currently flying through the Kuiper Belt is carrying technology that is now supporting pharmaceutical manufacturing and other applications on Earth.

A linear variable filter, or LVF, from Chandler, Arizona-based VIAVI Solutions Inc. has been refined over multiple NASA missions. VIAVI incorporates similar LVFs in its MicroNIR family of miniature spectrometers, which are used in pharmaceutical manufacturing and agriculture.

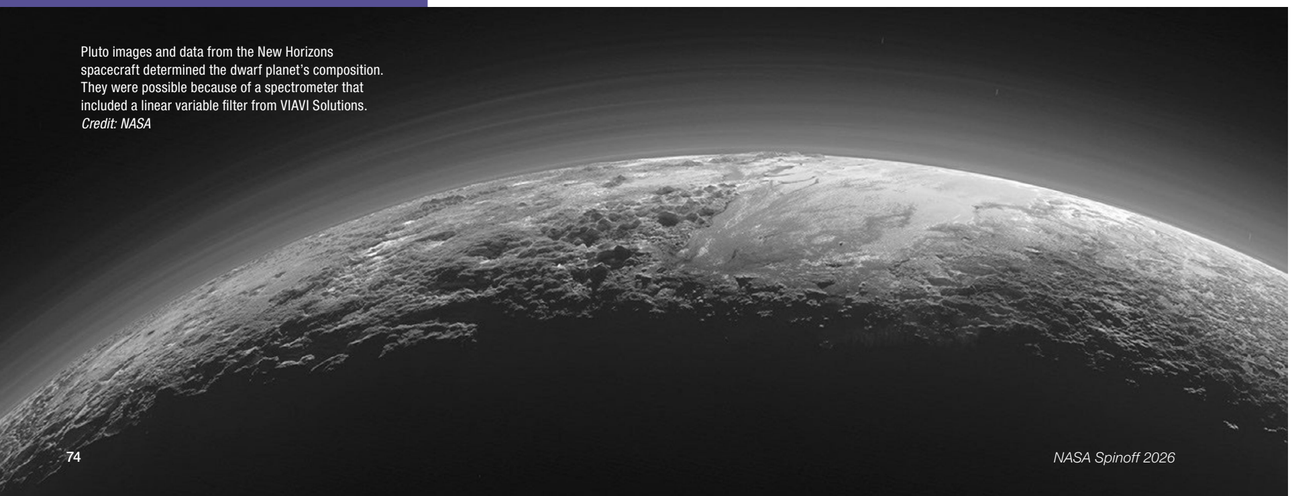
VIAVI's linear variable filter is flying on NASA's New Horizons spacecraft, which launched in 2006, reached Pluto in 2015, and continues to explore the Kuiper Belt, a region of icy objects and dwarf planets in the far reaches of our solar system.

"Before the NASA work, we had early prototypes of spectrometers utilizing our LVF technology, but they weren't as well engineered as the MicroNIR is," said Michael Klimek, who manages spectral sensing research and development for VIAVI in California.

"At the time, spectrometers were bulky, benchtop instruments," he said. "By leveraging our LVF technology, we were able to shrink the spectrometer to the size of a golf ball and optimize the power consumption of the device, a major innovation that has opened new applications and markets for spectroscopy."

Small and Light for Pluto

NASA uses spectroscopy to determine what planets and their atmospheres are made of by analyzing how light in the visible and non-visible ranges interacts with matter. While there are various ways to outfit a spectrometer, the linear variable filter has advantages, including size, simplicity, and the ability to adapt to different tasks.



Pluto images and data from the New Horizons spacecraft determined the dwarf planet's composition. They were possible because of a spectrometer that included a linear variable filter from VIAVI Solutions. *Credit: NASA*

The same filter technology that enables NASA to identify what planets are made of lies at the heart of VIAVI Solutions' Earth-based handheld spectrometers, one of which is pictured here analyzing ingredients in a food production setting. *Credit: VIAVI Solutions Inc.*

Dennis Reuter led the team at NASA's Goddard Space Flight Center in Greenbelt, Maryland, that developed the New Horizons instrument. That included the Linear Etalon Imaging Spectral Array, or LEISA, which carries the VIAVI filter. He said the simple assembly of LVF spectroscopy was an advantage.

"You just put this filter over the detector, and there's your spectrometer," he said.

Also, the filter can be designed to detect narrow spectral bands without picking up the bands in between, limiting the information — and, therefore, the data transmission needs — to what is useful, another space-saving feature.

"If you're going to Pluto, you want things to be light and small," Reuter said. "You can design this thing specifically for what you're looking at, and that also means you end up with less data, and smaller data volumes coming down, which makes a big difference."

By the time the New Horizons mission came around, NASA had already worked with VIAVI on a linear variable filter for a spectroscopy instrument on the Earth Observing-1 satellite, which launched in 2000.

"We had already had some back-and-forth with them, and the filter improved every time," Rueter said.

New Horizons in 2015 began sending back data from Pluto, including surprising images revealing previously undetected water ice and nitrogen ice, in addition to the methane ice scientists knew about. In 2016 Reuter and his team were finalists for a Samuel J. Heyman Service to America Medal for their work on the project.

The spacecraft is currently twice as far from Earth as Pluto and still making discoveries, though light is limited so far from the Sun.

VIAVI has continued to develop the filter for new NASA missions, such as Lucy, which launched in 2021 and will carry out surveys of the Trojan asteroids in Jupiter's orbit from 2027 to 2033, and the Europa Clipper, which launched in 2024 and is scheduled to arrive at Jupiter's moon Europa in 2030. The filter is also on the Spectro-Photometer for the History of the Universe, Epoch of Reionization and Ices Explorer or SPHEREx, an astrophysics mission that launched in 2025 and plans to spend the next two years collecting data on the full sky, including hundreds of millions galaxies and more than 100 million stars in the Milky Way to explore the origins of the universe.

Robust and Repeatable

Some of the same features that made VIAVI's linear variable filter attractive for a deep space mission also benefit terrestrial users of the MicroNIR family of miniature spectrometers.

The filter is monolithic, meaning there are no moving parts. "That makes it very robust and highly repeatable," VIAVI's Klimek said. "And, what's becoming more and more important, it has a very low unit-to-unit variability."

Initially, VIAVI focused on the device, relying on customers to build their own software models to analyze the raw data for their particular purposes. But the company found it could expand its customer base vastly by offering more assistance with data analysis.

VIAVI is currently helping agricultural customers use the handheld version of the MicroNIR to determine the best harvest times. In pharmaceutical manufacturing, VIAVI's spectrometers support blend and content uniformity. The MicroNIR also helps food producers detect fraudulent foodstuffs, grade produce on location, and assess key attributes such as moisture, fat, and protein content. ●

Saving Lives at Sea and on Land

Satellites carrying Search and Rescue Satellite-Aided Tracking technology act as the link between emergency beacons and worldwide search and rescue teams. ACR Electronics of Fort Lauderdale, Florida, manufactures locator beacons according to specifications developed in part by Goddard Space Flight Center, contributing to more than 63,000 rescues.

Emergency rescue thanks to satellite-based locator beacon

A boat can sink in under a minute, stranding passengers miles from land and leaving them virtually invisible amid the vast expanse of water. Survival can depend on emergency supplies such as a personal locator beacon (PLB) and emergency position-indicating radio beacon (EPIRB) to alert search and rescue teams. When a competitive fishing trip went wrong for Easton Barrett and his friends 40 miles off the Gulf Coast of Mississippi in 2024, a PLB helped the U.S. Coast Guard rescue the people clinging to coolers and treading water after being head-butted by sharks.

When a boat sank under Easton Barrett and three of his friends, the group was rescued after four hours in open water, thanks to a personal locator beacon (PLB). Now Barrett only goes out on the water with his emergency equipment in case disaster strikes. *Credit: Easton Barrett*

The group of five experienced boaters started the fishing competition by adding a last-minute piece of gear, a PLB, that a friend suggested they take just in case. It ended up sitting on a console instead of going into a locker, making it easy to grab later, when the friends realized their boat was sinking. Barrett said by the time they saw the engines were almost underwater, they only had seconds to put on lifejackets.

Realizing they had no cell service and their phone batteries were running low, they activated the PLB, which sent a distress signal to the Search and Rescue Satellite-Aided Tracking (SARSAT) technology carried by multiple satellites in middle and low Earth orbit. In the SARSAT system, developed in part by NASA, a dedicated frequency of 406 megahertz relays an emergency signal from anywhere around the world to satellites that send the transmitter's location to the nearest available ground station. A mission control center alerts rescue coordination centers to mobilize search and rescue crews for land or water emergencies.

For Barrett, that was a Florida Coast Guard boat, and he talks about the rescue whenever he can.

"Ever since, I have tried to teach others about safety on the water and in the outdoors by using a PLB," said Barrett. "If that will save one life, it's worth the effort."

Registered beacons, including the ResQLink PLB Barrett and his friends had, developed by ACR Electronics Inc., prompt a notification to the device owner's emergency contact, indicating a distress call was activated. All emergency beacons must meet the same strict system requirements. The rugged, buoyant, hand-held devices have a five- to 10-year battery life. Mikele D'Arcangelo, vice president with the Fort Lauderdale, Florida-based company, said the beacons continue to improve over time.

Worldwide Rescues

Congress initiated the satellite-based locator system after a 1972 airplane crash in a remote region of Alaska, impossible to find using technology of the day. NASA developed new technical specifications in conjunction with other U.S., Canadian, and French partners. NASA also developed the technical requirements for ground stations, PLB hardware, and signal monitoring improvements (Spinoff 2021, 2012, 2000, and more).

SARSAT began operations in 1982 before merging with a similar system developed by the Soviet Union known by the acronym COSPAS. The international COSPAS-SARSAT system began joint operations in 1985 using flight and ground technologies originally developed at NASA's Goddard Space Flight Center in Greenbelt, Maryland, where the agency's Search and Rescue office is located. Now there are 62 operational satellites in the program and 45 nations contributing services, from operating ground stations to providing rescue crews for aviation, ground, and water emergencies. The international collaboration is extremely successful.

In 2024, 411 people were rescued from life-threatening situations in and around the United States, according to the National Oceanic and Atmospheric Administration, which operates SARSAT. Barrett and his friends were five of over 63,000 lives saved by rescue operations since 1982. Advances in technology ensure rescues in remote locations can take place faster.

After the Global Positioning System (GPS) was established, locator beacons were adapted to include location information, which previously was computed by the satellite system using a method called "Doppler shift." The satellite emergency notification transmits once every 52 seconds, and GPS data makes it easier for rescuers when the transmitter isn't stationary.

Subscription-Free Safety

Airplanes, both small and commercial, now carry rescue beacons that use the COSPAS-SARSAT 406 signal. Boats are also using the emergency system. An innovation for marine transmitters is the addition of data from the mandatory automatic identification system (AIS). This homing signal uses a different frequency to provide a boat's course and speed. Locator beacons with AIS alternate between sending the position and AIS data, giving rescuers position information for at least 24 hours, longer if environmental conditions don't impact battery life.

Turning on a ResQLink View PLB from ACR Electronics will automatically "ping" orbiting satellites that send location information to the nearest search and rescue station. Whether on land or water, the appropriate resources will be dispatched to help anyone in distress anywhere in the world. *Credit: ACR Electronics Inc.*

A recent innovation is the first two-way communication signal between a beacon and the satellites. If a beacon is equipped with "return link" technology, it can receive a response from a satellite acknowledging the signal. The red and green lights on the beacon will flash blue. D'Arcangelo described it as a lifeline in a distressing situation.

> *"There's no subscription, and there's no cost for being rescued."*
>
> *Mikele D'Arcangelo, ACR Electronics*

"That blue light lets the survivor know their signal has been received. 'Someone somewhere got my signal, and they know I need help.' That's a critical emotional change for that survivor," he said.

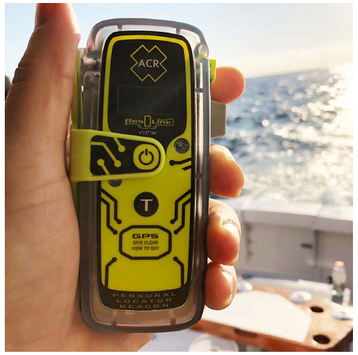
Not everyone will be in extreme conditions requiring that level of security, so ACR has a variety of locator beacons with different features in addition to emergency notification. The PLB Barrett and his friends used is normally carried by campers, hikers, or anyone engaged in land-based activities. But as the water rescue showed, any beacon will begin a rescue operation. That's why D'Arcangelo noted anyone going to sea or venturing into the wilderness can benefit from carrying a PLB.

A regular downhill skier in a high-risk avalanche area might prefer a longer battery life than someone simply going off-grid in a national park. The goal is to ensure cost isn't a barrier to safety and to

The U.S. Coast Guard is just one of many search and rescue resources mobilized to assist people when a distress beacon is activated in the water. Training exercises like this help keep skills sharp. *Credit: U.S. Coast Guard*

dramatically reduce the time it can take to find a missing person. Barrett and his friends might have been rescued within an hour, but they were turning the beacon on and off, not realizing the battery would last longer than a standard mobile device. As it was, the Coast Guard found them within four hours.

"Something like 3% of boaters have these beacons. That's way too low," D'Arcangelo said. "It's very easy to be out of cellphone range if you're out far on the water or you're deep in the woods. Unlike satellite products that require subscriptions, COSPAS-SARSAT is a government-funded satellite operation. There's no subscription, and there's no cost for being rescued." ●



Credit: ACR Electronics Inc.

Clipping on a PLB when you're hiking on a mountain or fishing on the water and far from a cellphone signal can make a rescue easier. When activated, these waterproof, buoyant beacons, like the one shown here, made by ACR Electronics, will send location data approximately every minute for at least 24 hours to guide search teams. *Credit: ACR Electronics Inc.*

"Ever since, I have tried to teach others about safety on the water and in the outdoors by using a PLB. If that will save one life, it's worth the effort."

Easton Barrett, ACR customer

Mission: Home

After 3D printing a model Martian habitat at Johnson Space Center, ICON built a 100-home community outside of Austin, Texas, where the company is headquartered.

Texas community is 3D printed like a Martian habitat

A Texas neighborhood of 100 brand-new curvy-walled homes was constructed with a 3D printer that also built a model Martian habitat for NASA. The technology may now be headed for the Moon.

Austin, Texas-based ICON Technology Inc.'s enormous Vulcan 3D printer extrudes a proprietary concrete mix print material to build up the walls of the home, layer by layer, for dwellings on Earth and, eventually, beyond.

ICON's collaborations with NASA began with the 3D Printed Habitat Challenge in 2019 to create shelters for Mars and other deep space destinations. A few years later, ICON won a NASA subcontract to 3D print a Mars habitat analog, a dwelling that crew inhabit on Earth for a year at a time as NASA studies the psychological effects on astronauts of a long stay on a distant planet.

Since then, the company has built more than 200 homes and other structures on Earth and won major NASA contracts.

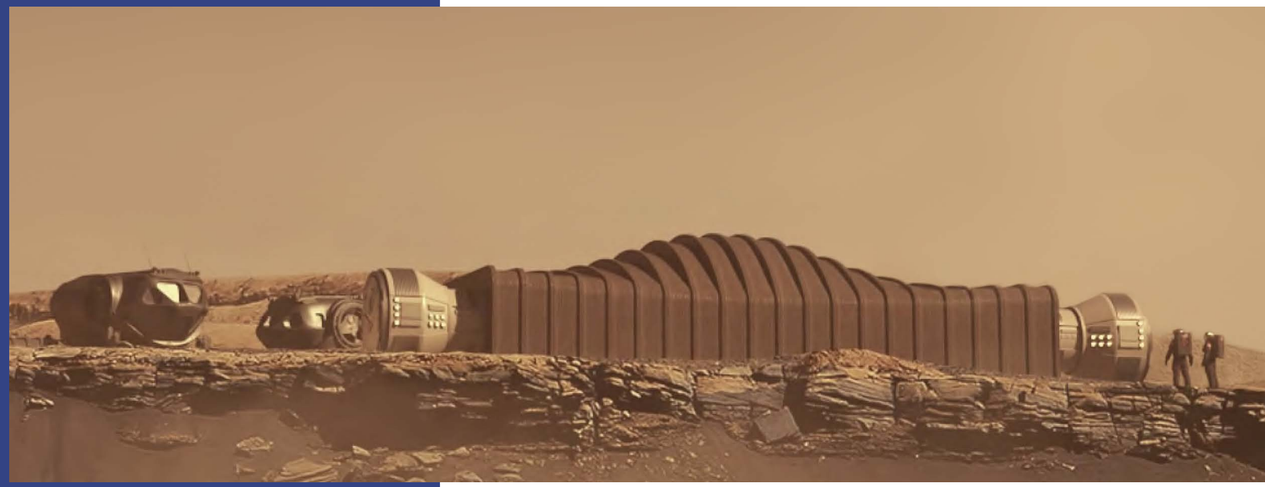
"Every project we complete introduces a new opportunity to think about how technology can improve the way we build, making it faster, more sustainable, and more beautiful in design." said Evan Jensen, ICON's senior vice president of engineering. Each project informs the next.

A Competition That Spurred an Industry

When NASA began designing its Mars Habitat Challenge over a decade ago, most 3D printers were boxes that might print out a trinket or ideally a useful part for something, recalled Monsi Roman, the competition's program manager at the time.

"We went from those boxes to the vision of 3D printed dwellings," she said. "But practically speaking, we still had to get to that level."

The NASA program spurred the entire industry of structural 3D printing, from wall systems to encouraging innovative print materials that could incorporate resources on the ground. Ideally, missions to the Moon or Mars will be able to build



After 3D printing a model Mars habitat at Johnson Space Center, illustrated in this artist's rendering, ICON printed a 100-home community outside of Austin, Texas. *Credit: ICON Technology Inc.*

ICON built Wolf Ranch, the world's largest neighborhood of 3D printed houses, in Georgetown, Texas. The company worked in collaboration with homebuilder Lennar, which handled the roofing and finishings. *Credit: ICON Technology Inc.*

with lunar or Martian regolith, the finely crushed surface rock dust, instead of transporting building material through space.

ICON was a finalist in the seal test stage of the habitat competition, which tested airtightness, qualifying it for the final round of the challenge later in 2019, but the growing company was not able to compete in the next level. ICON's signature Vulcan 3D printing system was headed to Tabasco, Mexico, to print houses for the underserved, which have since withstood a major earthquake. That project was in partnership with New Story Homes, a nonprofit that helps inadequately housed people become homeowners.

Stepping Stone

ICON's limited participation in the 3D Printed Habitat Challenge still bore fruit.

After the challenge had concluded in 2019, ICON CEO Jason Ballard met up with Roman at NASA's Marshall Space Flight Center in Huntsville, Alabama, while dropping his kids off at camp.

"He started telling me what ICON was doing, and I asked him to stay sitting right there while I ran to get one of the executives from our group," Roman recalled. "I said, 'You need to listen to this,' and after that, we started working with them."

ICON was already working on a project to rapidly build living quarters for the U.S. Air Force, with Small Business Innovation Research (SBIR) funding. The work resulted in a 3,800-square-foot training barracks in Bastrop, Texas, that was, at the time, the largest 3D printed structure in North America, according to the company.

Since then, ICON has also printed barracks and other structures for the Army, the Marine Corps, and other military organizations, all of which appreciate the speed of ICON's 3D printed construction as well as the ability to locally source raw materials for CarbonX, ICON's low-carbon concrete blend.

NASA ended up joining that initial Air Force SBIR effort in 2022, with a six-year, $57 million Phase III contract for lunar surface construction technology.

'Truthfully, It's Beautiful'

"The Mars Habitat Competition introduced a number of opportunities," ICON's Jensen said, citing the major SBIR award as well as an earlier project, the Crew Health and Performance Exploration Analog, or CHAPEA.

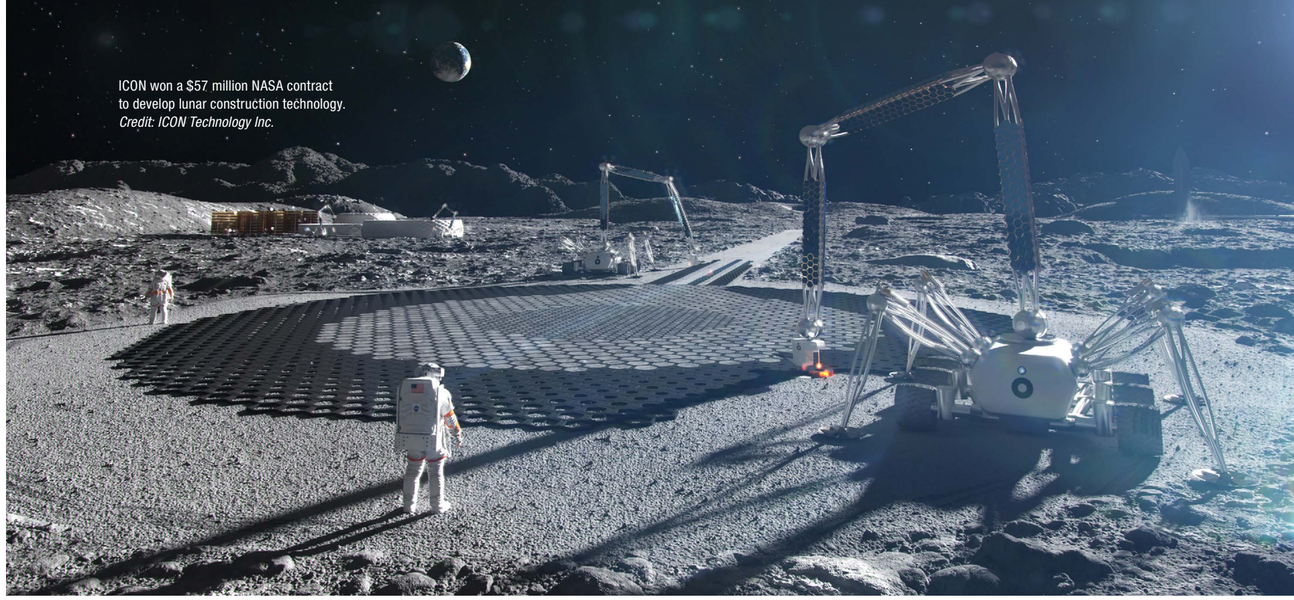
Before the lunar construction project, Roman had suggested that ICON and other companies from the habitat challenge respond to the request for proposals for the CHAPEA, the project to print a life-size model Mars habitat in a hangar at NASA's Johnson Space Center in Houston.

The CHAPEA dwelling is the one that houses crew members during a series of yearlong simulated Mars missions.

ICON ended up winning the subcontract in 2021 from Jacobs, the contractor that oversaw the construction of the 1,700-square-foot analog building called Mars Dune Alpha. The team that sorted through proposals and chose the winner had no ties to the Centennial Challenge.

"It was the first time that a structure like that had been 3D printed," said NASA's Roman, referring specifically to the printed dome roof. "And truthfully, it's beautiful."

The Wolf Ranch neighborhood includes eight floor plans designed by the Danish Bjarke Ingels Group, which also collaborated on the Mars habitat ICON built for NASA. *Credit: ICON Technology Inc.*



ICON won a $57 million NASA contract to develop lunar construction technology. *Credit: ICON Technology Inc.*

Jensen said the project requirements forced ICON to incorporate new considerations into the design, like a wall system that would work for NASA's needs — including airlocks and pass-throughs — but also remain stable.

"These are things which are really on the cutting edge that we were able to prototype for the first time within the analog itself," Jensen said.

The analog's first simulated Mars surface mission concluded in July 2024, when crew members emerged from the habitat after 378 days of "Marswalks," habitat maintenance, and other activities.

"The CHAPEA missions are critical to developing the knowledge and tools needed for humans to one day live and work on the Red Planet," then-NASA Administrator Bill Nelson said at the time.

Forever Homes

Jensen said the analog project "informed hardware, software, and architectural product development for many projects since — including completion of our 100-home subdivision of 3D printed homes."

ICON built the Wolf Ranch neighborhood outside Austin in Georgetown, Texas, in partnership with Lennar, one of the country's largest home builders, which handled the roofing and finishings. The community includes eight floor plans designed by the Danish Bjarke Ingels Group, which also collaborated on the Mars Habitat for NASA's CHAPEA.

Wolf Ranch is the largest neighborhood of 3D printed houses ever built.

"It represents a first-of-its-kind venture, showing how we can introduce 3D printing at scale for residential housing in a way that hasn't really been done before," Jensen said of the community.

"With our construction technology, the printer is basically agnostic to what it's printing," he said, "so we can introduce curved forms and interesting and more eccentric geometries without additional time or added cost."

ICON says its building technology comes close to zero waste. The company's concrete blend is moist enough to extrude but dries quickly enough to support the next layer, without having to trim edges or generate the type of waste that typically ends up in a construction site dumpster.

The concrete homes are built for the long haul, the company says: they can withstand hurricanes and earthquakes and resist mold, and they should still be standing strong after many decades. The community is nearing completion, and over 70% of the homes have been sold. The Wolf Ranch homes have sold in the $400,000 to $600,000 range.

Eye on the Sky

ICON is mission-driven. The company's stated aims include resolving the global housing shortage with millions of new homes that do not necessarily resemble houses that have been built in the past.

But ICON has also had an eye on the sky from the beginning, according to Jensen.

"We've always maintained an appreciation of how diversified this technology and its applications can be," he said. "I would say ambitions for construction on the Moon and, eventually, Mars, and additive construction in space generally, really go back to the origins of ICON."

NASA's Roman said ICON's expansive view of its technology's potential was compelling from the start. Now it's following through. ●

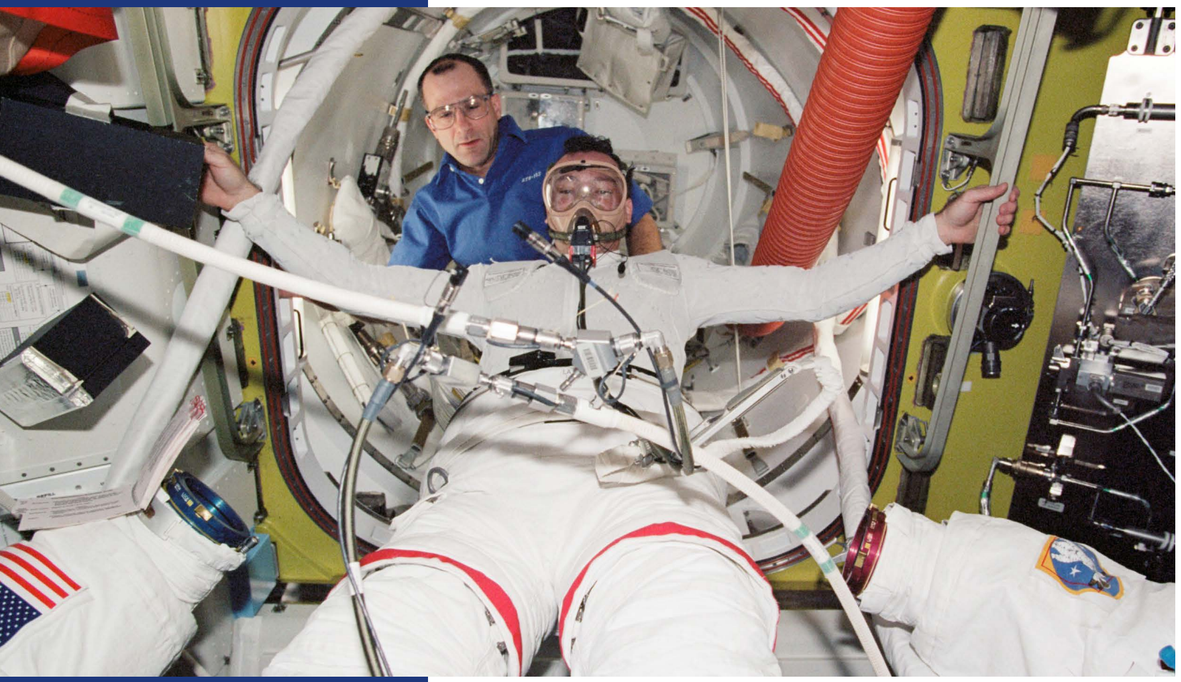
NASA Invention Goes Straight to the Heart

Pulmonary artery pressure sensor helps avert heart failure, keep patients out of hospital

Two engineers at Glenn Research Center developed a tiny, implantable transmitter and handheld reader. Endotronix of Naperville, Illinois, now part of Edwards Lifesciences, licensed the patent and used it to develop a heart monitor that warns heart failure patients of an impending crisis.

It's a good thing NASA technology is made for long journeys.

A new medical device that's helping heart failure patients live healthier lives began its daunting trek to market almost 25 years ago at NASA's Glenn Research Center in Cleveland, when two longtime lab partners observed the clumsy, wired sensors that monitored astronauts' vital signs while they exercised in space.



Astronaut Michael Lopez-Alegria carries out a pre-breathe exercise in preparation for a spacewalk. Astronauts' vital signs are closely monitored during pre-breathing, as they exercise while breathing pure oxygen to avoid decompression sickness. Two Glenn Research Center engineers thought wireless sensors would be less cumbersome, so they invented the system that eventually led to the Cordella Pulmonary Artery Sensor and Heart Failure System. *Credit: NASA*

"We were the pioneers in demonstrating that a printed spiral on a chip can have dual function, both as an inductor as well as an antenna."

Rainee Simons, Glenn Research Center

"We thought this scheme limits the mobility of the astronauts," said Rainee Simons. "If you could transmit the data wirelessly from sensors attached to the body to a console, that would be a major benefit to the astronauts."

By then, he and Félix Miranda had worked together on several communication technologies, including various antennas for space and aeronautics. They knew that a wireless sensor capable of monitoring vital signs, if they could build it, would be useful well beyond space exploration. So they applied for some seed money from Glenn's Commercial Technology Office — now known as the Office of Technology, Integration and Partnerships — and got to work.

"We are, by training and by experience, always responding to a particular need of the agency but at the same time thinking, what else can we do with this? What kind of needs can be addressed?" said Miranda.

They came up with an all-new radio-frequency device that would enable an unprecedentedly tiny, passive sensor to take measurements and communicate data with no embedded power source.

This little telemetry system, and the handheld device Simons and Miranda designed and demonstrated to get readings from the sensor, led to the development of the implantable Cordella Pulmonary Artery Sensor and Heart Failure System. The U.S. Food and Drug Administration (FDA) approved it for use in heart failure patients in June of 2024.

Rising pressure in the pulmonary artery, which carries blood from the heart to the lungs, is an early indicator of worsening heart failure, often beginning days or weeks before hospitalization becomes necessary, said Harry Rowland. He and heart surgeon Anthony Nunez cofounded Endotronix in 2007 to develop a product inspired by Miranda and Simons' invention.

"If you can measure that pressure, you can know what's going wrong early, enabling a clinician to intervene with things as simple as medication changes, which may prevent catastrophic events," Rowland said. "So this whole idea is all about proactive medical management."

Following FDA approval, Edwards Lifesciences Corp., a leader in technologies for patients with heart disease, acquired the Naperville, Illinois-based company to bring the Cordella system to more patients around the world.

But arrival at this point was anything but a sure bet.

Double Duty: Channeling Power, Transmitting Data

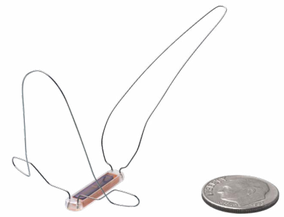
What Simons and Miranda first patented in 2003 wasn't itself a sensor but a tiny apparatus that could wirelessly power a little sensor or other microelectromechanical device and transmit information from it. Its secret lay in a multi-turn miniature spiral on a chip only about 1 millimeter square and capable of switching duties between inductor — channeling power from an outside radio-frequency ping and using it to get a sensor reading — and antenna, to send back a signal.

Though the invention was conceived for sensors on the skin, when the two engineers talked to potential users, they discovered the medical community was more interested in it for implantable devices. With a tiny profile, no wires, and no batteries, it was an ideal medical implant.

"There was a lot of interest from the medical community, for bone density measurements, for spinal cord injury patients, for monitoring the healing process," said Simons. So they tested it to prove it could receive and send signals through simulated body tissue.

Meanwhile, they developed a handheld device that could remotely couple with the little implant to momentarily power a sensor and then receive a reading from it. To keep the implant as small as possible, they put all the burden of signal amplification on the handheld reader.

This handheld reader pings the implanted Cordella sensor with a radio frequency and receives a response that indicates the pressure in the pulmonary artery. *Credit: Edwards Lifesciences Corp.*



Two NASA engineers had the idea that allowed the Cordella Pulmonary Artery Sensor to be tiny enough to implant in the pulmonary artery. The sensor has malleable anchors that conform to the artery walls to ensure stable positioning. *Credit: Edwards Lifesciences Corp.*

After the reader was patented in 2007, they published papers describing their invention. One of those caught Nunez's attention.

A heart surgeon in Peoria, Illinois, Nunez had recently been introduced to the concept of wireless pressure-sensing implants and was exploring the idea for various applications. This interest had led to his introduction to Rowland, who had just completed his Ph.D. in micromechanical engineering and nanotechnology manufacturing and was meeting with physicians around Illinois to discuss potential healthcare applications.

They began working together and went to meet Miranda and Simons to learn about their technology. Shortly after, they founded Endotronix, and the team began work under a Space Act Agreement to exclusively license the NASA technology for cardiovascular applications.

"This is where the real reward comes, to see that the technology is helping a lot of people." *Felix Miranda, Glenn Research Center*

A patient using the implantable Cordella Pulmonary Artery Sensor and Heart Failure System holds the reader to the chest and then gets the results through an app. *Credit: Edwards Lifesciences Corp.*

Measuring Where It Matters

They first set about bringing it up to the standards for a commercial medical device. "As we went to address the problem of heart failure management, we brought other technologies into play to make the solution actionable and practical in the real world," said Rowland, now senior vice president of implantable heart failure management innovation at Edwards.

They ended up with more than 30 patents, covering everything from the core technology to apps for the patient and physician to access the health data. "You needed many types of expertise to help bring this technology to life," said Rowland.

They settled on the pulmonary artery for early detection of heart failure, as heart failure hospitalizations occur when pressure builds until fluid seeps into the lungs. Any heart failure patients regularly measure their blood pressure, but pressure in the arm doesn't necessarily reflect what's going on around the heart, Rowland said. "You have to measure it where it matters to be able to manage heart failure effectively."

Beginning in 2017, the device underwent multiple clinical trials, ultimately treating more than 600 people. One trial showed a 73% reduction in heart failure hospitalizations at one year after the devices were implanted.

While the early warning of rising pulmonary artery pressure is key to prevention, Rowland said, the system also provides patients with easy, real-time access to accurate information about their heart health. This helps them see the impact of their lifestyle, helping them make healthier choices.

Less than a year after Cordella's FDA approval, Endotronix, now the Implantable Heart Failure Management unit of Edwards, is commercially launching the Cordella system and has nearly doubled to over 250 employees.

And more than two decades after their first patent on the technology, Simons and Miranda said their work is finally paying off. "This is where the real reward comes, to see that the technology is helping a lot of people," Miranda said.

But their invention has also spurred advances in other fields. Simons noted that more than 60 patents cite their original patents as prior art and apply the technology to monitoring anything from other aspects of human health to bridges and buildings. "We were the pioneers in demonstrating that a printed spiral on a chip can have dual function, both as an inductor as well as an antenna," he said.

As for monitoring astronauts' vital signs in space? "The farther they go from Earth, the higher the likelihood they will need medical attention," Miranda said. "This could be a tool in their toolbox." ●

The Cordella sensor is shown strung onto the delivery device that's used to implant it in the pulmonary artery. *Credit: Edwards Lifesciences Corp.*

Humanoid Robots Assist Assembly Lines

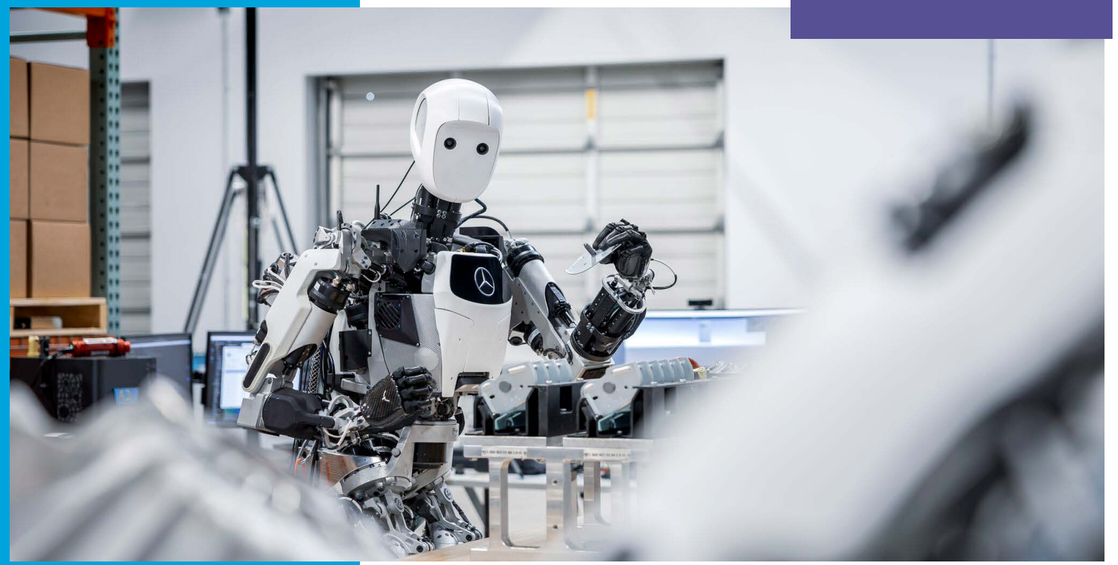
Apollo robots work in environments designed for people — on Earth and in space

While autonomous robots are playing larger roles in factories and warehouses, certain tasks still require the arms, legs, and eyes of a human. A self-driving tugger train that pulls boxes through a warehouse can't load or unload itself, for example. That's where Apollo comes in. The robot can pull boxes from shelves and walk them to a pallet as easily as anyone, without ever getting tired. With its general-purpose, humanoid form, it can switch between myriad tasks, as people do.

These robots from Austin, Texas-based Apptronik Inc. are currently helping humans in factories build Mercedes-Benz cars and even more Apollo robots. Equipped with AI, or artificial intelligence, Apollo was developed with NASA support and as a continuation of the space agency's own work on humanoid robots for space.

"Apollo is really the culmination of all of the lessons learned from over a decade working in humanoids," said Nick Paine, Apptronik's cofounder and chief technology officer. "NASA has been a partner throughout."

A humanoid robot from Austin, Texas-based Apptronik is the result of numerous collaborations with Johnson Space Center, including SBIR contracts. The Apollo robot is currently working in factories on Earth.



At 5 feet and 8 inches and 160 pounds, the Apollo humanoid robot has been designed to do useful work in factories and other environments. *Credit: Apptronik Inc.*

"You see all of the excitement and energy around humanoids today. I think the DARPA Robotics Challenge and NASA's role in it has a lot to do with that."

Nick Paine, Apptronik

Humanoids as Avatars

Humanoid robots can do many of the same jobs and move around the same spaces as humans, making them intriguing as possible coworkers on Earth and in space.

NASA began building a humanoid robot for space in the late 1990s, and in 2011 the second version of that effort, Robonaut 2, flew to the International Space Station, where it remained in residence until 2018.

R2 was initially just a head and torso with dexterous hands that made it capable of the types of maneuvers typically assigned to humans. In 2014, it received legs, allowing it to more easily move around the space station.

"The goal was to get it outside of the space station and have one of the astronauts inside operate it like an avatar," said Kimberly Hambuchen, deputy chief for the Software, Robotics, and Simulation Division within the Engineering Directorate at Johnson Space Center in Houston.

"We never met that goal," Hambuchen said, "but we found the humanoid form was a good generic robotic archetype that could fit into whatever we built for humans."

Valkyrie

In 2011, Apptronik's Paine was researching robotic actuation for his Ph.D. at the University of Texas when he and his advisor, Luis Sentis, joined a team of engineers at Johnson to build a humanoid robot, this one called Valkyrie, for a challenge hosted by the Defense Advanced Research Projects Agency, or DARPA.

For Paine, who was already familiar with the space agency's work with humanoids, having read and been influenced by several NASA papers on Robonaut 2, working on Valkyrie was a treat.

While Apollo is designed to work in factories and industrial settings, it could one day graduate to more domestic environments. *Credit: Apptronik Inc.*

"It was a great opportunity for me and my professor to go and work with such a high-caliber and skilled engineering team," he said, referring to Sentis, who also cofounded Apptronik several years later.

Although Valkyrie didn't win the DARPA competition, the robot was built with NASA needs in mind and continues to serve as a testbed platform to demonstrate robotic capabilities.

"You see all of the excitement and energy around humanoids today," Paine said. "I think the DARPA Robotics Challenge and NASA's role in it has a lot to do with that."

Shared Heritage

Following the competition, Paine and Sentis continued working on Valkyrie. When they founded Apptronik in 2016 with CEO Jeff Cardenas, the company's first job was a Small Business Innovation Research contract from NASA to develop their liquid-cooled robotic actuator technology. Actuators translate commands into movements.

The company continued working on NASA projects with funding for small businesses and through the Game Changing Development Program, and kept up with the robotics engineers at Johnson.

"We had a contract to work on some more commercialization-focused developments, partnering with NASA on something we could take to market," Paine recalled. "There has always been a sort of shared heritage."

Samuel Alex Sowell, a robotics engineer at Johnson, worked on several of these projects. "We helped with their first design and then were more hands-off with the second design," he said.

Maturing on Earth

Apptronik is launching an updated version of Apollo, its 5-foot, 8-inch robot weighing 160 pounds and capable of carrying up to 55 pounds. Apollo can be equipped with legs and feet or work as a mounted torso.

The next generation of Apollo is already under development, and the company hopes to ramp up production quickly.

In March 2024, Apptronik began working with Mercedes-Benz, bringing Apollo into the auto company's factories and plants. Nine months later, Apptronik announced a strategic partnership agreement with the Google DeepMind robotics team to grow Apollo's AI capabilities.

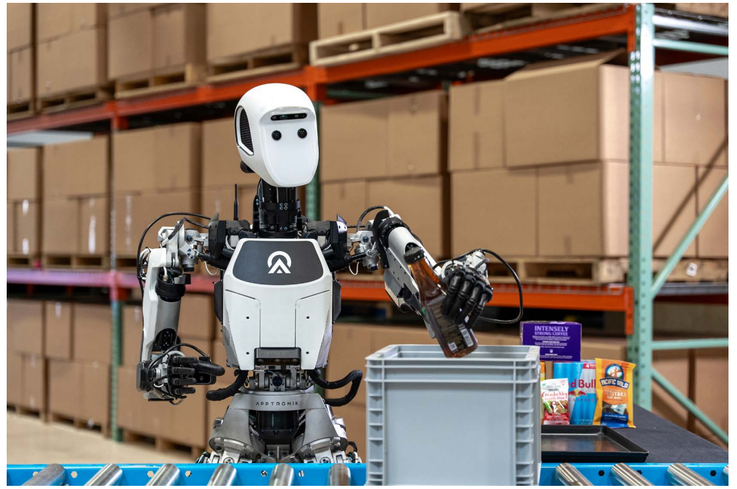
For the moment, Apptronik is working to improve Apollo's physical capabilities and ability to do useful work — often the monotonous or tedious tasks humans don't prefer — in factories and other environments. "It will take more time to see these systems graduate into environments with less trained individuals, like in the home," Paine said.

In 2025, Apptronik announced it had raised more than $400 million in its first major round of funding. Top investors included Google, Mercedes-Benz, B Capital, and Capital Factory.

NASA, meanwhile, isn't currently developing new humanoid robots, but the agency has a strong interest in the Earth-based humanoid robot industry, where the technology continues to mature.

Commercially produced humanoid robots could one day serve as extra crewmembers that don't need food, water, or air. "They could stay with whatever systems we put on the Moon or on Mars and continue to do maintenance work when there are no humans there," said NASA's Hambuchen.

"That's really why we continued to fund Apptronik," she said. "Because there was always that potential that eventually this technology could come back to space." ●



Apollo can perform the monotonous or tedious tasks humans don't prefer. *Credit: Apptronik Inc*

Apptronik and NASA employees stand with Valkyrie, a NASA-developed humanoid robot, during a 2021 meeting about one of the company's Small Business Innovation Research contracts. Apptronik's founders helped build Valkyrie. *Credit: NASA*

Planet in a Program

Joint effort yields open-source artificial intelligence foundation models of the entire planet

Engineers at Marshall Space Flight Center and IBM, headquartered in Armonk, New York, worked together to build artificially intelligent foundation models of the planet based on Earth-imaging and weather data, creating living digital models of the globe that can be trained for countless applications.

When NASA and IBM released their first version of Prithvi, an open-source artificial intelligence-based model of the planet, in late 2023, they weren't sure what anyone would do with it. A geospatial model capable of learning about and identifying different aspects of Earth's surface cover, it had potential for tracking land use or identifying areas of flooding or fire damage.

An application they couldn't have guessed at was predicting locust breeding grounds in several regions of Africa. But that's what one group did early on. "They sent an e-mail out of the blue saying, 'We've been trying to solve this problem for a long time, and we were unable to do it until you released this model,'" said Rahul Ramachandran, AI for science lead in the Office of the Chief Science Data Officer at NASA's Marshall Space Flight Center in Huntsville, Alabama. "So we were very surprised to see that."

This composite image from the Harmonized Landsat Sentinel (HLS) dataset shows the Dixie fire in Northern California on August 17, 2021, with active fire fronts visible north of Lake Almanor. The open-source Prithvi-EO-2.0 geospatial foundation model created by IBM and NASA was trained on HLS data. One task it's been trained to do is to spot areas burned by wildfires. *Credit: IBM Corp.*

The team working on Prithvi, which means Earth in Sanskrit, has now published the second version of this geospatial model, as well as another model, Prithvi for Weather and Climate. Both have been downloaded by tens of thousands of users.

Inspired by breakthrough developments in artificial intelligence, the agency teamed up with Armonk, New York-headquartered IBM under a Space Act Agreement to apply the principles of large language models to nonverbal Earth-imaging and weather data, creating living digital models of the globe that could be trained for countless applications.

Bringing Massive Datasets to Life

NASA is constantly developing new ways to make its ever-growing library of Earth-observation data useful to researchers, companies, and laypeople. "There's a tremendous amount of expense involved in launching these missions and collecting the data," said Ramachandran. "So part of this office's mandate is to look at how we can fully utilize this archive of data to further scientific knowledge."

In the early 2020s, advances in artificial intelligence appeared to provide just such an opening.

IBM and NASA have cooperated on projects since the Apollo days, and when advanced large language models like ChatGPT appeared around the end of 2022, researchers at the two organizations saw an opportunity. IBM was interested "because our main driver is to create the technology that advances the state of the art," said Juan Bernabé-Moreno, director of IBM Research Europe for Ireland and the United Kingdom and the company's accelerated discovery lead for climate and sustainability.

"We want to build everything transparently — what data went into it, how it was tested. Our goal is to empower scientists to accelerate science."

Rahul Ramachandran, Marshall Space Flight Center

First, coders at Marshall and IBM developed a language model called Indus, which is similar to models like ChatGPT but trained exclusively on scientific literature for internal NASA use. Then they wondered about applying a similar method to visual data to create a geospatial model of Earth.

"The approach is a slight modification but the same idea," said Ramachandran.

Large language models learn by trying to guess which words have been removed from sentences. Instead of using words, the team broke images from Earth-observing satellites down into small patches and hid some of them, he explained. "Now the network has to fill in the patch that's been hidden."

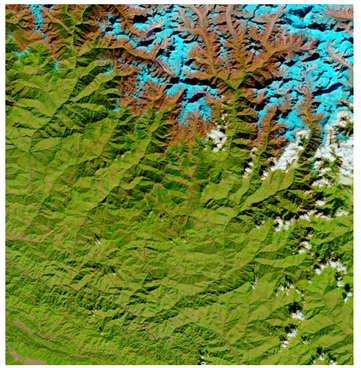
In both cases, the algorithms must discover relationships between data points to develop an understanding of the system they're observing. The eventual result is a foundation model.

A multi-layered neural network trained on vast sets of data, a foundation model can perform many different tasks quickly and accurately, as opposed to the traditional approach of building a model for a specific function. "You have pre-learned so much that you can specialize the model to do many, many things," Bernabé-Moreno said. "It's like a true Swiss Army knife. And that was revolutionary."

Artificial Intelligence, Real Benefits

Not only can it be trained for many tasks, but it does them surprisingly well. During the development of the weather and climate model, to demonstrate the system's power to a skeptical NASA meteorologist, the team removed all but 1% of the pixels from a temperature map of the entire globe. The model was able to accurately recreate the missing 99%.

"And this senior meteorologist said, 'I've never seen anything like that,'" Bernabé-Moreno said. "To be honest, we all were very surprised."



This false-color composite image made from HLS data shows snowcapped Himalayan mountains in November of 2022. *Credit: IBM Corp.*

The second, more comprehensive geospatial model was trained on the last decade of the Harmonized Landsat Sentinel dataset, hosted by NASA, which combines the archives of Landsat and ESA's (European Space Agency) Sentinel Earth-imaging missions.

It can tell users about Earth's surface at the local level or globally. For example, Bernabé-Moreno said, it can be used to detect flooding or the impact of wildfires. Based on as few as 500 examples of flooded or burned land, the system can detect them across the entire planet. It can also classify and identify land cover, for example quantifying worldwide coverage of different crops. And it can assign values to surface areas based on criteria such as their ability to sequester carbon, he said.

In support of reforestation efforts in Kenya, IBM is using the model to quantify forest mass, track forest cover, and identify carbon-capture potential for the carbon credit market. And because Landsat and Sentinel also track surface temperatures, the company was able to detect urban heat islands in Baltimore and Johannesburg.

The weather and climate model, meanwhile, is trained on the Modern-Era Retrospective Analysis for Research and Applications, Version 2 (MERRA-2) dataset, which is also hosted by NASA and compiles 40 years' worth of global weather data.

The goal for this model was not just to predict short-term weather — there are plenty of AI models for that already — nor even to predict the climate future. Current models for predicting Earth's climate decades into the future have very low spatial resolution, and one task the Prithvi weather and climate and model can do well is an operation called downscaling — essentially reducing the pixel size from around 100 miles across to six or seven miles. This shows what averages would be like for a particular area, assuming the climate forecasting model is correct. The team has tested this capability on past data and found it to produce accurate results, Bernabé-Moreno said.

He said the model is also useful for predicting the path of hurricanes, making seasonal forecasts, and combining weather models that have complementary strengths and weaknesses.

Open Development for Widespread Use

The team is already working on the next version of the weather and climate model, and everything is being released publicly on Hugging Face, an open-source machine learning platform.

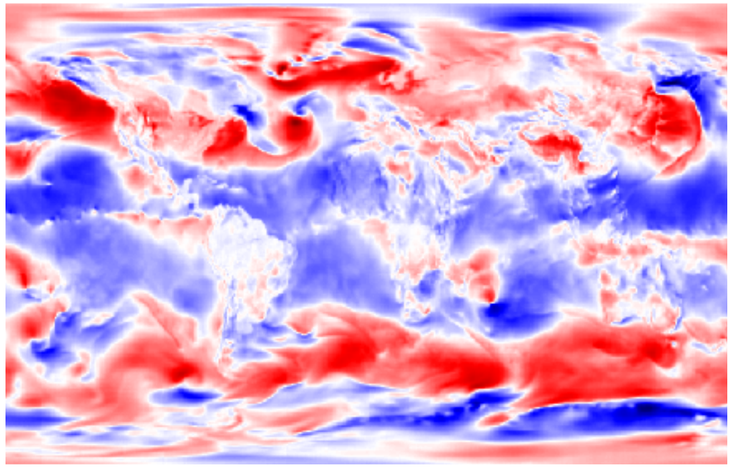
It's hard to know who's using the models for what, but Ramachandran said by May of 2025, the two geospatial models had been downloaded 50,000 to 60,000 times. "So that tells us they're being used quite extensively."

Open-source development has been key to rapidly creating models with broad applications, because it allowed the team to gain input and expertise from outside groups, Bernabé-Moreno said.

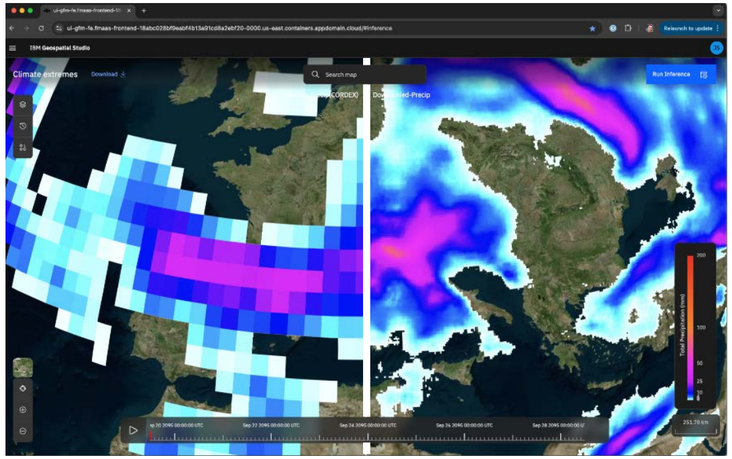
"We want to build everything transparently — what data went into it, how it was tested," added Ramachandran. "Our goal is to empower scientists with AI models to accelerate science."

To make AI more widely used throughout the agency, NASA and IBM plan to build a foundation model for each of the five divisions in NASA's Science Mission Directorate, although Earth Sciences has already landed two. A model of the Sun for the Heliophysics Division launched in August of 2025, a Moon model is currently undeway for Planetary Science, and a Mars model is in planning. Models for the divisions of Astrophysics and Biological and Physical Sciences are yet to be planned. A language-based model similar to Indus is in the works for use across the agency, enabling users to more easily interact with all of the NASA-IBM models. This model is intended to accelerate the discovery of insights for the broader scientific community.

IBM, meanwhile, is applying the same idea of foundational AI to the electrical grid, one of the most complex systems ever designed, to prepare it to draw energy from a wider variety of sources, said Bernabé-Moreno. "We really see that these building blocks with NASA can help us massively in our undertaking of creating this great foundation model." ●



This six-hour global forecast from the open-source Prithvi Weather and Climate foundation model created by IBM and NASA is an example of a "zero-shot" skill, a skill the model can perform without having been trained on it specifically. *Credit: IBM Corp.*



This example shows how the Prithvi Weather and Climate model can "downscale" climate predictions, which tend to have very low resolution. The downscaled map on the right has 12 times the resolution of the raw data on the left. *Credit: IBM Corp.*

Machines from Mars Make Beer Bubbly

Carbon-capture technology repurposed for breweries spreads and finds new applications

Earthly Labs of Austin, Texas, now part of Chart Industries, built small-scale carbon-capture technology based on a license from Pioneer Energy. Pioneer had developed the technology based on work the company's founder did for Johnson Space Center to enable the separation and combination of elements on Mars.

In 2021, Maine Beer Company's carbon dioxide supplier ran short on carbon dioxide.

"There was potential for our beer to go stale in the tanks," said Dave Love, the brewery's sustainability manager. "We wouldn't be able to use CO_2 for any of our bottling, kegging, or centrifuge operations."

The company managed to conserve enough of the gas to maintain operations even as CO_2 deliveries became inconsistent, but the event was a wake-up call. Consumable carbon dioxide, often a by-product of oil drilling and refining, became scarce when automobile use and air travel plummeted during the pandemic, and periodic shortages have persisted. Maine Beer had previously looked into technology that would let the company capture CO_2 from the fermenting process and use it for carbonation, Love said. They decided this was the time.

The solution the company settled on originated on Mars — or more specifically, in NASA's plans for extracting resources from the elements available on the Red Planet's surface. Now it's saving money

Earthly Labs' carbon-capture technology traces its roots back to NASA's in situ resource utilization efforts. One technology would capture carbon dioxide from the Martian atmosphere, break it down into carbon and oxygen, and combine each with hydrogen to make methane and water, respectively. The idea is to use elements available on the planetary surface rather than carrying them from Earth. *Credit: NASA*

and reducing emissions for a surprising variety of small businesses, including wineries, distilleries, power companies, and helium producers.

Beginning in the late 1990s, the company Pioneer Astronautics won multiple Small Business Innovation Research (SBIR) contracts from Johnson Space Center in Houston to build systems that could generate resources on Mars. The company's founder, Robert Zubrin, a longtime advocate for human travel to the Red Planet, had outlined these technologies in the Mars Direct plan he coauthored in 1990.

The technology his company built with SBIR funding from Johnson could capture carbon dioxide from the Martian atmosphere and combine it with hydrogen to produce water for life support and methane for rocket fuel. The water then could be broken down into oxygen for life support and hydrogen for further methane production. It was not known at the time that there is frozen water under the surface of Mars.

These capabilities weren't entirely new, but the company built systems that were compact, efficient, and automated.

In 2008, Zubrin founded Pioneer Energy after realizing he could rearrange these subsystems to create technology for the oil and gas industry here on Earth (Spinoff 2015, 2020).

It didn't take Zubrin and his staff long to realize that technology for capturing carbon dioxide from the Martian atmosphere and purifying, pressurizing, and liquefying it could do the same thing in a brewery. While most major brewers had carbon-capture technology, there was nothing available for the microbreweries that had been proliferating for over a decade. By late 2015, the Craft Brewery Recovery System was in production (Spinoff 2016). Automated and modular, it was aimed at breweries producing up to 60,000 barrels per year, but it could be stacked to accommodate higher outputs.

In the end, Pioneer Energy decided to keep its focus on the oil and gas industry, and the company made the system available for licensing.

Supply Security and Purer CO_2

In 2016, Amy George founded Earthly Labs of Austin, Texas, to work on small-scale carbon capture, which was virtually nonexistent at the time. She hit on microbreweries as a target application, and when she came across the Craft Brewery Recovery System, she recognized a game changer. The company obtained an exclusive license from Pioneer Energy.

A brewer makes adjustments to the Earthly Labs carbon-capture unit, which purifies carbon dioxide from the beer brewing process for use in carbonation. *Credit: Chart Industries Inc.*

"Most of the effort and policy had been focused on the largest emitters, and this represented a way for others to participate," George said. Branded CiCi, for "carbon capture," the technology is now packaged into three different systems to accommodate different capacities.

At Maine Beer, Love said supply chain security was the most important selling point. The company gets less than half of its carbon dioxide from its Earthly Labs system, purchasing the rest, but it's enough to get through a crisis. On two more occasions since the company acquired the system in 2022, its carbon dioxide supplier has run short, but the brewery never had to halt production.

"The second we're not able to get CO_2, it's immediately paid for itself. Because the revenue lost by dumping one batch of beer is well over $100,000," he said.

George said the shortages and price volatility that have marked the last five years have emerged as major drivers of interest, along with standards and incentives for reducing emissions.

"Most of the effort and policy had been focused on the largest emitters, and this represented a way for others to participate."

Amy George, Earthly Labs

Love noted that the carbon dioxide from the CiCi system is also purer than the industry norm. Beverage-grade CO_2 is at least 99.5% pure, while carbon dioxide from Earthly Labs' systems is closer to 100% pure.

But the technology isn't just helping brewers. After expanding into wineries and distilleries, the company started discovering other markets. Energy companies often generate carbon dioxide as a by-product, and if they capture that carbon, they can sell it. Several are now customers.

Among them are power plants that generate energy from waste, a practice that's gaining popularity as a "greener" option. Capturing carbon helps them boost that image, George said. They're also often major customers requiring large systems. "A brewery application might produce around 150 pounds of CO_2 per hour, and then a biogas plant might produce 3,000 pounds an hour or more," she said. "So it's just orders of magnitude larger."

In 2021, Earthly Labs was acquired by Chart Industries Inc., though it kept its brand name. George said Chart, which specializes in cryogenic equipment engineering, helped scale up the technology for applications like power plants.

Tech Helps Helium Industry Get Off the Ground

Another application that has brought in several new customers is helium production, she said. Once under the purview of the United States government, this is a relatively new industry. In 2024, Pulsar Helium Inc. signed an agreement with Chart for Earthly Labs to conduct engineering studies for a possible helium purification plant in Minnesota.

"Earthly Labs is really at the forefront, the cutting edge with the engineering of this purification technology," said Pulsar's president and CEO, Thomas Abraham-James.

Helium, which is used to make microchips and fiber-optic cables, among other applications, is found in underground deposits, much like oil. But it is always mixed with other gases, such as methane and carbon dioxide. At 14.5% helium, the gas at the site Pulsar discovered in Minnesota has the highest helium concentration in North America. It's also high in CO_2, which Abraham-James had initially planned to rebury, until he learned of the ongoing carbon dioxide shortage.

If all goes well, he said, an Earthly Labs plant will separate and purify both helium and CO_2 for the company to sell. In addition to carbonating beverages, carbon dioxide is used to preserve food, manage the acidity of drinking water, promote plant growth in greenhouses, make dry ice, and extract oil from wells, among other uses.

"Efficiency is the big thing they have, and then you get reduced operating costs," Abraham-James said of Earthly Labs, adding that the acquisition by Chart Industries introduced the helium expertise he'll also rely on. "I actually can't think of another company that's got that combined in-house ability."

George said becoming part of Chart also helped Earthly Labs spread internationally. She estimated the technology has more than 100 customers around the world, including in Europe, Australia, the Middle East, and Brazil. At home, she estimated it supports about 60 jobs, though that number is growing quickly.

She credited CiCi's success with the fact that it's compact, modular, and easy to install and use. While most carbon-capture systems take months to install, this one takes about a week. "Most of the technology, before NASA's innovation, came from the oil and gas industry, so they're very large," she said. "This helped open a whole new class of applications and was a catalyst for a new marketplace." ●

"The second we're not able to get CO_2, it's immediately paid for itself. Because the revenue lost by dumping one batch of beer is well over $100,000."

Dave Love, Maine Beer Company

"Earthly Labs is really at the forefront, the cutting edge with the engineering of this purification technology."

Thomas Abraham-James, Pulsar Helium

In 2022, under the guidance of sustainability manager Dave Love, far left, Maine Beer Company acquired one of Earthly Labs' carbon-capture units, primarily to address recurring shortages in the carbon dioxide necessary for carbonation. *Credit: Chart Industries Inc.*

Lunar Lattices and Their Earthly Impact

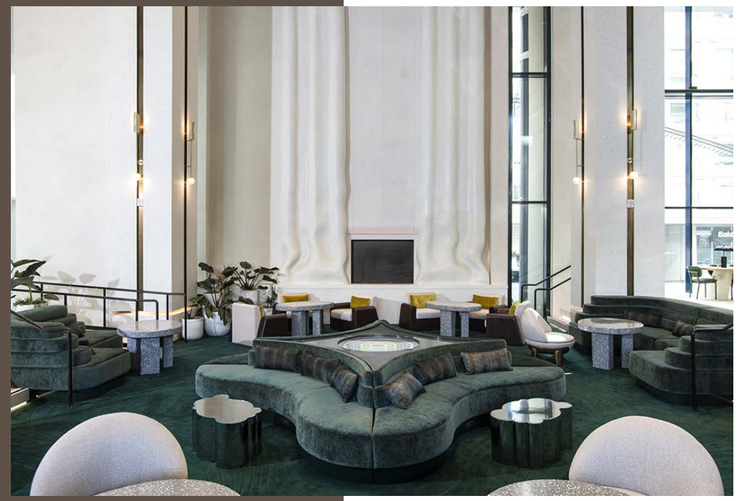
Novel 3D printing process enables lightweight structures in space and on Earth

Winning a 3D Printed Habitat Challenge at Marshall Space Flight Center and outfitting a model lunar habitat have helped Chattanooga, Tennessee-based Branch Technology evolve its signature Freeform 3D Printing technique, which it uses to manufacture custom terrestrial products, including wall panels and cladding.

An innovative 3D printing process that advanced NASA's approach to outfitting a lunar habitat is making buildings on Earth beautiful, efficient, and strong.

Instead of building up an object layer by layer, Branch Technology Inc. has developed what it calls Freeform 3D Printing, which creates shapes with lightweight lattice structures that can be filled or covered. The company uses the technique to manufacture visually interesting, modular building elements, such as wall panels and cladding.

"Our process eliminates a ton of material from something that otherwise might be printed solid all the way through," said David Goodloe, who leads the Chattanooga, Tennessee-based company's Advanced Concepts team, which manages the company's NASA collaborations.



Branch 3D prints lattice structures which can be filled or left hollow to create unique building components, like these drapery-inspired wall panels for the W Hotel in Hollywood. *Credit: Branch Technology Inc.*

In 2017, Branch won Phase II of the 3D Printed Habitat Challenge, a NASA Centennial Challenges competition to build a 3D printed habitat for deep space exploration.

"Winning that challenge actually introduced us to our first institutional investor," Goodloe said.

"Brick & Mortar Investments, based in Silicon Valley, California, saw this small, advanced robotics team from Chattanooga win this global NASA competition," he said. "When they heard about our vision for terrestrial construction, they invested in the company."

Teaming up with the architecture firm Foster + Partners and Stanford University, Branch went on to enter a cooperative agreement in 2021 with NASA's Marshall Space Flight Center in Huntsville, Alabama, to look at manufacturing for lunar surface habitation. This project involved outfitting a model lunar habitat with autonomously produced structures — interior walls, tools, ducting, furniture, and components.

Tracie Prater is a technical manager in the Habitat Systems Development Branch at Marshall who served as a subject matter expert for the Centennial Challenge and also worked with Branch on the cooperative agreement.

"With the 3D Printed Habitat Challenge, teams were focused on how to build a large habitat structure on a planetary surface," she said. "But once that structure is pressurized and ready for crew occupancy, how do you populate it with systems and supplies? That's what Branch was looking at through the cooperative agreement — what their on-demand fabrication process enables in terms of novel designs for interior items."

"With the 3D Printed Habitat Challenge, teams were focused on how to build a large habitat structure on a planetary surface."

Tracie Prater, Marshall Space Flight Center

Both NASA projects influenced Branch's offerings, according to Goodloe. For instance, NASA parameters for the Moon base led the company to enable its nozzles to extrude its signature lattice structures as well as more traditional layers. Branch uses this dual capability frequently, for example in its wall panels, where traditionally printed sections offer solid substrates for attaching fasteners.

The polymers Branch extrudes were informed by its materials science research for the Habitat Challenge, which asked that print material be made of something like the dust and rocks found on the Martian surface and mission recyclables. Branch came up with a basalt fiber-reinforced plastic, and from that work went on to develop an optimal loading recipe for its terrestrial "inks."

The company is now working on a NASA Small Business Innovation Research project to determine if its Freeform 3D Printing technology could build a 50-meter tower on the Moon. Branch also built a full-scale replica of the space shuttle and a cratered lunar surface facade for the Space Camp building at the U.S. Space and Rocket Center, also in Huntsville.

Branch's other projects include a 50-foot, drapery-inspired wall for the W Hotel in Hollywood, art installations, and building interiors and exteriors. The company's analysis of a high-rise building facade that was initially slated to receive precast concrete found Branch's panels would be 34 million pounds lighter, offer 49 times more insulation, and require no skilled labor or crane time to install. ●

Branch's work outfitting a prototype of a lunar surface habitat they developed, pictured here, under a cooperative agreement with Marshall Space Flight Center, helped the company evolve its printing processes. *Credit: Branch Technology Inc.*

Branch's 3D print process enables it to create visually interesting building parts, such as the façade of this bank in Chattanooga, Tennessee. *Credit: Branch Technology Inc.*

Technique for Manipulating Satellite Photos Now Reveals Ancient Images

Algorithm NASA first applied to satellite imagery is used to peer into antiquity

On the walls of a chamber near the top of the central tower in the ancient Cambodian temple Angkor Wat, paintings depict horseback riders and a traditional musical ensemble. Every day, thousands of visitors pass these images without noticing, because they're faded to the point of invisibility.

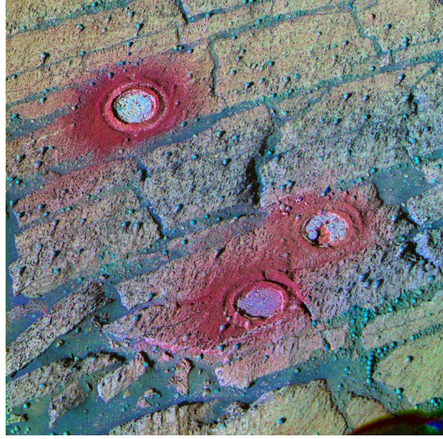
They were discovered, along with about 200 other paintings throughout the sprawling complex, between 2010 and 2012 by a Singaporean archaeologist using a method conceived at NASA's Jet Propulsion Laboratory in Southern California.

The technique, known as decorrelation stretch, heightens contrasts in digital imagery, making subtle differences clearer and features easier to spot. Originally used by NASA to extract more information from satellite imagery, it has proven useful in many fields but has come to be especially widely used for studying ancient rock art. This is partly because these images are commonly faded beyond recognition. But it's also due to the chance intersection of one man's hobby with his unrelated professional and educational background.

In the 1980s, one of Jon Harman's friends brought him along on a few field trips with a local rock art group, and the mystery surrounding these ancient images intrigued him. "No one really knows why people made the rock art they made, at least in many cases," he said. "And the symbols are quite strange."

Between 2010 and 2012, Singaporean archaeologist Noel Hidalgo Tan used the Dstretch plug-in to discover more than 200 faded paintings around the Angkor Wat temple complex in Cambodia. Almost invisible to the naked eye (left), this image in a chamber near the top of the temple's central tower depicts a traditional Cambodian musical ensemble known as a pinpeat. *Credit: Noel Hidalgo Tan*

Rock art enthusiast Jon Harman of Pacifica, California, created the Dstretch software plug-in to enhance digital imagery, based on the decorrelation stretch technique invented at the Jet Propulsion Laboratory. Dstretch is now widely used to make ancient, faded markings visible in photographs, among other applications.



In 2005, someone at a rock art conference showed Jon Harman this image of the Martian surface, with and without the decorrelation stretch technique applied. Recognizing the potential value for discovering ancient rock art, Harman found a NASA paper detailing the method and created the Dstretch plug-in for use with an open-source image processing program. *Credit: NASA*

At a rock art conference around 2005, someone showed him images from NASA's Mars Exploration Rover webpage, depicting the Martian surface with and without the application of decorrelation stretch. Seeing how much detail the technique revealed, he understood the implication for studying ancient, faded images.

He also happened to work in medical imaging. "I Googled it and found a NASA paper that explained how to do the algorithm," he said. "I knew from my medical imaging experience that I could do it, so I did."

Thus was born the Dstretch plug-in and, later, Dstretch apps for Android and iOS.

Rather than simply raising the contrast between colors, decorrelation stretch maps the original colors to a different, expanded range of colors. It's a complicated process that includes steps like diagonalizing color matrices. "Diagonalizing is algebra, and I have a PhD in math from Berkeley, where I studied algebra," said Harman, now retired in Pacifica, California.

The technique is based on the Karhunen–Loève Transform, a theorem used in statistical analysis and coinvented by Michel Loève, one of Harman's former math professors.

The Dstretch plug-in is for use with ImageJ, an open-source image processing and analysis program originally developed by the National Institutes of Health.

From Statistics to Geology

The paper Harman found detailing the process was written in 1996 by Ronald Alley, a JPL employee who at the time was part of an international team developing scientific requirements for the upcoming Advanced Spaceborne Thermal Emission and Reflection Radiometer (ASTER). That imager, built by Japan, was launched in 1999 on the Terra satellite, where it still operates today alongside its more famous counterpart, the Moderate Resolution Imaging Spectroradiometer, or MODIS.

In the 1990s, Alley was working with a group of geologists at JPL, finding applications for satellite data. But he had previously worked in a digital image-processing group, and his supervisor there, Jim Soha, had cowritten a 1978 paper along with another JPL employee that proposed applying the Karhunen–Loève Transform to digital imagery for color enhancement. It was this technique that came to be called decorrelation stretch, and Soha's group is where Alley learned to use it.

By the time scientists were making plans for ASTER, Alley and his geologist colleagues had been using decorrelation stretch to map lava flows on the big island of Hawaii for some time.

The original technique involved creating multiple intermediate images, each of which introduced slight inaccuracies through rounding. By replacing that process with one called matrix multiplication, Alley made decorrelation stretch both faster and more accurate.

He knew it would be useful for a multispectral imager like ASTER, which collects data in the visible spectrum and different infrared ranges, so he wrote the paper. "Someone had to write up a description of this thing so users would know what we were talking about," he said.

Michael Abrams, the current ASTER science team leader, said his group still uses decorrelation stretch on infrared imagery to track plumes from volcanic eruptions, whose sulfur dioxide, ash, and water vapor have distinct infrared absorption bands.

"Someone had to write up a description of this thing so users would know what we were talking about."

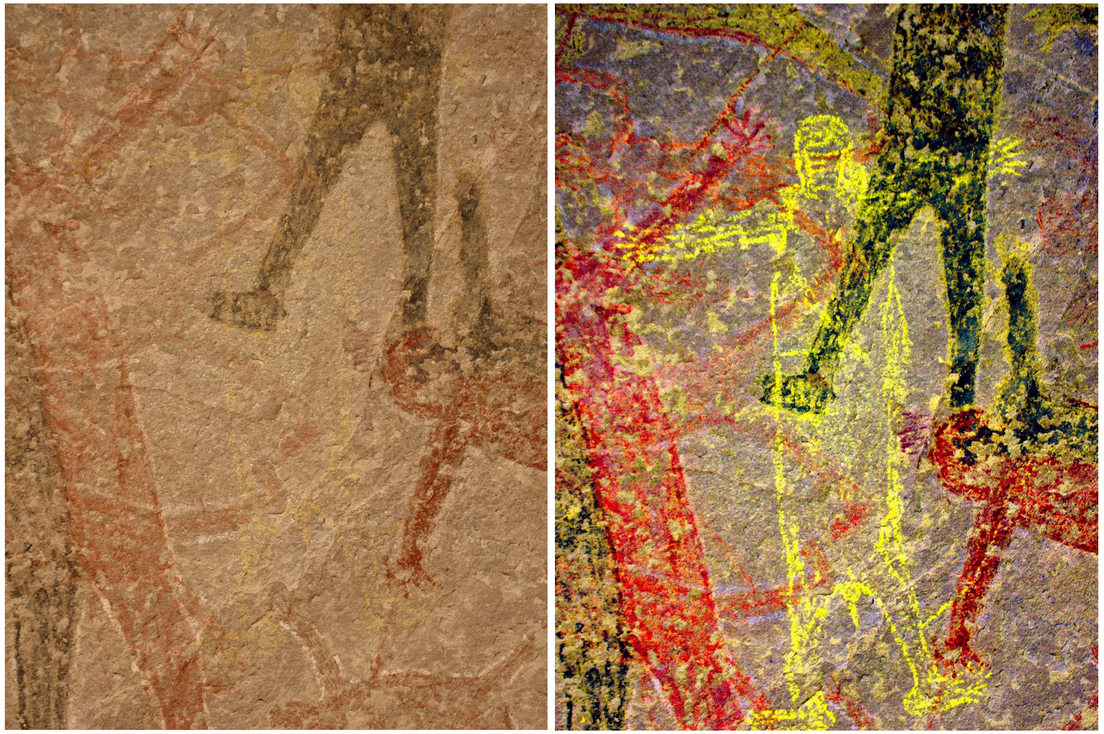
Ron Alley, Jet Propulsion Laboratory, retired

Dstretch User Base Expands

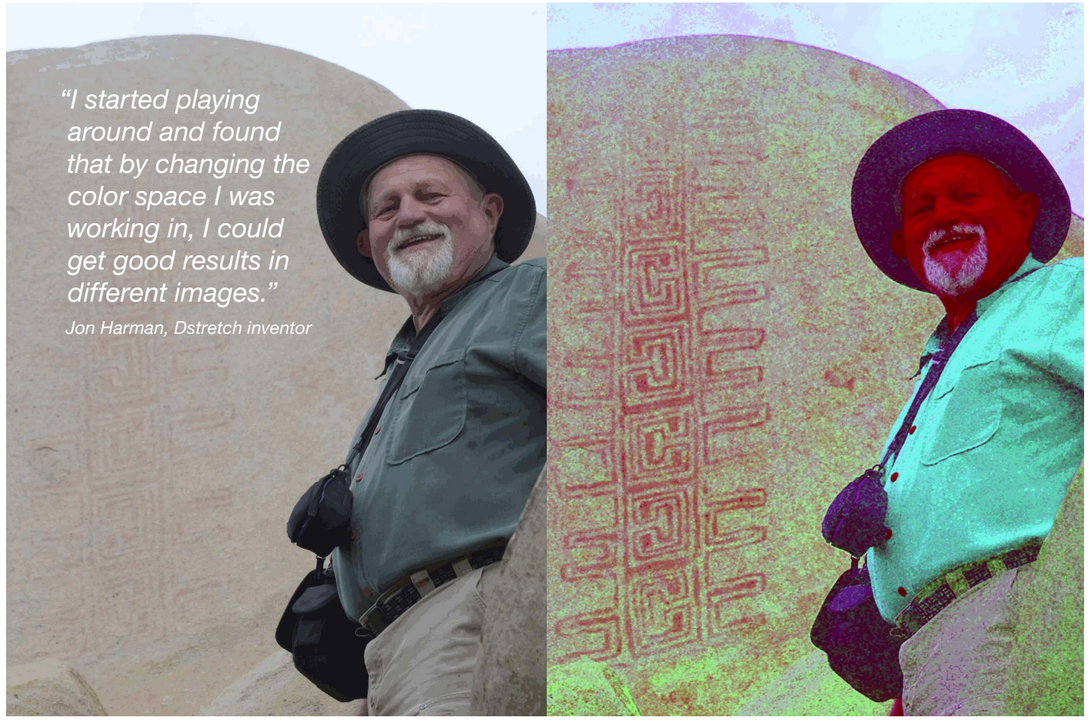
Harman first applied his Dstretch plug-in to photos he had taken of rock art in Baja California, Mexico. In one image featuring several human figures, a new yellow figure seemed to materialize from nowhere when the algorithm was applied. “That convinced me of the usefulness,” he said. “Then I started playing around and found that by changing the color space I was working in, I could get good results in different images.”

A color space is a range of numerically represented colors, such as the red-green-blue, or RGB, color space common among screen devices. Dstretch includes custom color spaces that have proven useful with Harman’s extensive image collection. In this way, Dstretch is tailored to rock art, but it can be and is used in many other contexts.

Harman said he gets about 200 requests per year from all over the world, which he fulfills for $50 apiece. Around 2010, he created smartphone apps that use a shortcut to mimic decorrelation stretch. “To do the actual Dstretch on a phone would be difficult and take forever,” he said. The apps cost $20 and have been downloaded thousands of times. Papers have been published describing Dstretch’s usefulness in archaeology.



As he was developing the Dstretch plug-in, Harman applied it to this image from the Cave of San Borjitas in Baja California, Mexico. When the yellow figure appeared in the middle of the picture, he knew he had something useful. *Credit: Jon Harman*



Harman poses in front of an example of the Rancho Bernardo style of Native American artwork that’s barely visible until Dstretch is applied. *Credit: Jon Harman*

Space Technology Down to Earth, Then Underground

Pictographs at the Årsand 1 site in western Norway, including a sun, stylized human figures, and various shapes and patterns, were first documented in 1940. The use of Dstretch in 2008 and 2012 uncovered about 15 previously undocumented figures and revealed new details in 28 others.

In the ancient Egyptian cemetery of Beni Hassan, archaeologists used Dstretch to discover images of bats and pigs, animals rarely depicted in ancient Egyptian art.

In Alberta, Canada’s Writing-on-Stone Provincial Park, famous for its indigenous rock carvings and paintings, Dstretch revealed what could be considered an early form of graffiti “tagging.” A pictograph of a horse and rider is believed to serve as a “calling card” from a Crow warrior, taunting his Blackfoot enemies.

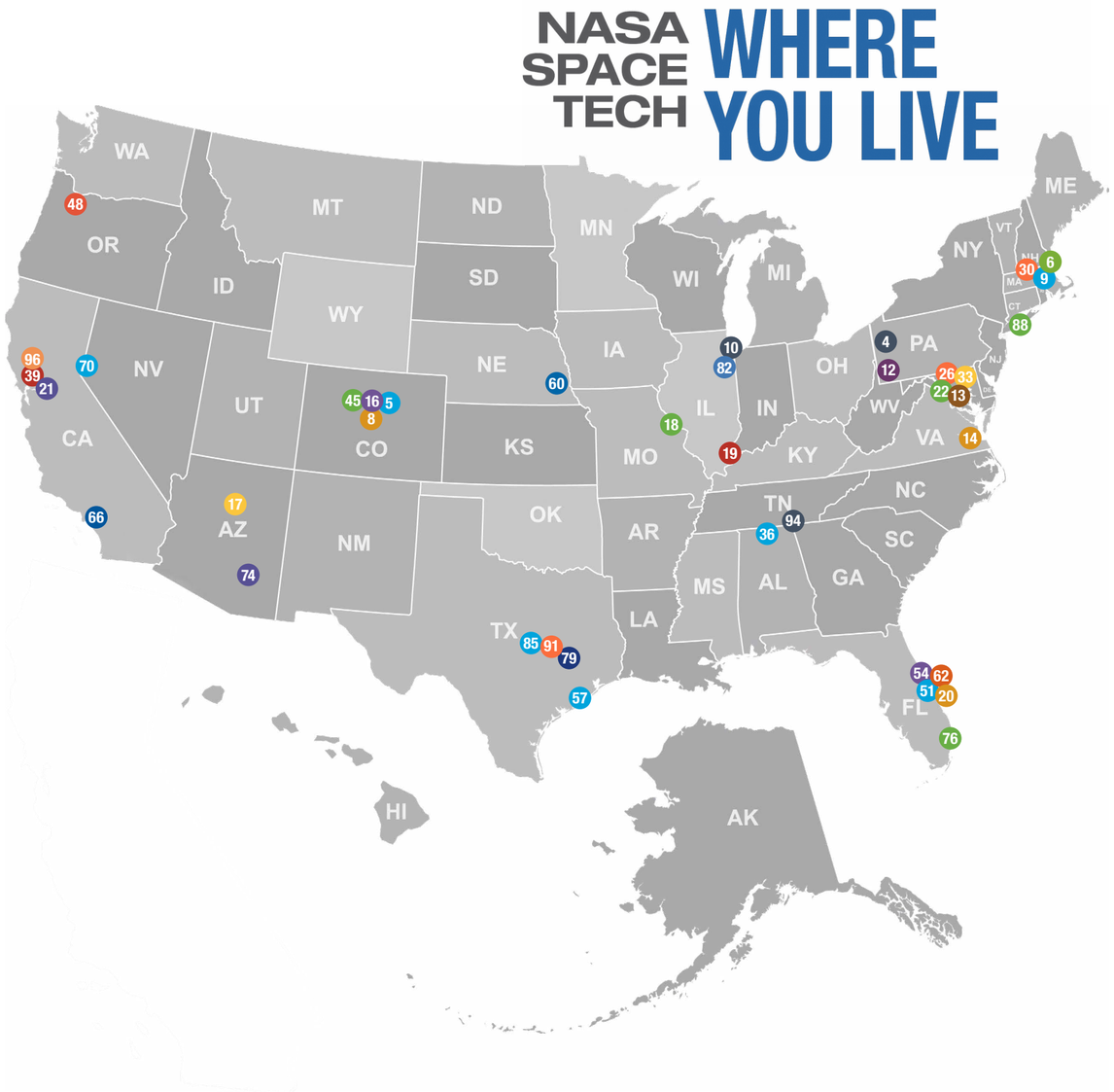
But the plug-in has also found use beyond rock art. The site of Vlochos in Thessaly, Greece, contains the remains of urban settlements built between 500 B.C.E. and 800 C.E. There, Dstretch applied to aerial imagery revealed areas of potential archaeological interest that had been missed by other methods, such as elevation models, ground-penetrating radar, electrical resistance surveys, and others. It also uncovered the remains of structures and buried building foundations in areas where factors such as metallic contamination made other techniques difficult.

In 2023, members of the University of Tübingen in Tübingen, Germany, and the Tennessee Division of Archaeology in Nashville, Tennessee, published a protocol for using Dstretch to enhance imagery of tattoos preserved on mummified human remains.

Given how well it worked on his own extensive collection of rock art imagery, Harman said he was not surprised that Dstretch found wide use in the rock art community. “But I’ve been surprised by a lot of the different applications people have found. So that’s been cool.”

Spinoff Technology Across the Nation

	Article	Technology	Company, Location
4	Teaching an Old Metal New Tricks	Shape memory alloy	Metalwerks, Aliquippa, PA
5	3D Printable Alloy Can Take the Heat	3D printing alloy	Elementum 3D, Erie, CO
6	Living Off Our Moon	Lunar resource analysis	Lunar Station, Cambridge, MA
7	The Impact of Space Junk	Space debris assessment software	Kepler Communications, Ontario, Canada
8	New Insulation Can Benefit Many Industries	Integrated multilayer insulation	Quest Thermal Goup, Arvada, CO
9	Knowledge Is Battery Power	Electric vehicle battery management	Electra Vehicles, Boston, MA
10	Handbag Made from Basic NASA Research	Fungi faux leather	The Fynder Group, Chicago, IL
11	NASA-Derived Textiles Go on Tour	Temperature-regulating cycling gear	Ekoi, Fréjus, France
12	Old-School Software Enables New Missions	STK Astrogator trajectory design software	Ansys, Canonsburg, PA
13	A Planetary Sensor's Earthly Applications	Silicon carbide photodiodes	CoolCAD Electronics, Greenbelt, MD
14	Softer Moon Landings for Companies	Psionic Navigation Doppler Lidar	Psionic, Hampton, VA
15	Spotting Invisible Gas Leaks	Methane plume detection	Momentick, Tel Aviv, Israel
16	Simulations That Are Positively Radiant	Radiation simulation software	Tech-X, Boulder, CO
17	Beat the 'Heet" at 400,000 Feet	Thermal protection systems	Miller Scientific, Flagstaff, AZ
18	Search for Life Helps the Search for Oil	Oil well sensors	Impossible Sensing, St. Louis, MO
19	Greens Grow in Circles	Vertical farming at home	Heliponix, Evansville, IN
20	Probe Deeper with Better Space Receivers	Miniature, reconfigurable space transponder	Argotec, Melbourne, FL
21	Weaving Data Fabric with AI	AI for drones and air taxis	Autonomy Assn. International, Mountain View, CA
22	Data Analysis Goes to the Dogs	AI data analysis software	Stardog Union, Arlington, VA
26	Feeding People Through Disasters	Satellite data mapping	World Central Kitchen, Washington, DC
30	Extraterrestrial Medical Diagnostics	Portable blood testing technology	1Drop Diagnostics US, Boston, MA
33	Filtering Out Risk	Satellite data aggregator	World Wide Fund for Nature, Washington, DC
36	Making Future Satellite Fuel Today	In-space propulsion systems	Rubicon Space Systems, Huntsville, AL
39	Boosting Bone Health	Bone-strengthening medical device	Osteoboost Health, Redwood City, CA
42	Aerogel Art Attracts Attention	Aerogel art	Ioannis Michaloudis, Limassol, Cyprus
45	NASA 'Arms' Astronauts, Industry with Robotic Intelligence	Robotic automation software	PickNik, Boulder, CO
48	Keeping Cool, Containing Flame	Aerogel insulation	Solarcore, Portland, OR
51	Forecasting Fish from Space	Ocean fishing forecasting	ROFFS, West Melbourne, FL
54	A Better Seat for the Seated	Smart wheelchair seat	Kalogon, Melbourne, FL
57	For Battery Safety, KULR Heads Prevail	Lithium-ion battery testing and safety	KULR Technology Group, Webster, TX
60	Robots in the Operating Room	MIRA surgical robot	Virtual Incision, Lincoln, NE
62	Lunar Gardening Device Grows Health, Beauty Ingredients	BioPod precision agricultural device	Interstellar Lab, Merritt Island, FL
66	Mapping a World of Data	Earth mapping	Esri, Redlands, CA
70	Drone Company Makes It Rain Forests	Seedball-launching drones	Flying Forests, Reno, NV
74	From Pluto to Farms and Pharmaceuticals	MicroNIR handheld spectrometer	VIAVI Solutions, Chandler, AZ
76	Saving Lives at Sea and on Land	Personal locator beacon	ACR Electronics, Fort Lauderdale, FL
79	Mission: Home	3D printed home construction	ICON Technology, Austin, TX
82	NASA Invention Goes Straight to the Heart	Implantable heart monitor	Endotronix, Naperville, IL
85	Humanoid Robots Assist Assembly Lines	Apollo humanoid robot	Apptronik, Austin, TX
88	Planet in a Program	AI foundation models of Earth	IBM, Armonk, NY
91	Machines from Mars Make Beer Bubbly	Small-scale carbon capture	Earthly Labs, Austin, TX
94	Lunar Lattices and Their Earthly Impact	3D printing for buildings	Branch Technology, Chattanooga, TN
96	Technique for Manipulating Satellite Photos Now Reveals Ancient Images	Software add-on to enhance digital images	Jon Harmon, Pacifica, CA



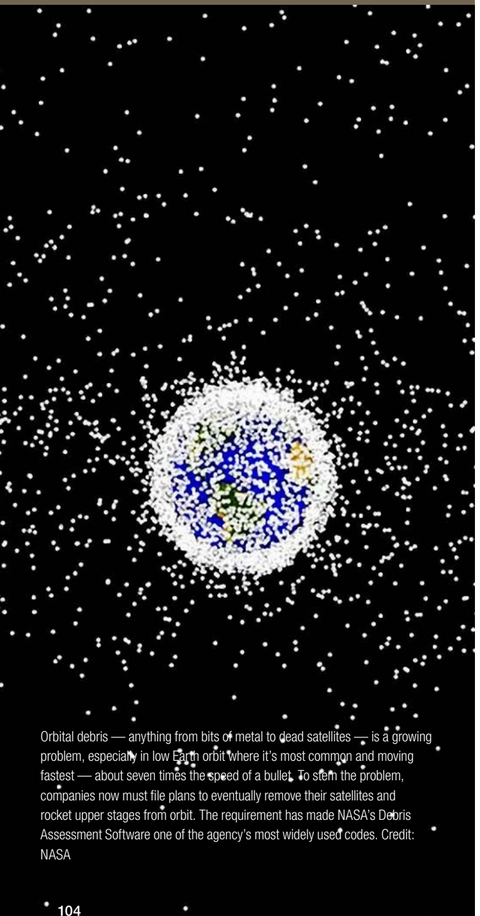
NASA's Pegasus barge, ferrying the launch vehicle stage adapter for NASA's SLS (Space Launch System) rocket, departs the agency's Marshall Space Flight Center in Huntsville, Alabama, August 21, 2024, passing through nearby Decatur. The cone-shaped adapter is part of the SLS rocket that will power the Artemis II mission, the first crewed flight of the agency's Artemis campaign. *Credit: NASA*

Technology Transfer Program

Every year, NASA invents or modifies technology, writes new code, and develops new solutions for agency initiatives. That might be a new sensor for an Earth-observing satellite to collect needed data or tweaking an algorithm to make that data accessible to anyone. The Technology Transfer program offers a number of initiatives to introduce entrepreneurs, college students, and others to the resources NASA makes available.

NASA Computer Code Contributes Well Beyond Space Economy

Now in its 13th year, the agency Software Catalog's scope and success continue to expand



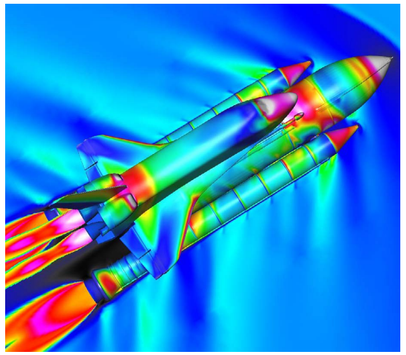
Orbital debris — anything from bits of metal to dead satellites — is a growing problem, especially in low Earth orbit where it's most common and moving fastest — about seven times the speed of a bullet. To stem the problem, companies now must file plans to eventually remove their satellites and rocket upper stages from orbit. The requirement has made NASA's Debris Assessment Software one of the agency's most widely used codes. Credit: NASA

When a senior NASA researcher and his friend were both dealing with aging parents whose health issues needed monitoring, he realized the software he'd been developing for space station mission control could be just the thing to help. The now-former Ames Research Center programmer and friend cofounded Ejenta Inc. to commercialize NASA artificial intelligence software originally created to monitor changes in astronauts' vital signs and automate the sorting and distribution of space station data (Spinoff 2021). Fourteen years later, some of the country's largest healthcare providers have incorporated Ejenta's version of the NASA-written codes into systems that monitor high-risk conditions in outpatients on Earth.

While the most famous technology to spin off from NASA often takes the form of machines, materials, and other tangible goods, many of the inventions the space agency offers to the public are bodiless lines of code, sets of instructions, algorithms for solving equations. Every year, NASA engineers create and update scores of computer programs to automate tasks that may be unique to space exploration or simply to help themselves do their jobs more efficiently.

The agency makes many of these codes available to the public through its online Software Catalog, where more than 1,200 programs are now available for download, free of charge.

"Large corporations often create their own internal software to help streamline their work, but these programs are never released to the public," said Dan Lockney, NASA's Technology Transfer program executive. "And commercial software that addresses industrial processes can be prohibitively expensive for small businesses and startups. Free software to meet challenges faced by both NASA and many businesses represents one more bag of seeds the agency plants in the U.S. economy."

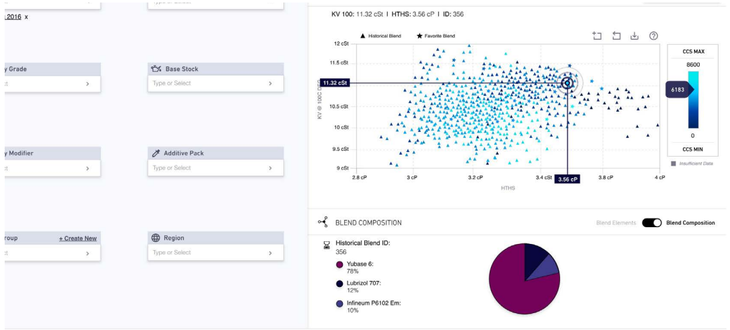


NASA has been at the forefront of computational fluid dynamics (CFD) software to model aerodynamic performance since the field's early days. NASA has released several CFD codes to the public, where they're now used by aircraft and spacecraft manufacturers, as well as automakers and many others. Here the NASA CFD flow solver OVERFLOW models the detailed interactions of flows around the space shuttle, its external tank, and its two solid rocket boosters. *Credit: NASA*

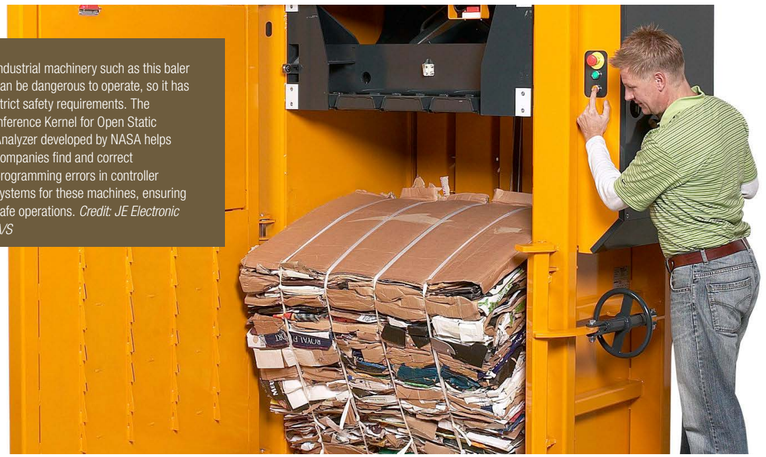
The software is often aeronautics-specific, with countless resources available to commercial space and aviation companies. The consistent frontrunner for NASA's most-downloaded program, for example, is the Debris Assessment Software that helps space launch companies meet federal requirements for planning to eventually take their satellites and rocket upper stages out of orbit (see page 7 of this edition).

Other programs originated with the space agency's work on spacecraft and aircraft but can be applied across many industries. These include computational fluid dynamics (CFD) programs that simulate aerodynamic forces and aircraft performance, such as the TetrUSS (Tetrahedral Unstructured Software System) software suite (Spinoff 2021), Pegasus (Spinoff 2018), OVERFLOW (Spinoff 2019), and others. NASA CFD software, also consistently ranked among the agency's most popular, is heavily used by most major aircraft and spacecraft manufacturers. But others use these programs for designing automobiles, boats, and other vehicles, for calculating wind forces acting on buildings, and even for modeling airflows in systems like air conditioning compressors.

The demands of space exploration, however, cut across every imaginable discipline, from human health to system monitoring, maximizing efficiency, and the writing of computer code itself. Among the many examples of successful commercialization of NASA software is an app for evaluating the fine motor skills of astronauts as they adjust to the absence or presence of gravity, now commercialized by Leidos Holdings for monitoring patients on Earth (Spinoff 2021). A company called Beyond Limits has used the latest versions of two of NASA's earliest artificial intelligence programs for very different purposes. First, the software helped place online advertisements (Spinoff 2016), and now it's helping oil drillers to choose well locations and smart power plants in West Africa to balance energy supplies and demands (Spinoff 2022). NASA project managers originally created a Microsoft Project add-on called Schedule Test and Assessment Tool (STAT) to weed out discrepancies in long, complex mission schedules. Now one of the agency's most-downloaded codes, STAT helps planners at companies, universities, government agencies, and other organizations not only to build and maintain coherent, consistent schedules for complicated projects but also to create performance reports, track margins and milestones, and compare and analyze data (Spinoff 2015).



The Cognitive Formulation Advisor is one of several tools that the company Beyond Limits made to support the energy industry with the help of NASA artificial intelligence software. *Credit: NASA*



Industrial machinery such as this baler can be dangerous to operate, so it has strict safety requirements. The Inference Kernel for Open Static Analyzer developed by NASA helps companies find and correct programming errors in controller systems for these machines, ensuring safe operations. *Credit: JE Electronic A/S*

The NASA Software Catalog even includes a program for analyzing programs: the Inference Kernel for Open Static (IKOS) Analyzer can scan any software code written in the C or C++ computer languages and flag possible errors, much like a grammar-check program proofreading an essay (Spinoff 2021). IKOS now saves users across various industries the thousands of hours it would take to review software line by line, as well as the untold costs of fixing bugs after they've already caused problems.

These are just a few of the many examples of NASA-invented software now in commercial use. To help potential users find the software that's most relevant to their purposes, the catalog is broken down into 15 categories, from aerospace and propulsion to medicine and biotech, manufacturing, optics, and robotics. The programs also fall under different release types, with some being open-source, meaning anyone can download them and also make modifications to the source code, while others are available to anyone who signs a software usage agreement. Others, depending on sensitivities, can be released only to U.S. citizens or even only to other government agencies. All are available at no charge.

The Software Catalog is updated every two years, with new and updated codes added and release restrictions periodically reviewed to see if they can be loosened. The latest version went public in July of 2025. In recent years, NASA's Technology Transfer program has accompanied the release with a series of live webinars, each featuring a presentation examining use cases for a particular software followed by a question-and-answer session.

"Commercial software that addresses industrial processes can be prohibitively expensive for small businesses and startups."

Dan Lockney, Technology Transfer program executive

These days, the space agency typically executes 5,000 or more software usage agreements every year.

"One of the amazing things about NASA is its ability to do research and create technology that is spun out and improves the U.S. economy, making it possible for people to do things that otherwise would not be possible," said Maartin Sierhuis, cofounder and chief technical officer of Ejenta, who turned the astronaut-monitoring software he'd developed for NASA into a program that helps care for outpatients. "We now have a care team that's just like in mission control." ●

The company that planned the construction of the Geostationary Operational Environmental Satellites-R Series, better known as GOES-R — shown here under construction at Goddard Space Flight Center — is among those who use the Schedule Test and Assessment Tool (STAT) software add-on to help verify the integrity of the project schedule. STAT, which helps users weed out scheduling discrepancies, create reports, track milestones, and perform other functions, is one of NASA's most popular codes among the public and industry. *Credit: NASA*

Spinoffs of Tomorrow

When a company, academic institution, nonprofit, or individual has a technology problem, NASA might just have the solution in the agency's patent portfolio. The Technology Transfer staff helps anyone consider which of the 1,000-plus patented technologies might be exactly what they're looking for. To learn more about the technologies in this section or any others — and get started licensing — contact Agency-Patent-Licensing@mail.nasa.gov.

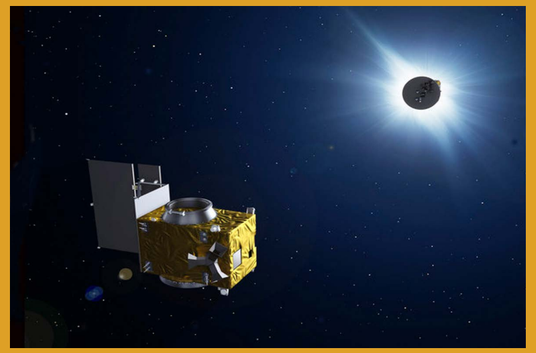
The X-59 Quiet Supersonic Technology research aircraft undergoes ground tests at Lockheed Martin's Skunk Works facility in Palmdale, California, on July 18, 2025. The X-59 is the centerpiece of NASA's Quesst mission to demonstrate technology to break the sound barrier without creating a loud sonic boom. ***Credit: NASA***

Ames

Monitoring and Control of Each Nanosatellite in a Cluster

A low-cost propulsion, navigation, and power-sharing technology

Ames Research Center has developed an innovative combination of a magnetometer, low-powered electromagnets, and resonant inductive coupling to create and control relative positioning of nanosatellites within a cluster. This is a revolutionary approach to enable distributed nanosatellite clusters with a focus on low-cost propulsion, navigation, and power sharing. Several nanosats can be clustered without the need for propellant-based propulsion systems or GPS by separating distinct subsystems into their own nanosats and producing them as generic, off-the-shelf components.

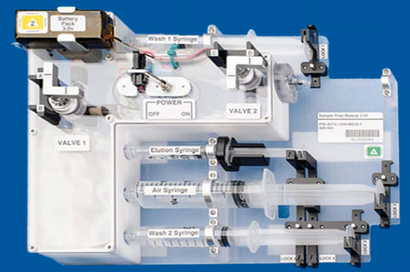


Benefits

- Reduced costs of development and operations
- Increased reliability and cluster capability
- Reduced time from mission concept to flight
- Increased efficiency with independent attitude control

Applications

- Space exploration
- Earth-observation systems
- Scientific research
- CubeSat/nanosatellite systems



Benefits

- Cost-effective, ready to use, and simple to operate
- Single-use, disposable, and portable
- Rapid run time
- Reduces or eliminates contamination concerns

Applications

- Medical diagnosis
- Food quality testing
- Bio-threat detection
- Life sciences industry

Rapid Nucleic Acid Isolation Method and Fluid-Handling Devices

Smaller, simpler sample-preparation system for analysis of gene expression

Sample preparation is a common bottleneck in genetic analysis. There is a need for a system that not only is mobile, ruggedized, and easy to use but also provides enclosed fluid handling, diminishing the risks of RNA contamination. Ames Research Center has developed a methodology and suite of devices to isolate nucleic acids and prepare samples for reverse transcriptase quantitative polymerase chain reaction analysis that solves the problem of contamination and degradation.

Armstrong

Benefits

- Variable spatial resolution along an optical fiber
- Allows parallel processing of thousands of measurements
- Reduces processing time and data volume

Applications

- Structural health of buildings, bridges, oil platforms
- Cargo load balancing, flight testing
- Active control of vehicle frames and suspension, wind turbine blades, aircraft, and more
- Monitoring procedures involving endoscopes, catheters

Adaptive Spatial Resolution for Focused Fiber-Optic Sensing

Innovation provides fast signal processing and precise measurement

This algorithm was originally developed to enhance Armstrong Flight Research Center's multi-patented Fiber-Optic Sensing System (FOSS). With over 2,000 sensors per fiber, FOSS enables thousands of high-resolution measurements at once, including strain, shape, temperature, pressure, and more. The new innovation allows users to specify spatial resolution and accuracy requirements by making it possible to optimize data transmission bandwidth and adjust processing to minimize extraneous computations. This new capability opens up myriad new applications for fiber-optic sensing systems.

Gateway to Integrate Wireless Sensors with Existing Aircraft

Architecture incorporates wireless technology into preexisting systems

Innovators at Armstrong Flight Research Center have found a way to add wireless sensors to aerospace vehicles without modifying existing avionics: a universal wireless access point, or "gateway," can communicate between existing onboard systems and wireless devices. This gateway can be reprogrammed to communicate with any wireless device. This architecture holds promise for other industries seeking to capitalize on the advantages of wireless sensors.

Benefits

- Rapid integration of off-the-shelf wireless sensors
- Eliminates weight of cabling
- Lower costs
- Streamlined industry infusion

Applications

- Testing aeronautic and automotive vehicles
- System health monitoring
- Infrastructure, manufacturing, and the internet of things

Glenn

Multi-Stage Filtration System

Particle impactor and scroll filter operate in high-temperature, extreme environments

This unique filtration system can collect a wide range of particle sizes. This capability keeps high-efficiency filter media from becoming overloaded with larger particles. Glenn Research Center's system uses an impactor filter to capture larger particle matter through inertial separation and impaction methods on surfaces. In this way, the device provides a pre-filter stage that protects the more critical stages of the filter system, extending the life of high-efficiency particulate arresting (HEPA) filter systems that are designed to capture ultrafine particles.

Benefits

- Provides operational longevity over state-of-the-art filter systems
- Low-maintenance, saving resources like crew time, waste disposal, and power usage
- Works in closed-system, extreme-temperature, and high-pressure environments

Applications

- HEPA filters
- Commercial aircraft
- Flow imaging research
- Submarines

Benefits

- Lightweight design is easily integrated into aircraft
- Overall system efficiency increases from 40% to 60%
- No hot moving parts, plumbing, or wiring
- Leads to significant savings in fuel, material, and maintenance costs

Applications

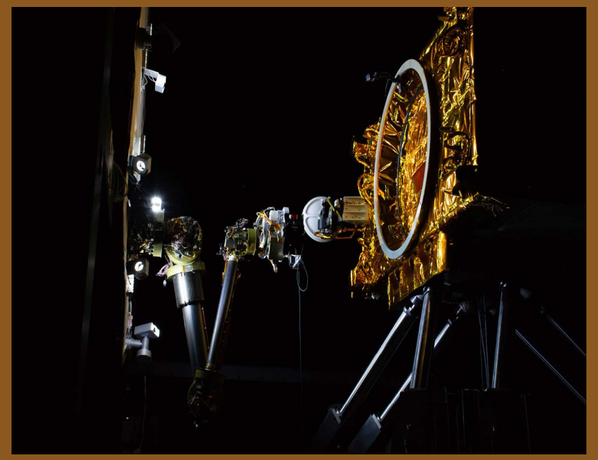
- Electric aircraft
- Aircraft auxiliary power units
- Remotely piloted vehicles
- Satellites

Signal Combiner for Wireless Communication

A frequency multiplexer combined with an analog-to-digital converter increases efficiency

This efficient way of combining primary and secondary signals with minimal loss and noise delivers the best opportunity to receive a desired signal that's not easily distinguished from background noise. While this new technology forms part of a radio for satellite ground stations, it is also poised to be an important piece in telecommunications devices, including cellphones, Wi-Fi, hot spots, satellites, and future wireless technologies.

Goddard



Benefits

- Minimizes alignment forces
- Minimizes wear
- Minimizes particle generation

Applications

- Satellite servicing
- Hydraulic connectors
- Telerobotics

Fluid Transfer Coupler

A fluid coupler with a low overall alignment, low insertion forces, and a locking mechanism

A fluid coupler is a hydrodynamic or hydrokinetic device used to transmit rotating mechanical power, consisting of a housing and two turbines, plus some hydraulic fluid. This Fluid Transfer Coupler addresses trades between ball-in-grove-type couplers and pivoting cogs, along with various types of seals. It can be used in automobile transmissions as an alternative to a mechanical clutch and also has widespread applications in marine and industrial machine drives, where variable-speed operation is essential.

High-Performance, All-Metal X-Band Patch Antenna

Rugged design and excellent performance in a small package

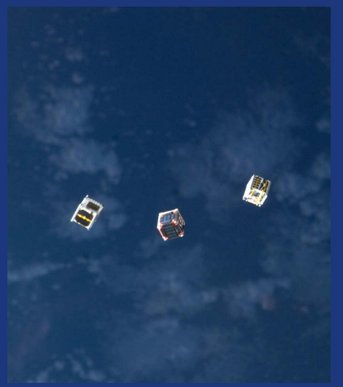
This all-metal X-band antenna was designed to meet the stringent requirements of high-precision space navigation antennas. Compared to commercially available patch antennas, NASA's antenna is more rugged, mitigates signal interference, and is capable of higher power handling. NASA's X-band antenna was designed to be mounted on a CubeSat but has the potential to be mounted on terrestrial aircraft and vehicles for either communication or radar applications.

Benefits

- All-metal construction provides robustness, radiation tolerance, high power loads
- Compact design: can fit in a coffee mug
- Built-in choke rings provide consistent signals
- Efficiency: integrated polarizer circuit eliminates need for rotation

Applications

- Commercial spacecraft
- Broadband networks
- Air traffic control
- Aircraft communications

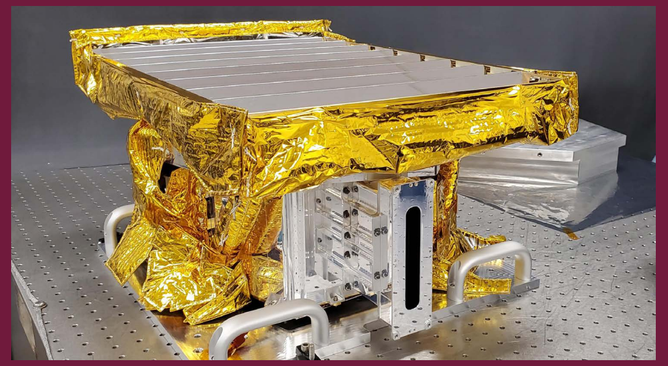


JPL

Mapping Lunar Minerals, Water, Temps

Sensor identifies essential resources on the Moon

Designed to address questions about the availability of water in permanently shadowed regions of the Moon, the High Resolution Volatiles and Minerals Mapper for the Moon (HVM3) is a multiband thermal imager that takes regional measurements. HVM3 can distinguish between different types of H_2O — molecular, frost, and ice. A related software and algorithm are also available.

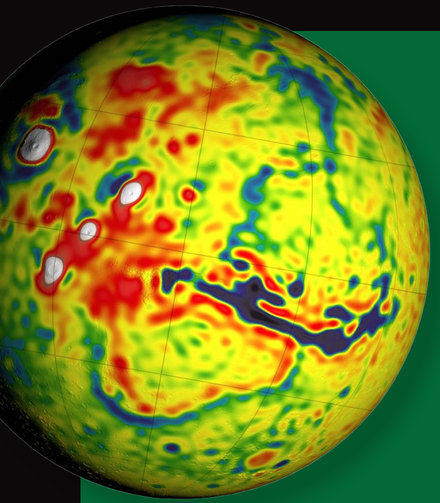


Benefits

- Area-specific data for shadowed lunar locations
- Confirms observations by other instruments
- Works in conjunction with a multiband thermal imager to measure surface temperature and mineralogical composition

Applications

- Commercial lunar satellites



Benefits

- Uses new computational tools that support task migration
- Supports tailoring models for unique elements like craters
- Customizable algorithms and preliminary MATLAB and Mathematica toolboxes

Applications

- Commercial lander mission
- Commercial rover mission
- Commercial asteroid mining

Calculating Gravity

Model gravitational fields for successful landing

Accurate gravity field calculations are necessary for landing on planets, moons, asteroids, or other irregularly shaped celestial bodies. But current methods become increasingly inaccurate near the surface. This highly accurate method for computing gravitational potential and gravitational force fields contributes to successful mission planning and execution.

Johnson

Benefits

- Small and lightweight
- Portable
- Chemical-free
- Uses minimal consumable products

Applications

- Drinking water purification
- Isolated geographic locations
- Hospital and research facilities
- Decontamination systems

Water Decontamination

Safely eliminate bacteria growing in drinking water systems

Biofilms can clog or interfere with water system functions, and bacterial ingestion can be harmful to human health. This microwave-based technology developed to purify contaminated water on the International Space Station eliminates bacteria that grow inside systems. It can be used for technology that generates drinking water and in equipment utilizing cooling loops and heat exchangers. It also removes bacterial contamination on a variety of surfaces.

X-Ray Radiography Optimization

Test and model crack sensitivity verification

Undetected cracks can cause catastrophic failure in numerous systems such as pressure vessels. This software technology uses a penetrameter-based model that can predict whether cracks of a certain size can be detected. This model can provide appropriate conditions to optimize X-ray crack-detection setup and allows users to test various approaches until the desired crack-detection capabilities are predictable.

Benefits

- Uses non-invasive procedure on test object
- Inexpensive to operate
- Provides high probability of detection
- Enables establishment of crack-detection requirements standards

Applications

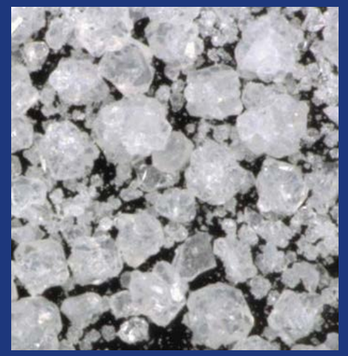
- Automotive
- Civil and structural engineering
- Industrial manufacturing
- Medical implant and prosthetic manufacturing

Kennedy

Wastewater Treatment and Remediation

Closed-loop system for recovering ammonia from wastewater

Kennedy Space Center has devised a system using an affordable medium that is highly selective for ammonia, allowing large concentrations of ammonia in wastewater to be reduced to levels less than 1 part per million. Following treatment, the medium is regenerated for reuse in the system, and ammonia is captured as a by-product. The technology could be incorporated into wastewater treatment systems at various stages — water treatment, effluent polishing, resource reclamation, resource recycling, gray water treatment, or others.

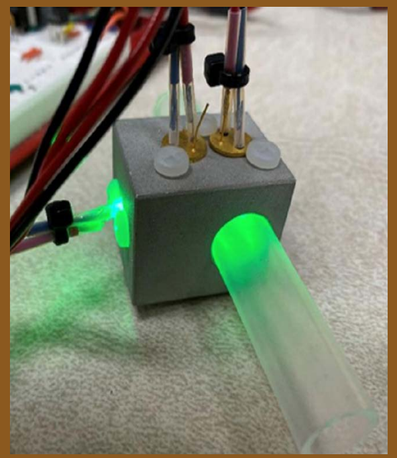


Benefits

- Higher capacity and lower cost than traditional absorbents
- Effective under varying ammonia concentrations
- Works in just seconds
- Easily regenerated media, allowing for repeated use

Applications

- Agricultural wastewater
- Wastewater from food processing, fertilizer, chemical, and textile plants
- Municipal water treatment
- Recycled and reclaimed water



Benefits

- Easy to adopt, built with commercial components
- Less prone to voltage drift and contamination than conductivity-based sensors
- Improved reliability
- Can be miniaturized to roughly one cubic inch

Applications

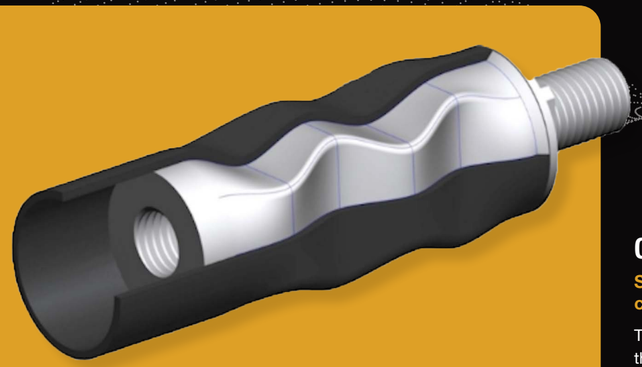
- Aerospace fluid management systems
- Food and beverage processing, pharmaceutical production, medical devices
- Wastewater processing

Optical Concentration Sensor for Liquid Solution

Light-scattering approach to precisely measure solution concentrations

Innovators at Kennedy Space Center have developed an optical sensor for measuring concentration in a liquid solution. The sensor was designed for measuring the pretreat solution concentration in the specialized toilet for the International Space Station. Using established methodologies and commercial components, the new sensor can precisely measure the concentration of pretreat within the solution using the light passed through and scattered by the solution. The sensor can be adapted to measure the concentration of solutions across various industries.

Langley



Benefits

- Increased structural integrity by reducing stress-related failure characteristics
- Can be formulated to fit a variety of joint shapes
- Corrosion resistant, lightweight, and electrically insulated
- Two or more tubular elements can be joined at a node point

Applications

- Aerospace
- Automotive
- Outdoor structures
- Sporting goods

Composite Joint Connector

Structural joint with multi-axis load-carrying capacity

Traditionally, composite joints can bear heavy loads along their length but tend to fail when stress is applied along multiple axes. This joint is designed to minimize stress concentrations, leading to overall increased structural efficiency when compared to traditional joints.

Flexible Lightweight Radiation Shielding

Method of making thin, flexible shielding integrated with common textiles

An innovator at Langley Research Center developed a method for making thin, lightweight radiation shielding that can be sprayed or melted onto common textiles such as cotton, nylon, polyester, Nomex, and Kevlar. The lead-free shielding is more effective at blocking radiation than similar thicknesses of lead but is up to 25% lighter. It can also be formed into a variety of garments with significantly greater comfort and conformity than the aprons currently in use.

Benefits

- Lead-free
- Ten to 25 times greater radiation shielding compared to similar thicknesses of lead
- 25% lighter than similar thicknesses of lead
- Can be applied to commercial fabrics

Applications

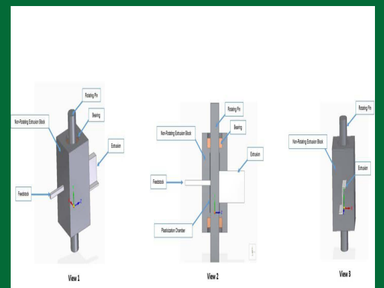
- Personal protective equipment
- Radiation shielding for hospital facilities
- Electronics
- Aerospace

Marshall

An Update for Friction Stir Welding

Modular add-on increases customization while saving money

The Conventional Friction Stir Extrusion Machine can be attached to a conventional friction stir welding system to create extruded parts of any length. This modular machine means a die can be easily replaced to create a variety of geometric shapes. It works with any metal alloy normally used in friction stir welding, including aluminum alloys and other lightweight or exotic alloys.

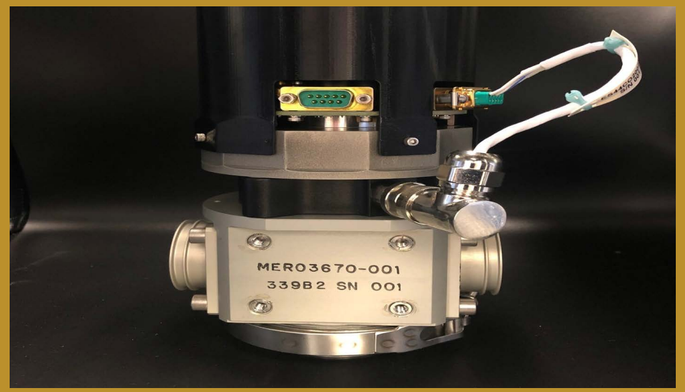


Benefits

- Improves existing systems with easy retrofits
- Easily customize extrusion shapes
- Cost-effective, low-volume runs
- Raw metal input doesn't require preheating

Applications

- Aerospace metal components (e.g., rib stiffeners)
- Automotive metal parts
- Railway car metal parts
- Ship-building metal parts



Benefits

- Extended lifetime in dusty environments
- Easier to fabricate and maintain
- Low-cost to manufacture

Applications

- Aerospace components
- Industrial processes
- Swing dryer towers
- Feed mill systems

Long-Lasting Valve for Dusty, Contaminated Places

Eliminating common problems caused by dust prevents damage

Valves subjected to airborne contaminants tend to have limited lifetime due to damaged seals, bearings, and other internal parts. NASA's Debris-Tolerant Valve is designed for use in machines in environments with airborne dust or other contaminants. A new cylinder design decreases dust collection within the valve. The valve design minimizes grinding, and the use of elastomeric seals prevents scratching. A port for fluid intake allows pressure to build slowly, eliminating the stirring of dust caused by rapid inflow of air.

Stennis

Benefits

- Vastly reduces testing cost and timeline
- Portable and self-contained
- Improves testing accuracy

Applications

- Rocket engine testing and development
- Fundamental nozzle research
- Simulation of combustion products (e.g., automotive testing)

HYPERFIRE

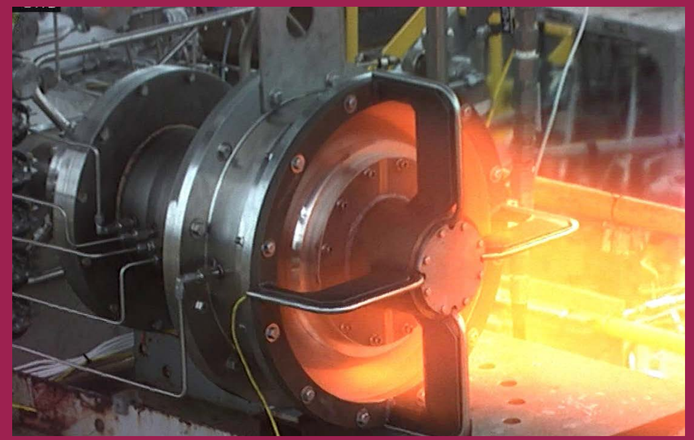
Hydrocarbon Propellants Enabling Reproduction of Flows in Rocket Engines

For ground-based rocket aerodynamics testing, engineers at Stennis Space Center discovered that ethane can be tuned to approximate rocket exhaust plumes generated by several common rocket propellants. This led to the development of Hydrocarbon Propellants Enabling Reproduction of Flows in Rocket Engines (HYPERFIRE), a sub-scale, non-reacting flow test system. HYPERFIRE uses heated ethane to enable physical simulation of rocket engines in an inexpensive, accurate, and simple fashion.

Supersonic Spike Diffuser

Double the pumping efficiency in one quarter the space

Standard cylindrical and second-throat diffusers create losses and result in an inefficient pumping process. Center-body diffusers increase the number of oblique shocks in the system by introducing multiple turns. A new spike diffuser developed by Stennis Space Center can provide double the pumping performance of second-throat diffusers by reducing core Mach number and flow deflection. This enables lower vacuum pressures via higher-expansion-ratio driving nozzles. Spike diffusers also require only 25% the length of second-throat designs.

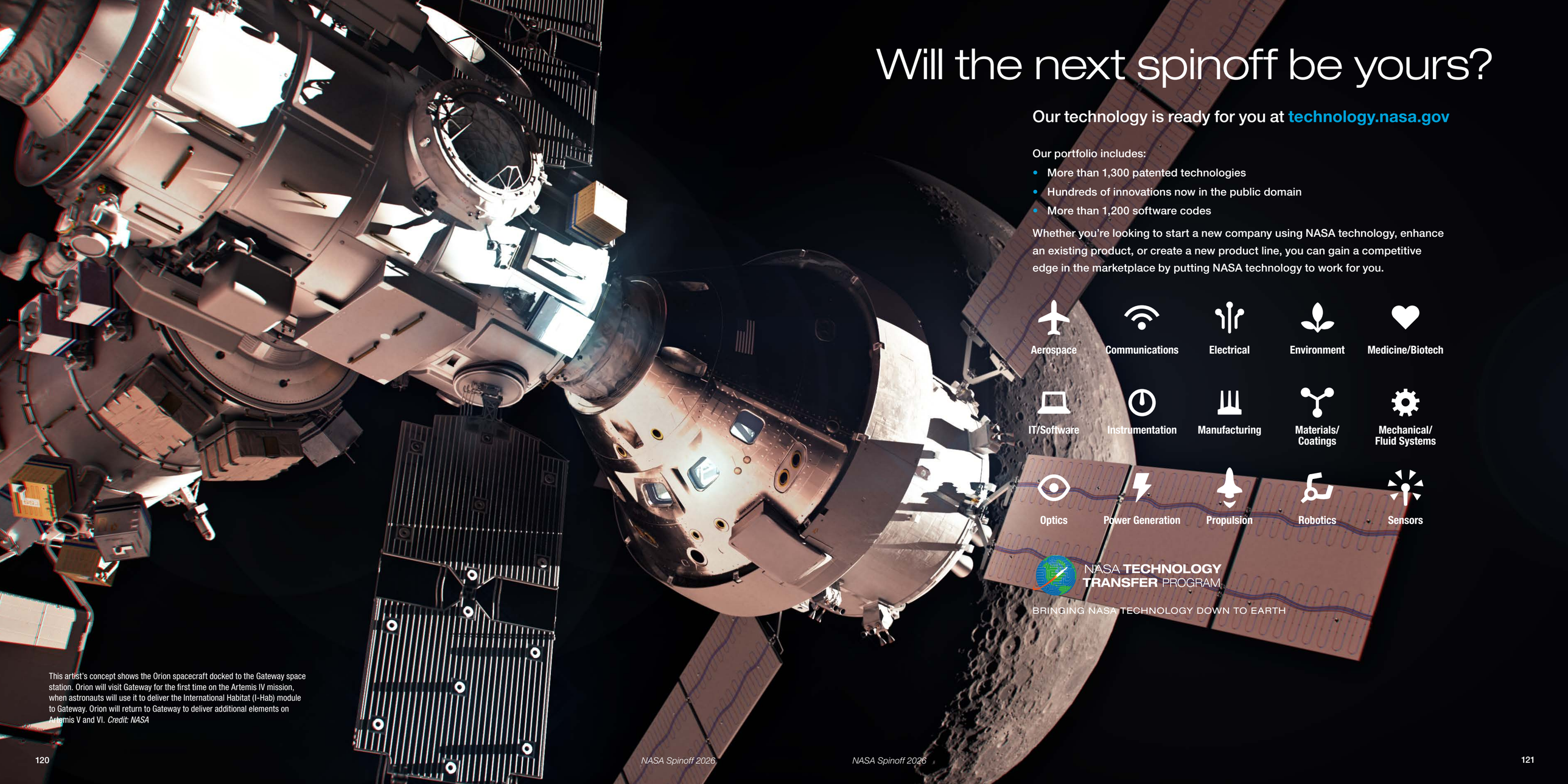


Benefits

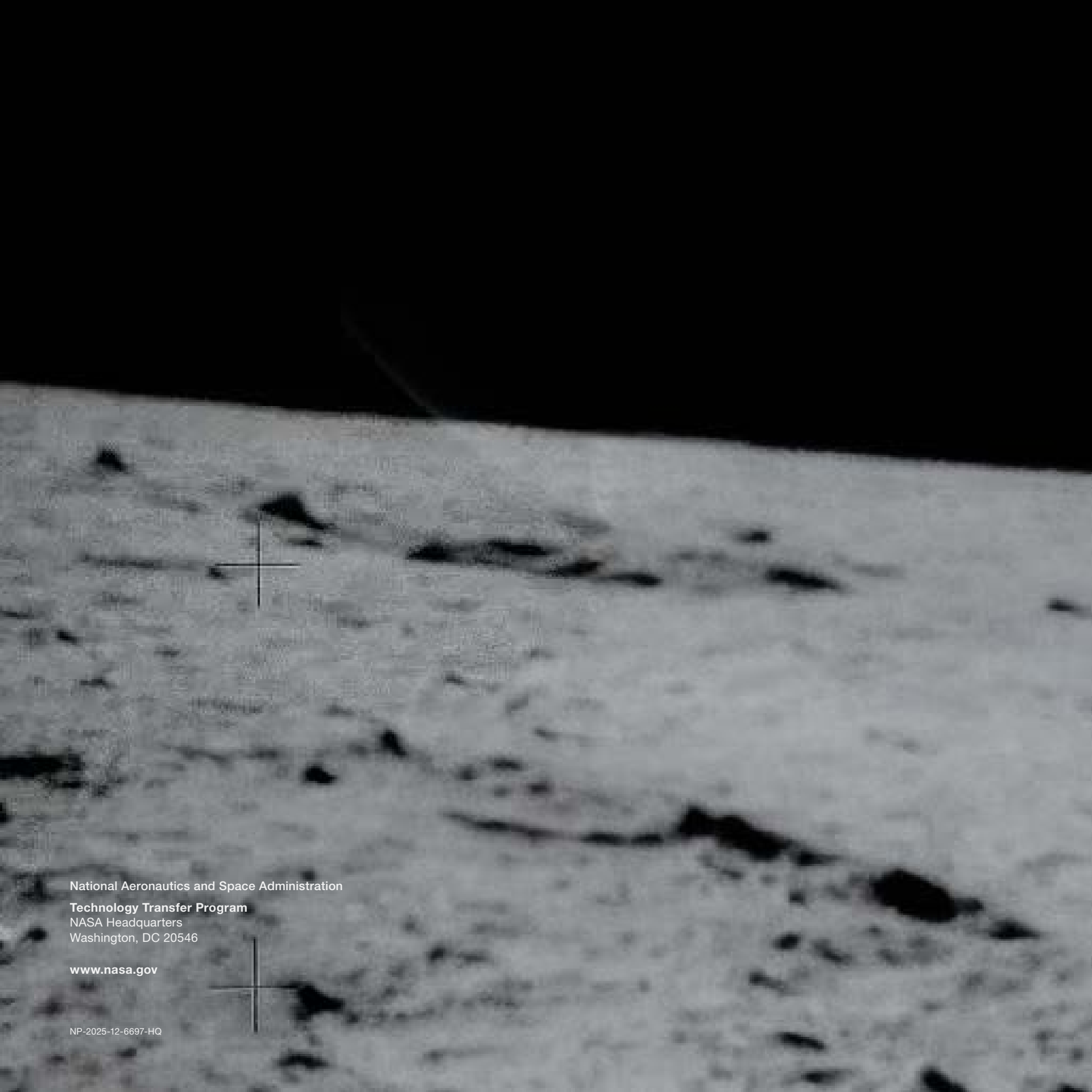
- Starting pressure ratio half of conventional diffusers
- Lower vacuum
- Spatially compact
- Reduced structural overhead

Applications

- Steel degassing
- Chemical processing
- Oil and gas refinement and edible oil processing
- Artificial fiber manufacturing



This artist's concept shows the Orion spacecraft docked to the Gateway space station. Orion will visit Gateway for the first time on the Artemis IV mission, when astronauts will use it to deliver the International Habitat (I-Hab) module to Gateway. Orion will return to Gateway to deliver additional elements on Artemis V and VI. *Credit: NASA*



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