National Aeronautics and Space Administration

Partners in Innovation

GODDARD SPACE FLIGHT CENTER | INNOVATIVE TECHNOLOGY PARTNERSHIPS OFFICE | ACCOMPLISHMENTS REPORT 2014

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INNOVATIVE TECHNOLOGY PARTNERSHIPS OFFICE

2014 From the Chief

Partners in Innovation: The definition of a partner is "one associated with another especially in an action," while innovation refers to "the introduction of something new." Thus, the theme of this year's annual report is the association of people to introduce new things. That perfectly describes the function of this office, which connects innovators here at the Goddard Space Flight Center with partners in outside organizations.

We've seen some impressive collaboration this year, as covered in the four quarterly issues of our Tech Transfer News: Last Winter, we covered the Global Precipitation Measurement (GPM) mission, which is a collaboration between NASA Goddard and the Japan Aerospace Exploration Agency (JAXA). The GPM Core Observatory is part of a larger constellation of satellites, operated with space agencies in India and Europe – a truly global collaboration to provide vital climate change data.

In the Spring issue, we covered partnerships between materials scientists here at Goddard and industrial partners that will lead to new products based on innovative materials including Graphene a "wonder material" with properties and performance advantages that point toward the next generation of optics and sensors and unmanned spacecraft, Lotus Coating, which uses the "lotus effect" found in nature to simulate an ultra-hydrophobic and self-cleaning nano-texture for dust mitigation, and a Molecular Adsorber Coating for controlling dangerous outgassing that also acts as thermal control for sensitive instruments.

In the Summer, we covered Goddard's work on small satellites, including Firefly, a CubeSat designed to study lightning developed in a partnership between Goddard and the National Science Foundation– which is just one of a number of examples where Goddard is working with partners to maximize scientific return from small missions that can be launched on short time scales at minimal cost.

And in the Fall we covered Big Data, where it's difficult to predict just who a partner might be. Data originally collected by Goddard for scientific purposes can also be used by natural resource firms, insurance companies, or analytics providers. It should come as no surprise that Goddard is at the forefront of cloud computing, and our scientists, engineers, and project managers are hard at work to build a Big Data architecture that pushes the transformative limits of the cloud even further.

Beyond the main topics covered in the quarterly magazines, we review overall activities of the ITPO, with a special focus on our technology transfer program. This year, our team delivered an unprecedented three hundred and seven (307) new technology reports (NTRs). In the pages that follow, you will find coverage of our work related to Small Business Innovation Research (SBIR) / Small Business Technology Transfer (STTR) awards, patents and Space Act Agreements. You will also read about some of our outreach efforts, with innovative partners including Peter Cullen, the voice actor behind Hasbro's OPTIMUS PRIME character, and science fiction writer Dr. William Forstchen.

I am proud of the team here in the ITPO, and I invite you to read about the many partnerships we've fostered in 2014.

Nona Cheeks
Chief, Innovative Technology Partnerships Office (Code 504) NASA Goddard

Tech Transfer Reports

2014 Year in Review

In this report we review some of NASA Goddard's major technology transfer related events and accomplishments of 2014. As with past reports for previous years, our focus is on NASA Goddard technologies, originally developed to support space missions, that can be adapted and applied for terrestrial use. These include:

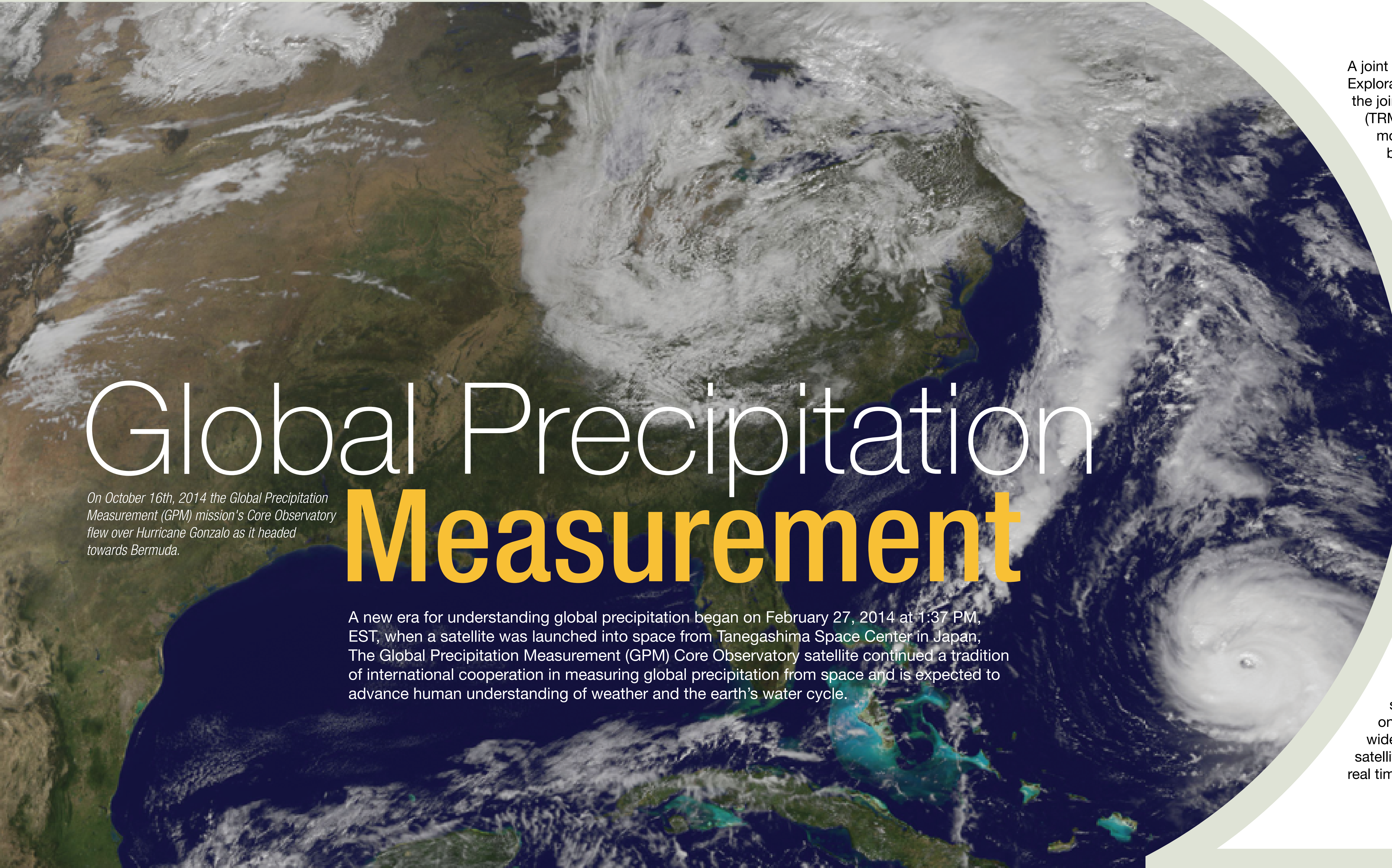
GLOBAL PRECIPITATION MEASUREMENT (GPM): A joint mission between NASA and the Japan Aerospace Exploration Agency (JAXA), continues a tradition of international cooperation in measuring global precipitation from space and is expected to advance human understanding of weather and the earth's water cycle. Goddard innovations used for the GPM mission include (among other things): software for spacecraft flight control, operational simulation and space and ground comparison, a visualization tool for validation network geometrically-matched ground- and space-based radar data and a dual-wavelength, dual-polarized doppler precipitation radar (D3R) that was developed under a series of SBIR awards.

CUBESAT/SMALLSAT: Goddard continued to innovate on small satellites this year with projects including the National Science Foundation Firefly mission, Compact Radiation Belt Explorer (CeREs), and Dellingr, a double-width six unit (6U) CubeSat named after the Norse god of the dawn. The center is also working to produce advanced on-board computing platforms that will support future small satellite missions moving beyond Low Earth Orbit, and provides support for small satellite missions through the Wallops Flight Facility.

MATERIALS SCIENCE: Goddard scientists and engineers have developed a number of advanced materials, including ultra-thin films of the "wonder material" Graphene that provide high strength and conductivity while remaining transparent, a new coating technology that mimics the natural structure of the lotus plant to deliver new materials that are ultra-hydrophobic, self-cleaning, lightweight, and cost effective, and a Molecular Adsorber Coating developed to address the problem of outgassing on space flight missions, which can damage sensitive instruments and shorten the life and performance of critical equipment.

BIG DATA: As advanced instruments deliver ever-large streams of data, Goddard is responding with innovative methods for data compression and processing. Examples include the Virtual Climate Data Server (vCDS) which virtualizes access to a vast store of climate data, and Modern Era Retrospective Analysis for Research and Applications Analytic Services (MERRA/AS) which improves data performance, and provides refined data sets to users.

We also review 2014 activities of the Innovative Technology Partnerships Office (ITPO) which is primarily responsible for facilitating the transfer of NASA Goddard technologies for use in other government centers, academia, and private enterprise. The ITPO also plays a leading role in bringing new technologies into NASA Goddard, through programs such as the Small Business Innovation Research (SBIR) and Small Business Technology Transfer (STTR) programs. This 2014 accomplishments Report also looks back at technology transfer events and initiatives in which the ITPO participated. We also list patenting and technology reporting associated with NASA Goddard scientists and innovators.



Global Precipitation Measurement

On October 16th, 2014 the Global Precipitation Measurement (GPM) mission's Core Observatory flew over Hurricane Gonzalo as it headed towards Bermuda.

A new era for understanding global precipitation began on February 27, 2014 at 1:37 PM, EST, when a satellite was launched into space from Tanegashima Space Center in Japan. The Global Precipitation Measurement (GPM) Core Observatory satellite continued a tradition of international cooperation in measuring global precipitation from space and is expected to advance human understanding of weather and the earth's water cycle.

A joint mission between NASA and the Japan Aerospace Exploration Agency (JAXA), GPM builds on the success of the joint NASA/JAXA Tropical Rainfall Measuring Mission (TRMM) launched in 1997. TRMM was designed to measure moderate to heavy tropical rain and carried the first space borne precipitation radar. It provided the very first three-dimensional images of storm systems, making possible innovative weather analysis. However, TRMM only monitors moderate to heavy rain precipitation over tropic and subtropic regions. The GPM Core Observatory will expand this view from the Arctic circle to the Antarctic circle, and will be able to measure light rain and frozen precipitation. To deliver the data required to accomplish program goals, GPM is equipped with a 13 channel microwave imager and a dual frequency precipitation radar.

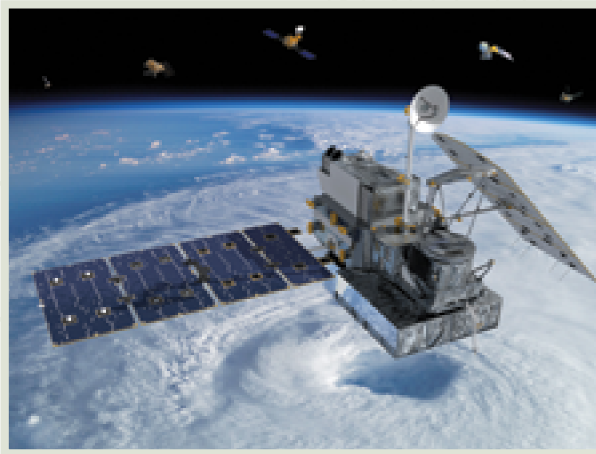
The GPM Core Observatory can observe storms forming in the tropical oceans and track these storms as they move. These advanced observations are expected to help meteorologists study the internal structure of storms throughout their life cycles, including how they change over time. This may help to explain why some storms change in intensity as they transition from the tropics to the mid-latitudes.

The Global Water Cycle

Moisture and precipitation in the atmosphere are studied to understand the role precipitation plays in the global water cycle. But water is difficult to measure consistently around the globe and precipitation varies over land and oceans. Ground-based measurements of precipitation are limited to specific sites and even less information is available on oceanic precipitation. Satellite observations offer a wider view. TRMM and GPM are part of a constellation of satellites (9 in all) that provide global precipitation data in near real time, updated every three hours.

Combined, the constellation provides scientists with precipitation intensity and variability within storms, information on the microphysics of ice and liquid particles in clouds, the amount of water actually falling onto the Earth's surface, and a three dimensional view of storm and cloud structures. This data helps meteorology and climate scientists improve climate and weather forecast models (including forecasts of hurricanes, floods, droughts and landslides) and design integrated hydrologic models of watersheds.

According to Deputy Project Manager Candace Carlisle, while GPM is a Class B mission, it benefitted from a multitude of technologies that Goddard developed for, and used on, prior missions. However, during GPM development, new technologies, including flight software, validation technology, and simulator technology were developed and used specifically for this mission.



Visualization of the GPM Core Observatory and partner satallites. —IMAGE BY NASA

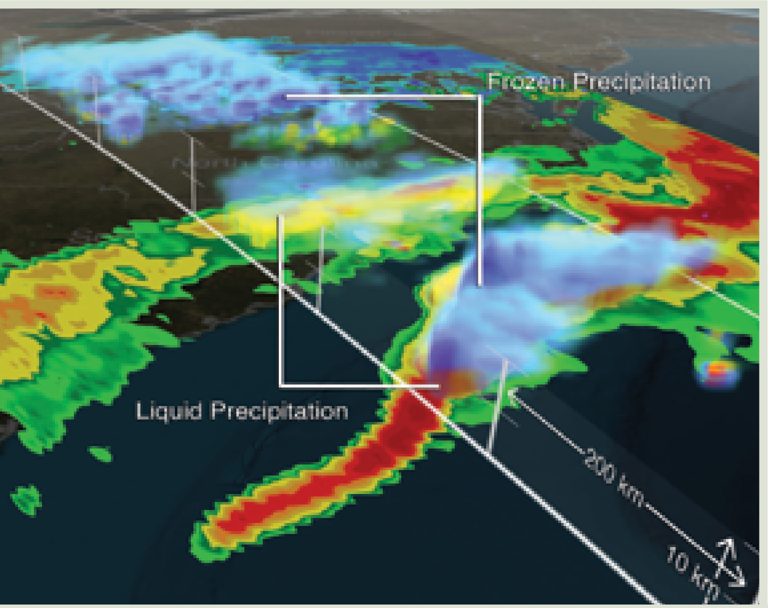
Global Precipitation Measurement Spacecraft Flight Software (GSC-16669-1)

The GPM spacecraft flight software (FSW) controls and coordinates all aspects of spacecraft operation in nominal and anomalous conditions. The Flight Software also monitors the health of most orbiter subsystems and takes corrective actions when necessary. FSW uses Goddard's Operating System Abstraction Layer and Core Flight Executive software. Ten Core Flight System (cFS) applications were also co-developed by GPM and Code 582 and are now available in the Code 582 library for future mission use.

Several NASA centers use cFS. For example, the Johnson Space Center used cFS on project Morpheus (which developed and tested a prototype planetary lander capable of vertical takeoff and landing), Ames Research Center used it on the LADEE (Lunar Atmosphere and Dust Environment Explorer) mission, and Goddard Space Flight Center used it on the MMS (Magnetospheric Multiscale) mission. The Johns Hopkins Applied Physics Laboratory and other commercial organizations are also interested in it.

GPM Space and Ground Radar Comparison Software (GSC-15469-1)

GPM space and ground radar comparison software was designed by NASA scientists to support a prototype Validation Network for the GPM mission. The current software version collects data from the Precipitation Radar instrument flying on the TRMM spacecraft. It also collects ground radar data from US weather service radars. The software re-samples both data sets to a common grid and generates statistics that compare radar reflectivity and rain rates. This data collection and comparison is performed by the software on a routine basis. The software is scalable making it easy to add new ground radar sites.



A storm observed by the NASA/JAXA GPM Core Observatory.
—IMAGE BY NASA

GPM Visualization Tool for Validation Network Geometrically-Matched Ground-and Space-based Radar Data (GSC-15785-1)

This software provides visualization tools that allow easy comparison of ground- and space-based radar observations. The software was initially designed to compare ground radar reflectivity from operational, ground-based, S and C-band meteorological radars with comparable measurements from the TRMM satellite. The software allows both ground and space based radar data to be compared for validation purposes and is a critical piece of the validation process for the GPM mission.

GPM Operational Simulator (Go-SiM) Core (GSC-16262-1)

Global Precipitation Measurement Operational Simulator (Go-SiM) core is a software-only simulator capable of executing GPM operational systems. Capabilities include communicating with GPM's unmodified ground system, loading and running unmodified binary versions of spacecraft flight software, executing faster than real-time, integrating with Wind River workbench, and injecting faults via ground system. Go-SiM interfaces to the Goddard Dynamic Simulator (GDS) software to obtain spacecraft environmental models (i.e. Gyros). This was the same GDS that was used to test the spacecraft.

GPM Operational Simulator (Go-SiM) Instrument Simulations (GSC-16265-1)

Go-SiM Instrument Simulations are software-only science instrument simulations of the GPM Microwave Imager and the Dual-Precipitation Radar. The software-only simulations satisfy the bus controller on the GPM 1553 instrument bus, allowing the flight software to operate as it would under normal conditions when both science instruments are present, and do not affect the execution of the flight software.

Intercalibration of Measurements from Microwave Sensors for TRMM and GPM Using a Well Validated Radiative Transfer Code (GSC-16810-1)

This research developed a robust intercalibration technique that can be applied to the higher frequency sounding channels for the NASA Global Precipitation Measurement (GPM) mission. Intercalibration of these high frequency sounding channels will require accurate and timely estimates of the temperature and water vapor profiles.

Optical Alignment of the GPM (GSC-17020-1)

Optical alignment of the star trackers on the GPM Core Observatory was a challenge for several reasons. The first involved the layout and structural design of the GPM Lower Bus Structure (LBS) in which the star trackers are mounted. Second, the star tracker shades blocked line-of-sight to the primary star tracker optical references. Scientists initially made minor changes in the original LBS design. These changes would allow for the installation of a removable item of ground support equipment (GSE) that could be installed whenever measurements of the star tracker optical references were needed. For various reasons, this approach did not work. Scientists then developed an alternative technique to theodolite autocollimation for measurement of an optical reference mirror pointing direction when normal incidence measurements are not possible. This technique was used to successfully align the GPM star trackers and has been used on a number of other NASA flight projects.

Flight Software Math Library (GSC-16102-1)

This library is a collection of reusable math components providing typical math utilities required by spacecraft flight software. It increases flight software quality reusability and maintainability by providing a set of consistent, well-documented, and tested math utilities. In addition, it is easily ported because it only has dependencies on the American National Standards Institute (ANSI) C computer language.

eePRoM File System (GSC-16852-1)

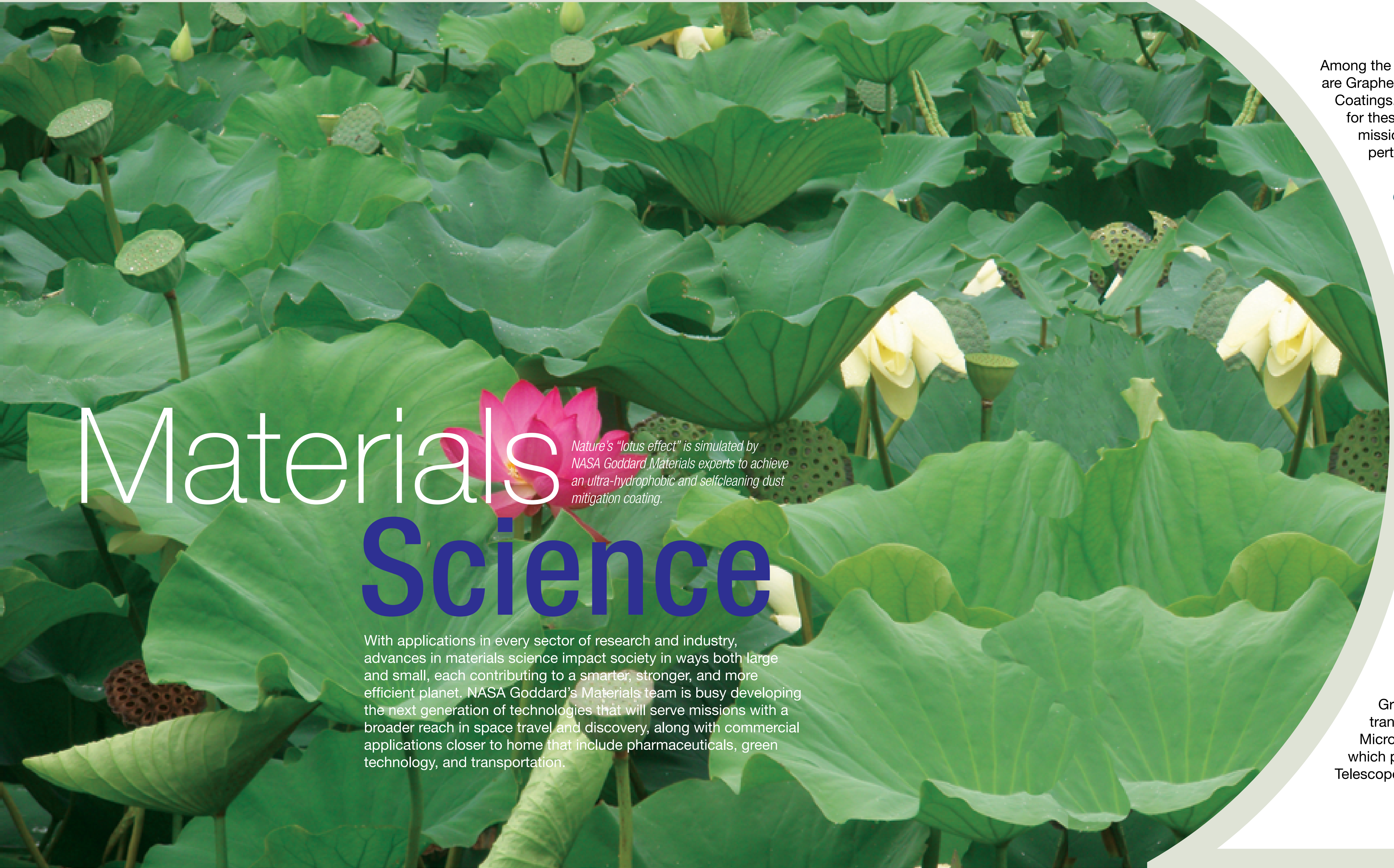
This is a simple and reliable file system for embedded systems. It can be used on embedded systems where a file system is needed for data access from RAM, PROM or EEPROM but resources may not be available for a full file system. In addition, it can be used where the ability to patch, dump, and diagnose files is required.

Dual-wavelength, Dual-polarized Doppler Precipitation Radar (D3R)

Remote Sensing Solutions received Phase I, II and III SBIR awards to develop the D3R for the GPM mission. The goal was to design a portable, all-weather multi-wavelength antenna that would act as the ground base calibration and validation system for GPM. The company leveraged a novel waveform and transceiver design and worked with Colorado State University and GSFC to complete the design. The radar simultaneously acquires dual-polarized Doppler and reflectivity precipitation volume backscatter measurements in the Ka (35 GHz) and Ku band (14 GHz) wavelengths with sensitivity close to traditional tube-based precipitation radar but eliminates any blind region. The D3R antenna is a key technology element for this mission, with a unique calibration and validation (calval) capability that allows the mission to constantly update its own performance.

Remote Sensing Solutions believes this technology can, with minor modifications, be used for a broad range of terrestrial uses and plans to pursue those potential markets.

The GPM High Gain Antenna System (HGAS) in integration and testing at Goddard Space Flight Center. —PHOTO BY NASA



Materials Science

Nature's "lotus effect" is simulated by NASA Goddard Materials experts to achieve an ultra-hydrophobic and selfcleaning dust mitigation coating.

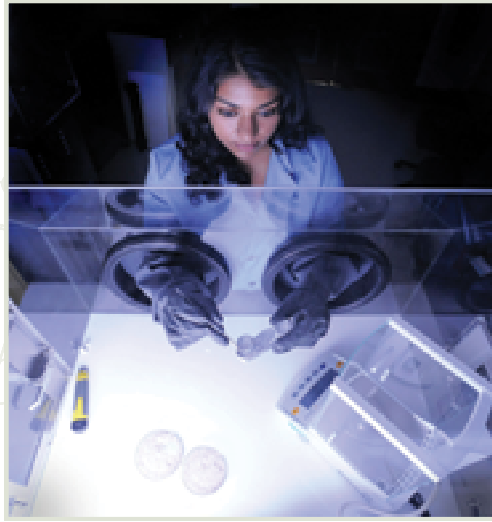
With applications in every sector of research and industry, advances in materials science impact society in ways both large and small, each contributing to a smarter, stronger, and more efficient planet. NASA Goddard's Materials team is busy developing the next generation of technologies that will serve missions with a broader reach in space travel and discovery, along with commercial applications closer to home that include pharmaceuticals, green technology, and transportation.

Among the exciting materials science developments at Goddard are Graphene, Lotus Coatings, and Molecular Adsorber Coatings. Here, we explore a range of potential applications for these materials-based technologies, including NASA mission-specific applications and commercial applications pertaining to technology transfer opportunities.

Graphene (GSC-16148-1, GSC-16335-1, GSC-16423-1, GSC-16560-1, GSC-16813-1)

Described by its developers as a "wonder material," graphene exhibits remarkable properties of strength, conductivity, and transparency. This unique combination of performance specifications makes it an ideal ultra-thin material for a wide range of applications. In a single atomic layer, which can be achieved using low-pressure chemical vapor deposition, graphene has shown high conductivity for electron mobility, while also maintaining 95% transparency – some 10% better than current Indium-Tin-oxide (ITO) electrodes that are widely used in NASA flight missions. Graphene electrodes also demonstrate high transparency in the UV region, achieving 80% quantum efficiency compared to 10-20% efficiency in current silicon-based detectors. These qualities are augmented by graphene's strength and structural toughness, enabling high performance in extreme conditions, especially when exposed to severe radiation. This overall robustness, combined with superior conductivity and transparency, makes graphene a valuable material with a wide range of applications both for NASA missions and in the commercial world.

Graphene's combination of high conductivity and transparency make it an ideal electrode material for Microshutter Arrays (GSC-16148-1, GSC-16335-1), which play a critical role in optics for the James Webb Telescope and other space missions. Graphene offers cost and performance advantages over current Indium-Tin-Oxide (ITO) electrodes, which are more expensive and have limited transparency. According to Principal Investigator, Harvey Moseley, "Microshutters are a remarkable engineering feat that will have applications both in space and on the ground, even outside of astronomy in biotechnology, medicine and communications."



Goddard technologist Nithin Abraham, studies a paint sample in her laboratory —PHOTO BY NASA

Graphene's high electron mobility and transparency also make it an ideal material for Schottky photodiodes (GSC-16423-1) in UV detectors. Graphene Gallium Nitride (GaN) Schottky diodes have the potential to reach record total quantum efficiency of 80%, compared to current silicon-based detectors that have 10-20% total quantum efficiency in the UV region. This performance advantage is made possible by the extreme transparency of single-layer graphene, 40% greater than its current platinum counterpart (90% vs. 50%). Future earth science, planetary science, and heliophysics missions will all benefit from UV detectors with superior performance.

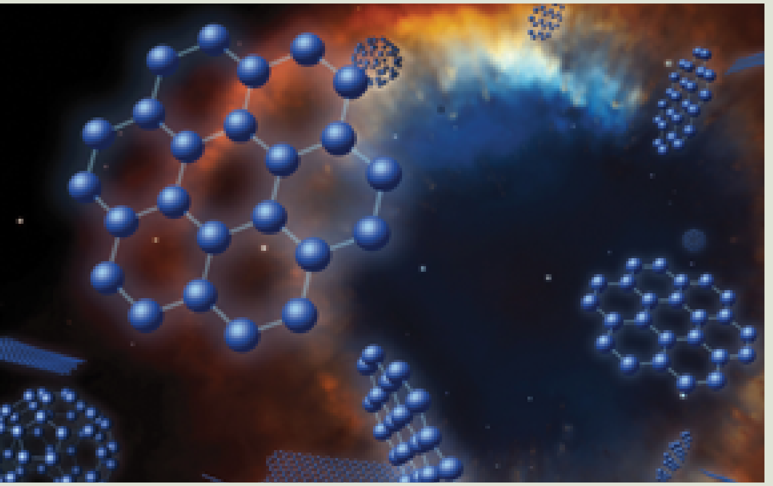
Cryogens and the lightweight cryotanks that store them are used in many NASA missions. If tanks cannot achieve a sufficiently low leak rate, however, exposure to cryogens can compromise mission integrity. In addition to graphene's extraordinary electro-optical qualities, it has also demonstrated impermeability to all gasses and liquids (except for water), and therefore could make an excellent cryotank barrier layer (GSC-16560-1) for future missions. By reducing the mass of cryotanks while increasing performance, both time and money is saved in weight allocations and testing schedules.

Graphene's ultrathin properties and ability to be synthesized with a selected range of pore sizes makes it an exciting material for environmental applications, including air filters (GSC-16813-1). Graphene and graphene derivatives such as graphene oxide can provide effective and inexpensive solutions to air filter technologies, and can be engineered to specific pore sizes from nanometers to microns between crystal grains, depending on the particulate and hazardous chemical requirements for air filters. Such graphene-based air filters could be used in home, office, transportation, manufacturing, mining, and a wide range of other applications.

Graphene is also being developed for use in touchscreens, with the potential to replace Indium-Tin oxide (ITO), which according to a recent article on Bloomberg BusinessWeek, "is too brittle for bendable displays and isn't durable or effective enough for devices with screens bigger than about 10 inches."

Lotus Coating (GSC-15819-1, GSC-16117-1, GSC-17004-1)

Nature has served as a source of inspiration for art and science throughout the millennia of human progress. In particular, the lotus plant (Nelumbo nucifera), used as a spiritual symbol in Buddhism, is now a model for an extremely hydrophobic dust mitigation coating.



An artist's concept of graphene, buckyballs and C70 superimposed on an image of the Helix planetary nebula, a puffed-out cloud of material expelled by a dying star. —IMAGE BY NASA

The unique structural and chemical properties of the lotus plant, known in nature as "the lotus effect," make it ideal for anti-contamination and self-cleaning purposes. Because of these properties, drops of water on a lotus leaf completely clean the surface, removing dirt and other materials. With a nano-texture coating, similar properties can be achieved on materials including glass, ceramic, and metal. The Lotus Coating—composed of layers of silica, zinc oxide, or other oxides and mixtures—is ultra-hydrophobic, self-cleaning, lightweight, and cost effective. Its reduced surface area, due to the lotus-like structure, contributes to the self-cleaning property while also providing excellent dust mitigation. The Lotus Coating has demonstrated excellent stability and resistance to ionizing and displacement radiations.

NASA Goddard's Lotus Coating (GSC-15819-1) was developed primarily for dust mitigation. Undesirable dust accumulation on spacecraft, instruments, and astronaut extravehicular activity (EVA) suits (including visors) has been well documented, and future missions risk compromised performance if sensitive equipment is damaged by dust. By reducing surface energy and the amount of surface area needed for attachment, Goddard's nano-texture Lotus Coating sheds dust particles without interfering with the substrate material. If dust does accumulate on the surface, the coating is easily cleaned using air, water, brush, vacuum, and/or vibration. Preliminary R&D by the Materials team suggests it can be used to mitigate dust on spacecraft components including thermal control surfaces, solar array panels (and other optical surfaces), airlock walls (and other habitation areas), astronaut EVA suits and tools, and astronaut visors.

The Lotus Coating's combination of properties that minimize particulate build-up and facilitate cleaning of particulate contamination, along with its ultra-hydrophobic nature, offer advantages in commercial applications such as building windows and automotive windshields. This could lead to significant time and cost savings for window cleaning on commercial buildings; and to improved automotive windshields safety.

The NASA Goddard Materials team is also collaborating with International Photonics Consultants/Northrop Grumman Aerospace Systems on a testing program for the Lotus Biocide Coating (GSC-16117-1) on the International Space Station. This coating is being developed to address bacterial and particulate concerns during long-duration crewed space missions in enclosed environments. It uses nano-sized semiconductor semimetal oxides to neutralize biological pathogens and toxic chemicals, and may provide a lightweight technology to improve health and safety aboard spacecraft and space stations. The Lotus Biocide Coating also maintains the performance advantage of stability in harsh environments, and will not degrade with time or exposure to radiation or biological/chemical agents.

Here on Earth, the Lotus Biocide Coating also has promising applications in hospitals, pharmaceutical manufacturing, chemical processing and manufacturing, and other commercial industries with high risk of microbial contamination.

Molecular Adsorber Coating (GSC-16105-1, GSC- 16156-1, GSC-17075-1)

Goddard's Molecular Adsorber Coating (GSC-16105-1) was developed to address the problem of outgassing on space flight missions, which can damage sensitive instruments and shorten the life and performance of critical equipment such as optical surfaces, solar arrays, thermal control systems, electronics, and detectors. The sprayable zeolite-based adsorber coating replaces ceramic pucks that take up valuable space, and more importantly, add extra weight to limited mission requirements. This extra weight also adds cost due to an increased testing schedule, which translates to both time and money for the mission.

The coating's ability to control adverse on-orbit molecular contamination will ensure optimal performance over longer durations, improving mission success while eliminating the need for superfluous mounting hardware used with cordierite adsorber pucks. Even though the pucks are relatively inexpensive to fabricate, the sheer amount needed to remediate offgassing—for example, there are over 60 pucks inside the Hubble Space Telescope—combined with the cost and severe inconvenience of supporting their use, creates ample opportunity for an innovative replacement material. Easy spray application, reduced mass allocation, simpler hardware design and integration, and a shortened test schedule gives the Molecular Adsorber Coating a clear advantage over the existing technology.

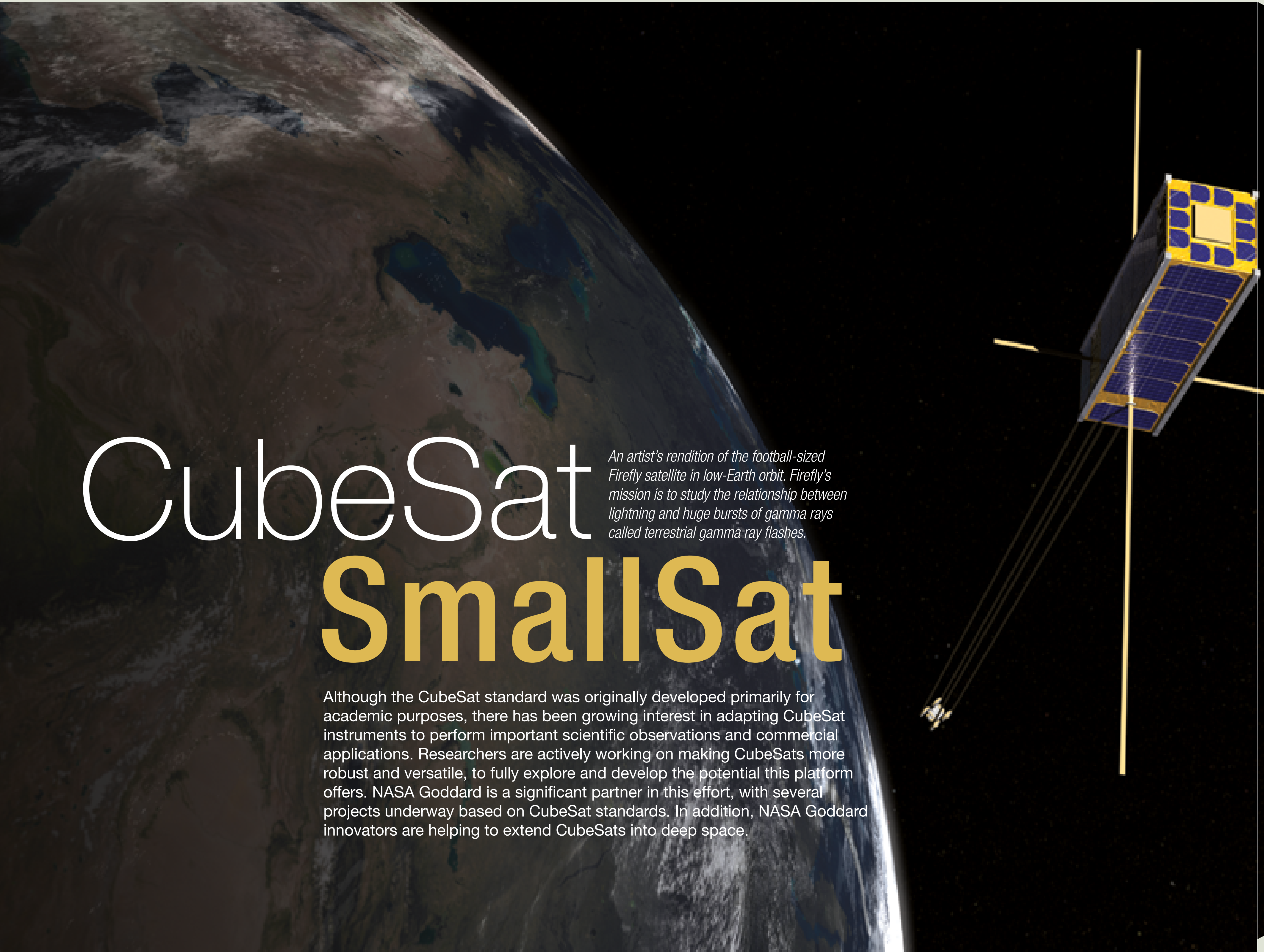
Molecular outgassing is also an issue in aerospace and automotive manufacturing. Contamination can effect sensitive instrumentation and pose health risks for passengers. According to an article discussing how adsorber coatings can kill "new car smell", "The problem is, that smell – or outgases as NASA calls them – is generated by chemicals and solvents used to manufacture dashboards, car seats, carpeting and other components that are not particularly good to breathe and as NASA points out, some can be detrimental to sensitive satellite instruments containing the same ingredients." [1]

The adsorber coating (GSC-16156-1) has also been demonstrated on conductive fiber velvet mats, which dissipate charge buildup and provide a greater adsorbtive capacity by increasing the available surface area of the coating. This added adsorptive capacity combined with conductivity in the fiber velvet mats could also be beneficial in electronics manufacturing. Not only does coated fiber pile eliminate the possibility of electrostatic discharge events, it can also reduce the need for costly vacuum bakeouts. The surface area for coated velvet fiber mats may be increased several thousand fold as techniques are refined, which may lead to further commercial applications where contamination and charge buildup are of concern.

A final application of the adsorber coating is described by the Materials team as a formulation of white molecular adsorber paint (MAC-W) (GSC-17075-1), which has shown excellent adhesion to multiple substrates, including but not limited to composites, cellulose-based materials, aluminum, and other metals. The MAC-W coating can also be applied to flexible surfaces and has an improved and more efficient spray process. MAC-W is an excellent example of the kinds of innovations made possible by the Molecular Adsorber Coating platform, and suggests a strong commercial outlook given the flexibility of the technology and ability to adapt the coating to specific performance requirements for niche applications.

Engineers prepare and install the Microshutter Array simulator onto the NIRSpec Engineering Test Unit.
—PHOTO BY NASA

[1] Michael Cooney, "NASA paint kills that new car smell, saves satellites too," Network World web site, http://www.networkworld.com/article/2223528/data-center/nasa-paint-kills-that-new-car-smell--saves-satellites-too.html.



CubeSat SmallSat

An artist's rendition of the football-sized Firefly satellite in low-Earth orbit. Firefly's mission is to study the relationship between lightning and huge bursts of gamma rays called terrestrial gamma ray flashes.

Although the CubeSat standard was originally developed primarily for academic purposes, there has been growing interest in adapting CubeSat instruments to perform important scientific observations and commercial applications. Researchers are actively working on making CubeSats more robust and versatile, to fully explore and develop the potential this platform offers. NASA Goddard is a significant partner in this effort, with several projects underway based on CubeSat standards. In addition, NASA Goddard innovators are helping to extend CubeSats into deep space.

CubeSats: From the Classroom into Space

The CubeSat standard was initially conceived in 1999, through collaboration between California Polytechnic State University and Stanford University. Its primary function was to provide students a way to gain hands-on experience with designing and building operational satellites, without incurring the high costs historically associated with satellite development. To do this, two important characteristics were defined for CubeSats:

- Volume is confined to a 10 cm cube, with a mass not to exceed 1.33 kg. This defines a "1U" CubeSat; the specification has subsequently been amended to include larger devices.
- Projects are built from readily available off the-shelf components.

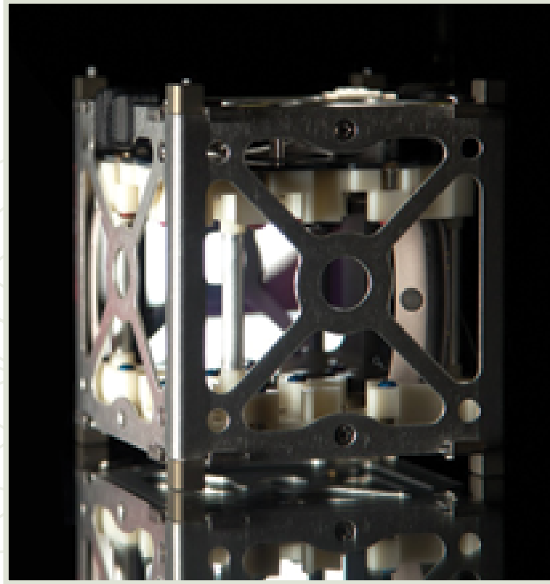
To further reduce cost, CubeSat projects have up to now been launched as secondary payloads carried aboard other scheduled missions. The first CubeSat was launched in 2003 on board a Russian rocket. Since then, dozens of other CubeSat projects have been placed on orbit.

Originally, CubeSat functionality was relatively modest; its goal was to provide "Sputnik-level" capabilities. But as students familiar with this platform graduated into professional careers, they began to look to CubeSats to perform important scientific applications associated with their job responsibilities. In this regard, CubeSats offer some important advantages in terms of cost and development time. To exploit these advantages, the science and engineering communities are actively examining ways to enhance CubeSat functionality and overcome some of its inherent limitations.

CubeSats and Wallops Flight Facility

One key challenge to using the CubeSat platform for serious science and commercial applications is propulsion. As noted earlier, CubeSat missions have historically been launched only as secondary payloads. The CubeSat community is now looking for a dedicated launch capacity for placing CubeSat projects onto Earth orbit and beyond.

The National Science Foundation (NSF) selected Wallops Flight Facility in 2008 to collaborate with their CubeSat activities, a collaboration that is ongoing. Currently, the services that Wallops Flight Facility provides to the NSF and their CubeSat teams include the following:



A 1U CubeSat. —PHOTO BY NASA

- Mentoring to CubeSat developers from the Wallops Flight Facility engineering staff.
- Use of lab test facilities such as GPS simulation, antenna testing, and vibration testing.
- Interfacing with the launch vehicle provider.
- Ground station support with a 60-foot dish. This allows CubeSats to transmit at up to 200 times the typical data rate.

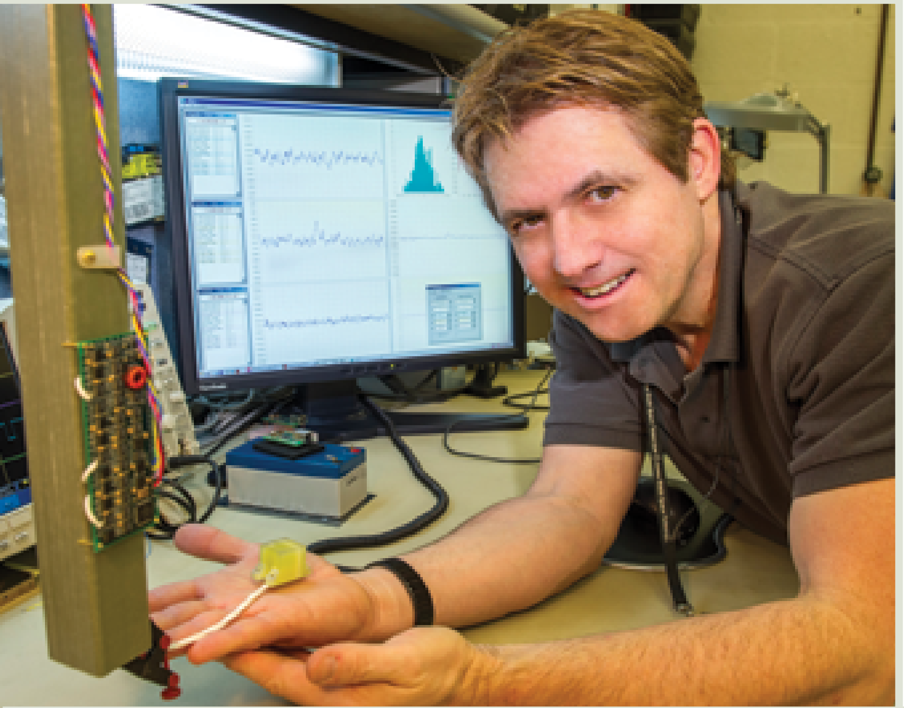
"The value-added support that we provide to the CubeSat community is an extension of the support we provide to the suborbital community," states Scott Schaire (former Small

Satellite and Orbital Payloads Projects Manager for Wallops Flight Facility, Suborbital and Special Orbital Projects).

There are now numerous CubeSat proposals in the works. For example, the DoD and NASA are looking for a dedicated launch vehicle for CubeSat that can place satellites in orbit for $2 million and under. Some proposed vehicles are currently in development. According to Mr. Schaire, "CubeSats provide a method for placing instruments in orbit quicker than with conventional satellites."

Ben Cervantes (Mission Planning Lab Lead, Wallops Flight Facility) echoes this theme. "Wallops has a lot of experience in suborbital flight, usually involving satellites or other UAVs [unmanned aerial vehicles]. CubeSats fit nicely into this niche, and aligns very well with what Wallops does, which primarily involves low-cost missions. We're developing technologies to be more and more miniaturized, to fly on UAV missions. When a technology is sufficiently miniaturized, it can fly on a CubeSat to gather science data.

Propulsion technologies beyond rocketry are also being examined. "We're looking at other ways to launch CubeSat projects, including high-altitude balloons" notes Mr. Cervantes. "For example, there's a program called High Altitude Student Payload, or HASP for short. This program involves teams of students developing balloon-borne projects. So far we've launched somewhere between 12 and 16 payloads, using a gondola structure. One project involved launching a number of instruments over Antarctica. These devices were in the air for 50 days, reaching altitudes of 115,000 to 130,000 feet. That's above 99.9% of the Earth's atmosphere, so for all intents and purposes they were in space."



Other potential propulsion methods include launching CubeSat devices from an airplane platform, or even via a cannon-type device to shoot CubeSats into orbit. "Wallops currently holds a record for the longest cannon-based launch of a particular diameter projectile without any propulsion on the projectile," says Mr. Schaire. "Wallops has looked at hosting a railgun which uses electromagnetic force to propel the payload. I don't see this technology being used to launch CubeSats into Earth orbit; but it could possibly be used on the moon to launch payloads from the moon into deep space."

The design engineer of a new magnetometer system, Todd Bonalsky, holds the tiny device while in his laboratory. —PHOTO BY NASA

NASA Goddard Helps Expand CubeSats into Deep Space and "Beyond Low Earth Orbit" Orbits

Beyond propulsion, a major limitation in the CubeSat standard's potential as a deep space and long-duration "beyond LEO" science platform is its current lack of robustness and reliability. NASA Goddard is playing an important role in addressing this limitation.

Another NASA Goddard effort is SpaceCube Mini, a miniaturized version of the SpaceCube 2.0 high-performance data processor small enough to be used on CubeSat missions. As Thomas Flatley (Branch Head, Science Data Processing Branch) explains, "one proposed synthetic aperture radar instrument on a mission to Mars could fill up its onboard data recorder with nine minutes of data. With SpaceCube a mission could process raw data in real-time and only store processed data or extracted information, yielding significant savings in on-board storage and downlink bandwidth, and enabling 24/7 operations."

This technology can offer similar advantages in Earth science, in applications such as hyperspectral imaging and lidar. SpaceCube provides both data reduction and onboard "situational awareness." For example, a SpaceCube processor could detect events such as a forest fire or algal bloom on-board in real-time, and then send live images to on-site firefighters or research ships at sea.

Other areas in which NASA Goddard can provide special value to the CubeSat effort include electronics miniaturization, where NASA Goddard has a large and diverse body of dedicated technical expertise; and communications, especially in S-band and X-band.

CubeSat Missions at NASA Goddard

Several CubeSat projects are currently in development at NASA Goddard. Among these is the National Science Foundation's Firefly mission, which launched on November 19, 2013. Firefly will explore the relationship between lightning and so-called Terrestrial Gamma Ray Flashes (TGFs), a phenomenon first discovered in the 1990s.

Firefly will investigate which types of lightning produce TGFs, to help scientists better understand the cumulative effect that terrestrial lightning has on the upper atmosphere and near-Earth space environment.

Another NASA Goddard CubeSat project is the Compact Radiation Belt Explorer (CeREs). This is a 3U CubeSat that will be placed in a high inclination LEO. CeREs will study primary radiation belt energization, as well as loss electron spectra and microbursts. It will also observe solar electron spectra from > 5 keV.

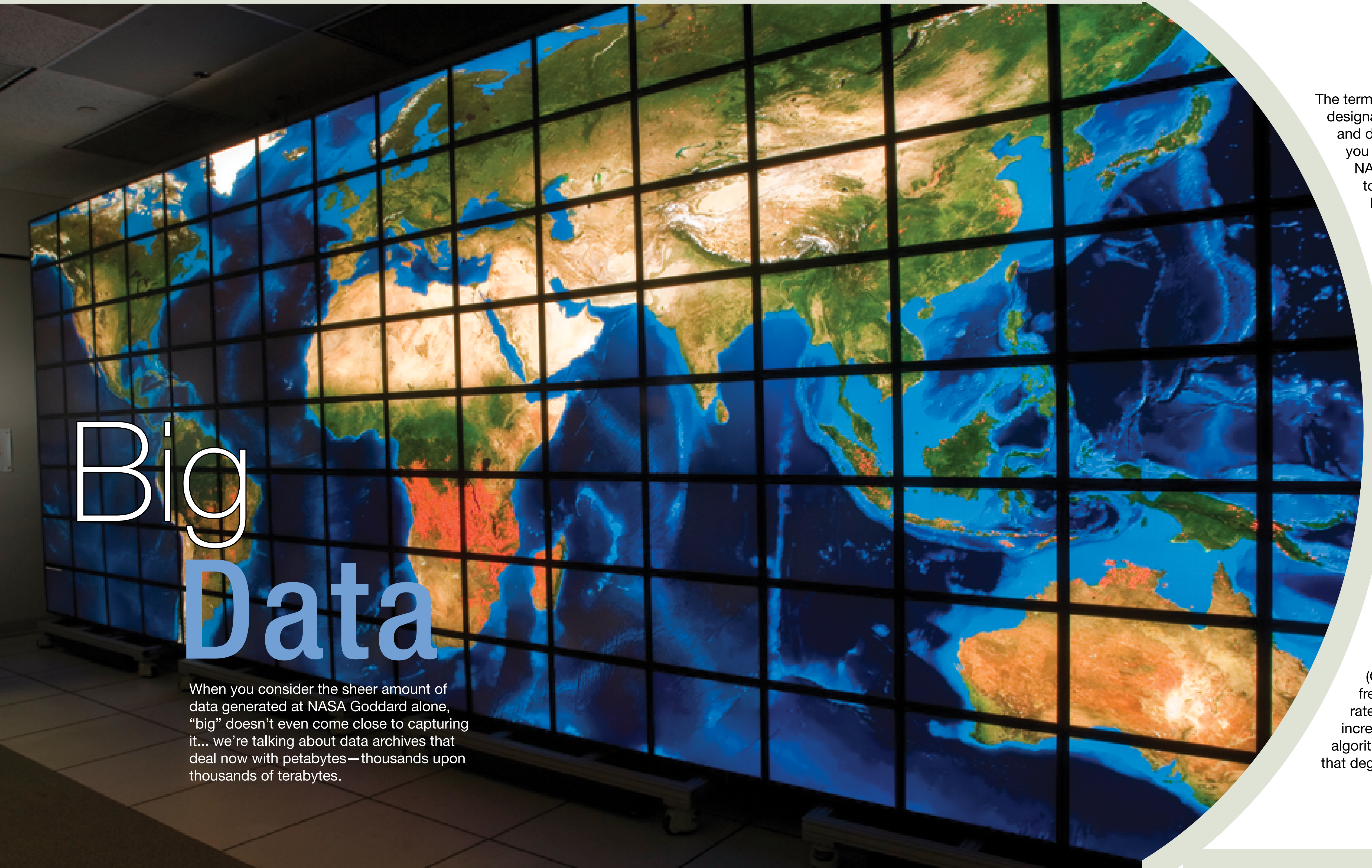
NASA Goddard and the Future of CubeSats

As we've seen, NASA Goddard is playing a critical and growing role in helping extend CubeSat capabilities. The ultimate goal is to develop CubeSat technologies that deliver high accuracy, lower power, multi-node, and distributed operation suitable for deep space. In this way, NASA Goddard innovation has become an important driver behind the ongoing evolution of CubeSat from a teaching tool to a robust platform for contributing to the advancement of Earth and space science.

Takeaways

CubeSat is a standard originally developed to provide students hands-on experience with small satellites. In recent years, the CubeSat standard's purpose has expanded to include science applications. NASA Goddard is actively helping CubeSats evolve into a more robust platform suitable for applications outside the classroom. For example, Wallops Flight Facility is enabling innovative new missions via value-added services for the CubeSat community. Other NASA Goddard technology initiatives, such as SpaceCube, are designed to enhance CubeSats for potential deep space, long-duration and "beyond LEO" applications. NASA Goddard is also adopting CubeSats for several upcoming missions, including Firefly and CeREs.

Todd Bonalsky and Eftyhia Zesta pose with a special gimbal table they designed to test CubeSat-compatible magnetometer systems at the Goddard Magnetic Test Facility. —PHOTO BY NASA



Big Data

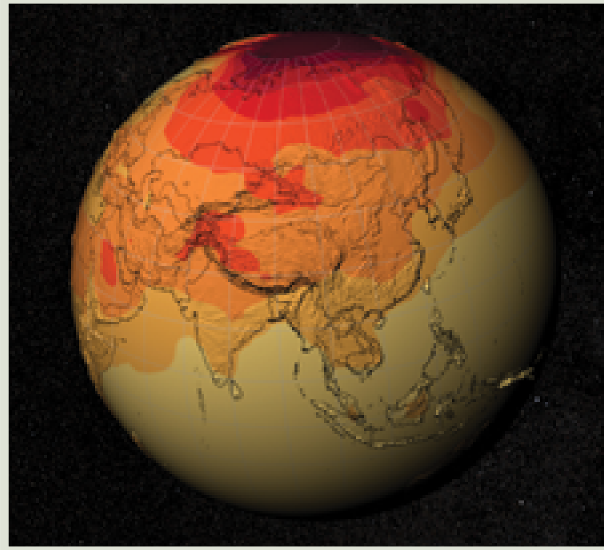
When you consider the sheer amount of data generated at NASA Goddard alone, “big” doesn’t even come close to capturing it... we’re talking about data archives that deal now with petabytes—thousands upon thousands of terabytes.

The term “Big Data” doesn’t sound like a very precise designation for an industry with enormous market growth and dramatic impact on the world economy, but when you consider the sheer amount of data generated at NASA Goddard alone, “big” doesn’t even come close to capturing it. A more appropriate adjective would be “enormous,” since we’re talking about data archives that deal now with petabytes—thousands upon thousands of terabytes. Not surprisingly, Goddard Space Flight Center is at the forefront of data generation, capturing, processing, analysis, storage, and delivery. Not only are NASA’s spacecraft generating enormous amounts of data in both Earth and space observation, but our computer scientists and engineers are also busy setting a standard of innovation for how to process and use that data. Indeed, big things are happening at Goddard Space Flight Center in the arena of Big Data.

Big Data at NASA Goddard: New Technologies Improved Compression and Processing

As observation data continues to be generated by Goddard Space Flight Center at extraordinary rates, the quality of that data will largely determine the application utility and commercial potential. This is especially true for image data, which requires higher quality and improved compression for optimal delivery. Estimated Spectrum Adaptive Postfilter (ESAP) and Iterative Prepost Filtering (IPF) Algorithms (GSC-14213-1) provide both advantages, using frequency-based, pixel-adaptive filtering for low bit rate JPEG-format images and MPEG-format video. By increasing the signal-to-noise ratio, the ESAP and IPF algorithms can significantly reduce the blocking artifacts that degrade image quality in high compression.

Data compression is critical for the future of Big Data. Without increased processing speed and resolution, data performance and optimization will not be achieved. An advanced version of the Universal Source Encoder for Space (USES) lossless data compression processor has been developed, which offers improved quantization capability in a radiation tolerant field-programmable gate array (FPGA). The new Flight Lossless Data Compression Electronics USES-32 (GSC-17101-1) supports compression at a rate of up to 100 million samples per second, with data up to 32 bits. This is a significant improvement to the current USES, which is limited to 15 bit data and a 20 Msample/sec rate. Increased data generation means new challenges in data processing and refinement as well, two functions essential for Big Data commercialization. One of these challenges is how to work with nonlinear data, such as water waves and wave evolution. The Huang-Hilbert Transform (HHT) Data Processing System (GSC-14591-1) was designed to address the difficultly associated with nonlinear data sets. The PC-based hybrid system demonstrates clear advantages over traditional Fourier-based methods, which cannot adequately translate linear analysis to nonlinear phenomena.



The UN Intergovernmental Panel on Climtae Change relies on doxens of modeling groups, including Goddards Institute for Space Studies. The report’s authors evaluate the latest results from climate models run on supercomputers to simulate how Earth might respond to different senarios of greenhouse gas emissions and reduction measures. —PHOTO BY NASA

Virtual Climate Data Server (vCDS) and MERRA Analytic Services (MERRA/AS)

One of the most exciting Big Data projects at NASA Goddard Space Flight Center is the Virtual Climate Data Server (vCDS). There is a shift occurring in the paradigm of data analytics and delivery, moving away from client-side processing, where data would be downloaded and processed by the user, into the realm of Platform-as-a-service (PaaS) and Software-as-a-Service (SaaS) delivery. The fundamental reason for this shift is the enormous size of contemporary data sets, which are only getting bigger. To streamline productivity and make Big Data more efficient for the user, processing is being done where the data resides, so that huge amounts of data do not need to move, thereby saving the user from the time and storage requirements necessary to download or input massive data sets. The vCDS Concept, Design, Architecture, and Operation (GSC-16444-1) is described as "a software appliance specialized to the needs of data-centric climate applications". Along with PaaS and SaaS capabilities, the architecture of the vCDS, which takes advantage of enhancements to the integrated Rule-Oriented Data System (iRODS) that manages data and data products, enables a virtualization of the climate server. This opens up avenues for Virtualization-as-a-Service (VaaS): "a capacity to respond in an agile way to new customer requests for data services and a path for migrating existing data services into the cloud." There are a number of administrative extensions and analytic tools built into the VaaS architecture and vCDS platform. These enhancements to the iRODS, such as the NetCDF Module, can provide "policy-based control over collection-building, managing, querying, accessing, and preserving NetCDF scientific data sets" (GSC-16445-1).

Other extensions help system management by supporting metadata compliance and administrative monitoring (GSC-16446-1), or allow for multiple vCDS software stacks to be automatically built in diverse computing environments (Repetitive Provisioning: GSC-16447-1). All of these vCDS-related technologies benefit NASA's missions by augmenting the effectiveness of remote sensing and climate modeling capabilities.

A NASA computer model simulates the astonishing track and forceful winds of Hurricane Sandy. —IMAGE BY NASA

MERRA Analytic Services (MERRA/AS)

Along with the shift toward VaaS data delivery through the vCDS system, there are efforts underway to increase the analytic capabilities of data processing at NASA Goddard. The Modern Era Retrospective Analysis for Research and Applications Analytic Services (MERRA/AS) were developed to improve data performance, and also provide more refined data sets to users and customers. MERRA/AS is described as a "cyberinfrastructure resource for developing and evaluating a new generation of climate data analysis capabilities" (GSC-16594-1). Working with NASA's Observations for Model Intercomparison, the new analytic architecture will reduce the time spent in the preparation of data products for use in scientific and commercial applications. Initial applications for NASA include supporting the Virtual Climate Data Server (vCDS) technology, currently used by the NASA Center for Climate Simulation (NCCS) to deliver Intergovernmental Panel on Climate Change (IPCC) data to the Earth System Grid (ESG). Similar to the extensions that increase capabilities through the vCDS system, there are a number of Application Programming Interface (API) developments that correspond with MERRA/AS, in order to facilitate and refine data processing and delivery at NASA Goddard. "Persistence Services (PS) allow users to store, download, annotate, and otherwise manage MERRA Analytic Services (MERRA/AS) codes or scripts that implement the map and reduce functions of their analyses" (GSC-17115-1). Another CDS API creates a Reference Model, Library, and Command Interpreter for uniform control and "harmonization" between system components (GSC-17117-1). These technologies refer to a series of capabilities that are enabled over the vCDS through what is called "MapReduce analytics." The Climate Data Services (CDS) API enables MapReduce to process data with higher performance across scalable data management (GSC-17118-1); for instance, the virtualized system can refine raw data at faster speeds and according to more climate variables, thereby delivering more refined data sets for end users.

The CDS API Client Distribution Package contains the code, tools, and information necessary for end-users to work with the data once delivered over the vCDS (GSC-17116-1). Without these advanced APIs, the MERRA/AS capabilities would not be optimized for such an impressive breadth of potential CDS applications.

New Applications for Climate Data Services

According to a 2014 Forbes online article, the International Data Corporation and International Institute of Analytics predicted the Big Data market would reach $16.1 billion by the end of the year, growing six times faster than the overall information technology market. How much of that market might be applicable to NASA Goddard's Climate Data Services is difficult to predict, but it is telling that agri-business giant Monsanto spent a reported $1.1 billion to acquire Climate Corporation in October of 2013. Large scale agriculture is just one of the potential applications for data products and services related to climate science. Climate data also has significant potential for the energy industry. NASA Goddard CDS technologies can help renewable energy efforts by analyzing weather and creating advanced models for predictive investment.

Observational data can be extremely useful for traditional energy companies seeking to improve their monitoring systems for oil and gas extraction. Not to mention, NASA data can play a role in the identification of future energy sources and contribute to a more sustainable energy industry overall. Other promising applications for NASA Goddard's Big Data technologies include land imaging, emergency management, and disaster relief, and insurance assessment. With the help of a new generation of Climate Data Services and analytic tools, city planners and policy makers can make better and more informed decisions about how to best address the challenges of our changing climate.

This close-up view shows one row--approximately 2,000 computer processors--of the "Discover" supercomputer at the NASA Center for Climate Simulation (NCCS). Discover has a total of nearly 15,000 processors. —PHOTO BY NASA

itpo
NASA GODDARD
INNOVATIVE TECHNOLOGY PARTNERSHIPS OFFICE

Innovative Technology Partnerships Office

The Mission of the Innovative Technology Partnerships Office (ITPO) is to see that maximum benefit is obtained from innovations developed by Goddard Space Flight Center scientists and engineers. It does this by connecting internal innovators at GSFC with external partners including corporations, startups, universities, and other government agencies. The office manages three major program areas:

- Technology Transfer: Promoting the transfer of GSFC-developed technology to the private sector, including managing GSFC's invention portfolio.
- SBIR/STTR: Managing the award of R&D contracts to small businesses and university partners consistent with the directives of the NASA-wide and GSFC-specific Small Business Innovation Research (SBIR) and Small Business Technology Transfer (STTR) programs.
- Partnerships: Facilitating creative collaborations between GSFC researchers and external parties for mutual benefit.

The office also engages in a number of networking and outreach events, which support the major program areas by raising awareness of Goddard's activities.

The ITPO achieved measurable progress in all three program areas during the 2014 fiscal year, generating nine patents, seventeen space act agreements, more than eight SBIR/STTR awards and no less than 308 New Technology Reports (NTRs).






Ted Mecum

Senior Technology Manager

"We are here to help NASA Goddard protect its strategic assets. The first step in that is to identify those assets. In many cases, inventors may not even realize the potential impact their technology may have outside of the Center."

Aprille Ericsson

SBIR/STTR Program Manager

"Innovators often seem to believe their technology has only one unique purpose, and may not be suitable for anything other than the space application for which it was originally developed. The ITPO philosophy is just the opposite: the possibilities are endless."

Ramsey Smith

SBIR/STTR Deputy Program Manager

"The SBIR/STTR program is an invaluable resource to both the NASA technology community and our nation's small business community that will continue to benefit NASA for years to come."

Enidia Santiago-Arce

Technology Manager

"The ITPO is here to help. We don't just go around collecting NTRs [New Technology Reports]; our ultimate goal is to empower the use of NASA Goddard technology beyond the original space applications for which it was developed."

Technology Transfer

This year we highlight the Technology Transfer program, in which the ITPO works with Goddard inventors to "harvest" inventions, secure intellectual property protection (including patents, when appropriate), and market those inventions to external partners. NTRs are a key element in that process – they disclose that a new technology is available.

Generally, an NTR is Filed by a Member of the Team which Invented a New Technology.

At the ITPO, NTRs are reviewed to ensure the form is properly filled out and assigned a unique case number. A team of on-site engineering contractors review the NTRs to identify which inventions would be potentially marketable and thus worth patenting. Those identified as potentially valuable are referred to a NASA engineer who recommends whether to patent, publish, or (in some cases) market to possible partners under a non-disclosure agreement. In some cases, inventions are referred to an outside contractor for additional evaluation. The ITPO works with Goddard's patent counsel office on potentially patentable items, to determine whether an invention is patentable, and whether NASA has clear title to it.

ITPO senior technology manager Daryl Mitchell asked us to draw attention to two issues: "When in doubt, submit - let the office work on it. Sometimes things turn out to be patentable that surprise us! Disposition of technology being evaluated involves multiple reviewers - it's not just some guy in a corner. We are always looking to improve the process, if people have ideas on how to improve the process - talk to the technology manager who handles your division." He also asked us to point out that Goddard inventors are entitled to a generous share of any royalties paid when their inventions are licensed. For instance, if only one inventor is named in a patent, that inventor is entitled to the first $5,000 in royalties, plus 25% of any royalties over $5,000 per fiscal year. See NASA Procedural Requirement (NPR) 2092.1B for details.

The number of NTRs this year is so large that we are unable to list them all – interested readers can find them in back issues of the ITPO's quarterly Tech Transfer News magazine, available online at http://itpo.gsfc.nasa.gov/news-events/news/.

Harvesting NTRs is just the beginning of the technology transfer process. In addition to securing intellectual property (IP) rights through patents and other means, the ITPO works with external partners to provide access to Goddard's invention portfolio, communicate IP protection status, highlight technologies available for license and facilitate agreements with NASA.

SBIR/STTR Programs

The ITPO is also responsible for Goddard's SBIR/STTR and Partnership programs. SBIR and STTR are government-wide programs which fund research, development, and demonstration of innovative technologies that fulfill agency needs and have significant potential for successful commercialization. Small businesses with 500 or fewer employees and non-profits including universities and research laboratories with ties to small businesses are eligible to participate. Both programs operate in three phases:

- Phase I is the opportunity to establish the scientific, technical, and commercial feasibility of the proposed innovation in fulfillment of NASA needs.
- Phase II is focused on the development, demonstration and delivery of the proposed innovation.
- Phase III is the commercialization of innovative technologies, products, and services resulting from either a Phase I or Phase II contract. Phase III contracts are funded from sources other than the SBIR and STTR programs and may be awarded without further competition.

SBIR Phase I contracts are for 6 months and STTR Phase I contracts for 12 months, both with a maximum funding of $125,000. Phase II contracts are for 24 months with a maximum funding of $750,000. Historically, the percentage of Phase I proposals to awards in NASA's SBIR/STTR program is approximately 13-15% for SBIR and STTR, and approximately 35-40% of the selected Phase I contracts are competitively selected for Phase II follow-on efforts.[1]

The ITPO's role in the process begins with identifying Research & Development needs at Goddard and identifying which are appropriate for an SBIR/STTR award. The ITPO then announces SBIR/STTR opportunities, facilitates the

[1] "NASA SBIR Basics," NASA web site, http://sbir.nasa.gov/content/nasa-sbirsttr-basics (accessed February 12, 2015).

Dennis Small

Technology Manager

"We use NASA Goddard technology to build partnerships with industry, government agencies, and universities. Our office works to license NASA Goddard developed technologies that have commercial application that leads to stimulating … the economy world-wide."

Darryl Mitchell

Senior Technology Manager

"The America Invents Act has significantly changed the playing field. In order to avoid disclosing the details of an invention before the IP protection is securely in place, we now tend to be more targeted in our approach to promoting technologies."

Nona Cheeks

ITPO Chief

"It's important to understand that technology transfer is a two-way street. Not only does it involve applying a NASA-developed technology to an industry need; it also entails filling a NASA need by forming relationships with outside entities."

awards and manages the overall award process in collaboration with a designated Goddard Contracting Office Technical Representative (COR) who manages the technical aspects of particular awards.

Partnerships

Goddard researchers have various needs that can be met using existing NASA vehicles including procurement, SBIR/STTR, and internal R&D. Other needs, however, fall outside the bounds of existing programs that can potentially be met instead through creative collaborative partnerships facilitated by the ITPO. For example, assume a NASA researcher has insufficient funding/equipment/materials/skills to meet an R&D challenge beyond existing programs. An industry/university/government partner could supply part or all of the needed funding/equipment/materials/skills to NASA in exchange for an option to license any resultant inventions if interested. Similarly, the challenge may be to find an industry partner to commercialize NASA's successful R&D and then supply a product or service back to NASA to meet mission needs. While many unique scenarios exist, in all cases GSFC would benefit from a collaboration with an outside third party. In suitable situations, the ITPO can help NASA researchers to seek out such partners, vet candidates, and establish win-win agreements to make the collaboration a reality.

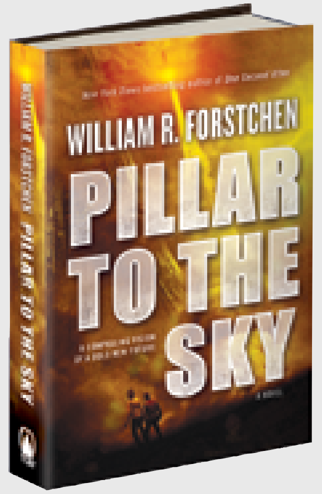
The process begins when a NASA civil servant at Goddard identifies a need for outside help and brings that need to the attention of the ITPO. The office then considers the extent to which creating a "Partnership Project" is warranted (since the ITPO has limited resources and partnership establishment is also most likely when a win-win scenario can be envisioned). If a project is pursued, common steps include the following:

- The ITPO and researcher reach agreement on the value NASA can bring, and seeks, from a partnership.
- The ITPO engages its network to seek out and vet potential partners, engaging researchers to aid in the vetting process as it proceeds.
- Negotiations are held if promising partner candidates are identified.
- The appropriate partnership agreement (e.g., Space Act Agreement) is established to allow GSFC researchers and the partner to officially collaborate for mutual benefit.

As we've seen, the ITPO engages in a broad range of activities to support the commercialization of Goddard technologies, and to augment Goddard's in-house R&D efforts with outside help.

Pillar to the Sky

A Novel Set at Goddard



Many scientists and engineers (and even some astronauts) have said they were inspired by reading science fiction. Robert Goddard, for whom the Goddard Space Flight Center (GSFC) is named, said that he began dreaming of space flight after he read The War of the Worlds by H.G. Wells. In Pillar to the Sky that pattern is reversed: Science-fiction writer William Forstchen's novel was inspired by NASA and is actually set at GSFC. In the near future, GSFC scientist Gary Morgan overcomes political and technical obstacles to get a space elevator built – a literal pillar to the sky that makes low-cost access to space a reality, leading to orbital industries that will save humanity from a new dark age.

The book was supported by Goddard's Innovative Technology Partnership Office (ITPO). Enidia Santiago-Arce, a former electronic design engineer who works in the ITPO arranged a tour of the center for Forstchen, and some of the technology described in Pillar was directly inspired by that visit. The book is a work of fiction – the author wasn't told what to write – but according to Santiago-Arce: "We are trying to make sure the science in the book is as accurate as possible."

While Pillar is a work of fiction, Santiago-Arce says Goddard's support of the author has a serious purpose: "We want to inspire young people to go into science and engineering - find a way to make technology exciting."

Since Robert Goddard was a science fiction fan, we think he would approve!

NASA GODDARD OPTIMUS PRIME Spinoff Challenge

One of the ITPO's most innovative outreach activities features a popular TRANSFORMERS character. For the past three years, elementary, middle school and high school students have participated in the OPTIMUS PRIME Spinoff Challenge. Student teams submit three minute video clips describing their favorite NASA spinoff story, featuring technologies originally created for space and modified into everyday products used on Earth. Examples include items such as memory foam, invisible braces and scratch-resistant lenses for eyeglasses. First place winners from each category (grades 3-5, 6-8, & 9-12) were then invited to participate in the OPTIMUS PRIME Spinoff Production Workshop at Goddard from April 24-25, 2014. Goddard Center Director Chris Scolese and voice actor Peter Cullen, the man behind the voice of OPTIMUS PRIME both participated in an awards ceremony, during which the students shared their submitted videos, and were then presented with an OPTIMUS PRIME trophy. The students also created professional Public Service Announcements (PSA) on Goddard spinoffs for use later in the year.

In August, the ITPO announced educational scholarships for top-placing students in the contest. Scholarships for the first, second and third place winners in each age category (elementary, middle school and high school) sponsored by the American Society of Mechanical Engineers (ASME) Foundation could be used to support current and future educational pursuits.

"Our support of the contest aligns with our goal of promoting the many disciplines of science and engineering available to students," said Matt Schatzle, executive director, ASME Foundation. "The ASME Foundation is committed to supporting the continued growth of technical professions with our scholarships."

"The OPTIMUS PRIME Spinoff Challenge is an innovative way of building a dialogue with the public regarding the benefits of NASA research and development outcomes," said Nona Cheeks, chief of Goddard's Innovative Technology Partnerships Office. "The students' creativity and skill demonstrated in each of the videos helps NASA to be more effective at raising public understanding of how our technologies provide benefits as space applications as well as in industries such as environmental, medical and manufacturing."

The contest will continue in 2015 – and grow, through partnerships with NASA's RealWorld InWorld Engineering Design Challenge, and the James Webb Space Telescope mission. Two new challenges will be offered: The OPTIMUS PRIME Spinoff Video Challenge for grades 3 – 12 and The OPTIMUS PRIME Spinoff InWorld Challenge for grades 6 – 12. For more information, see http://itpo.gsfc.nasa.gov/optimus/challenge_overview.php.

The contest winners were acknowledged all over Goddard, including by Center Director Chris Scolese (far right). —PHOTO BY NASA

2014 Space Act Agreements

New York Film Academy
Documentation of James Webb Space Telescope (JWST) development.

littleBits Electronics, Inc.
Development of a unique educational product that engages young children in NASA technology.

Google, Inc.
Studies determining the effects of space weather on data center error rates and stability.

University of Florida
On Orbit Radiation Hardened by Software (RHBS) technology experiments aboard the International Space Station.

NASA Goddard University of Florida Liaison Gary Crum (center) with Alex Wilson (left) and Chris Wilson (right). —PHOTO BY NASA

United States Department of Energy
Gamma-detectors with ultra-high energy resolution for accurate non-destructive assay of nuclear materials.

The Aerospace Corporation
Collect and analyze observations from GPS side lobe transmissions to a high-altitude satellite using highly sensitive GPS ground receivers.

The United States Strategic Command
Communications support for the Space Track website and Orbital Data Request customers.

Rolls-Royce Corporation
Braze joint performance prediction methods for critical structures subjected to complex loading conditions.

Patents Issued 2014

Zero Dead Time High Event Rate, Multi-Stop Time-To-Digital Converter
U.S. Patent 8,816,273
George Suarez, Jeffrey J. DuMonthier

Miniaturized Laser Heterodyne Radiometer for Carbon Dioxide, Methane and Carbon Monoxide Measurements in the Atmospheric Column
U.S. Patent 8,699,029
Emily W. Steel, Matthew L. Mclinden

Photonic Choke-Joints for Dual Polarization Waveguides
U.S. Patent 8,693,828
Edward J. Wollack, Kongpop U-Yen, David T. Chuss

Imaging Device [Non-Scanning Laser 3D Imager]
U.S. Patent 8,547,531
Michael A. Krainak

Superconducting Transition Edge Sensors
U.S. Patent 8,674,302
John E. Sadleir

Low Conductance Silicon Micro-Leak for Mass Spectrometer Inlet
U.S. Patent 8,742,468
Dan N. Harpold, Hasso B. Niemann, Brian G. Jamieson, Bernard A. Lynch

Device and Method for Gathering Ensemble Data Sets
U.S. Patent 8,687,742
Paul E. Racette

Developing and Maintaining Evolving Systems with Software Product Lines
U.S. Patent 8,694,963
Michael G. Hinchey, James L. Rash, Joaquin Pena

Vectorized Rebinning for Fast Data Down-Sampling
U.S. Patent 8,816,884
Bruce H. Dean, Jeffrey S. Smith, David L. Aronstein

Emily W. Steel with the mini-LHR —PHOTO BY NASA

2014 SBIR/STTR Activities

2014 SBIR Phase I

Decisive Analytics Corp.
Arlington, VA
An Interactive Visual Analytics Tool for NASA's General Mission Analysis Too

CU Aerospace, LLC
Champaign, IL
Parallel Nonlinear Optimization for Astrodynamic Navigation

Thinking Systems, Inc.
Tucson, AZ
Parallel Enhancements of the General Mission Analysis Tool

Enlumen Technology, Inc.
Mountain View, CA
Eyesafe Direct Laser Source for LIDAR

Fibertek, Inc.
Herndon, VA
Methane LIDAR Laser Technology

Quinstar Technology, Inc.
Torrance, CA
W-Band Solid State Power Amplifier for Remote Sensing Radars

Virginia Diodes, Inc.
Charlottesville, VA
Integrated Receivers for NASA Radiometers

Indiana Integrated Circuits
South Bend, IN
Heterogeneous Chip Integration for GHz Systems

EPIR, Inc.
Bolingbrook, IL
Megapixel Mercury Cadmium Telluride Focal Plane Arrays for Infrared Imaging out to 12 Microns

QmagiQ, LLC
Nashua, NH
Dualband MW/LW Strained Layer Superlattice Focal Plane Arrays for Satellite-Based Wildfire Detection

Materials Modification, Inc.
Fairfax, VA
Nanocrystalline Mg-Doped Zinc Oxide Scintillator for UV Detectors

Structured Materials Industries, Inc.
Piscataway, NJ
ZnMgO Nanowire Based Detectors and Detector Arrays

Black Forest Engineering, LLC
Colorado Springs, CO
Development of a Radiation Hardened CZT Sensor Array and 1U CubeSat Flight Test

QuSpin, Inc.
Westminster, CO
Micro-Fabricated Atomic Magnetometer With Hybrid Vector-Scalar Operation

Pacific Microchip Corporation
Culver City, CA
Rad-Hard Sigma-Delta 3-Channel ADC for Fluxgate Magnetometers

Atmospheric & Space Technology Research Associates, Inc.
Boulder, CO
Developing Near Real-time Data-Assimilative Models and Tools for the Space Environment

Remote Sensing Solutions, Inc.
Barnstable, MA
Miniature Ka-Band Automated Swath Mapper (KASM)

Southwest Sciences, Inc.
Santa Fe, NM
High Accuracy CO2 Instrumentation for UAVs

Southwest Sciences, Inc.
Santa Fe, NM
Unmanned Aerial Vehicle Diode Laser Sensor for Methane

ADVR, Inc.
Bozeman, MT
Seed-Derived Second Harmonic Source for In-Situ Alignment and Calibration of Trace Gas Measurement Instruments

AOSense, Inc.
Sunnyvale, CA
A Portable Source of Lattice-Trapped and Ultracold Strontium (PLUS)

ZeCoat Corporation
Torrance, CA
Broadband Reflective Coating Process for Large FUVOIR Mirrors

Voxtel, Inc.
Beaverton, OR
Monolithic Gradient Index Phase Plate Array

Survice Engineering Company, LLC
Belcamp, MD
Innovative Non-Contact Metrology Solutions for Large Optical Telescopes

Barron Associates, Inc.
Charlottesville, VA
A Dropsonde UAV for Atmospheric Sensing in a Turbulent Environment

Gener8, Inc.
Sunnyvale, CA
Miniaturized High Performance Optical Gyroscope

QorTek, Inc.
Williamsport, PA
Ultraprecision Pointing Accuracy for SmallSat/CubeSat Attitude Control Systems

Optical Physics Company
Calabasas, CA
Interferometric Star Tracker

Triton Systems, Inc.
Chelmsford, MA
Spacecraft Thermal Control System Not Requiring Power

Applied Material Systems Engineering, Inc. (AMSENG)
Schaumburg, IL
Advanced Thermal Interface Material Systems for Space Applications

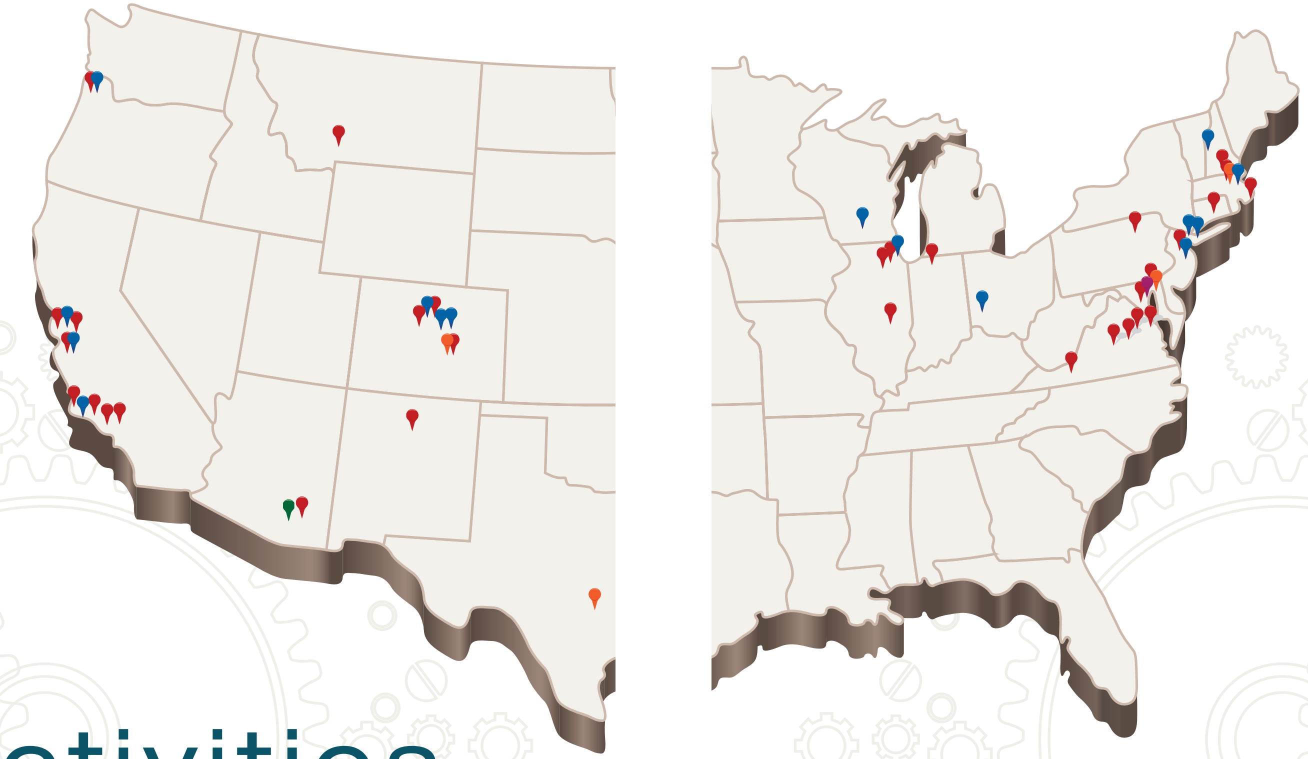
Thoughtventions Unlimited
Glastonbury, CT
Extreme Environment Ceramic-To-Metal Seal

GeoVisual Technologies, Inc.
Boulder, CO
A Continuously Updated, Global Land Classification Map

Applied Research, LLC
Rockville, MD
A New Class of Flare Prediction Algorithms: A Synthesis of Data, Pattern Recognition Algorithms, and First Principles Magnetohydrodynamics

Applied Research, LLC
Rockville, MD
A Robust and Automated Hyperspectral Damage Assessment System Under Varying Illumination Conditions and Viewing Geometry

Phoenix Integration
Blacksburg, VA
Integrated Modeling, Analysis, and Verification for Space Missions



2014 STTR Phase I

Made in Space, Inc.
Wilmington, DE
MicroCast: Additive Manufacturing of Metal Plus Insulator Structures with Sub-mm Features

2014 SBIR Select Phase I

Intelligent Automation, Inc.
Rockville, MD
Low-Frequency, All Digital Radar (ADR) for Biomass and Ice-sheet Investigations

Nanohmics, Inc.
Austin, TX
Improved Hyperspectral Imaging Technologies

Applied NanoFemto Technologies, LLC
Lowell, MA
On-Chip hyperspetral imaging system for portable IR spectroscopy Applications

Microelectronics Research Development Corporation
Colorado Springs, CO
Radiation Hardened Structured ASIC Platform for Rapid Chip Development for Very High Speed System on a Chip (SoC) and Complex Digital Logic Systems

2014 SBIR Select Phase II

Litespar, Inc.
Tucson, AZ
Atmospheric Lidar with Cross-Track Scanning

2014 SBIR Phase II

Barber-Nichols, Inc.
Arvada, CO
High Speed Compressor for Subcooling Propellants

SySense, Inc.
El Segundo, CA
Framework for the Design and Implementation of Fault Detection and Isolation

Vescent Photonics, Inc.
Golden, CO
EO Scanned Micro-LADAR

Voxtel, Inc.
Beaverton, OR
Flexible, High Performance Microlens Array Technologies for Integral Field Spectrographs

MP Technologies, LLC
Evanston, IL
High-performance 1024x1024 MWIR/LWIR Dual-band InAs/GaSb Type-II Superlattice-based Camera System

United Silicon Carbide, Inc.
Monmouth Junction, NJ
The First JFET-Based Silicon Carbide Active Pixel Sensor UV Imager

Madison CryoGroup, LLC
Middleton, WI
Cryocooler With Cold Compressor for Deep Space Applications

Creare LLC
Hanover, NH
Lightweight Superconducting Magnets for Low Temperature Magnetic Coolers

Honeybee Robotics, Ltd.
Brooklyn, NY
A Comet Surface Sample Return System

Optra, Inc.
Topsfield, MA
Multi-Configuration Matched Spectral Filter Core

Iris AO, Inc.
Berkeley, CA
Fabrication Process and Electronics Development for Scaling Segmented MEMS DMs

Gener8, Inc.
Sunnyvale, CA
Fiberless Optical Gyroscope

Black Swift Technologies, LLC
Boulder, CO
Soil Moisture Mapping sUAS

RNET Technologies, Inc.
Dayton, OH
OrFPGA: An Empirical Performance Tuning Tool for FPGA Designs

MaXentric Technologies, LLC
Fort Lee, NJ
Assimilation Dynamic Network (ADN)

Creare LLC
Hanover, NH
Ultra-Miniaturized Star Tracker for Small Satellite Attitude Control

National Aeronautics
and Space Administration
Goddard Space Flight Center

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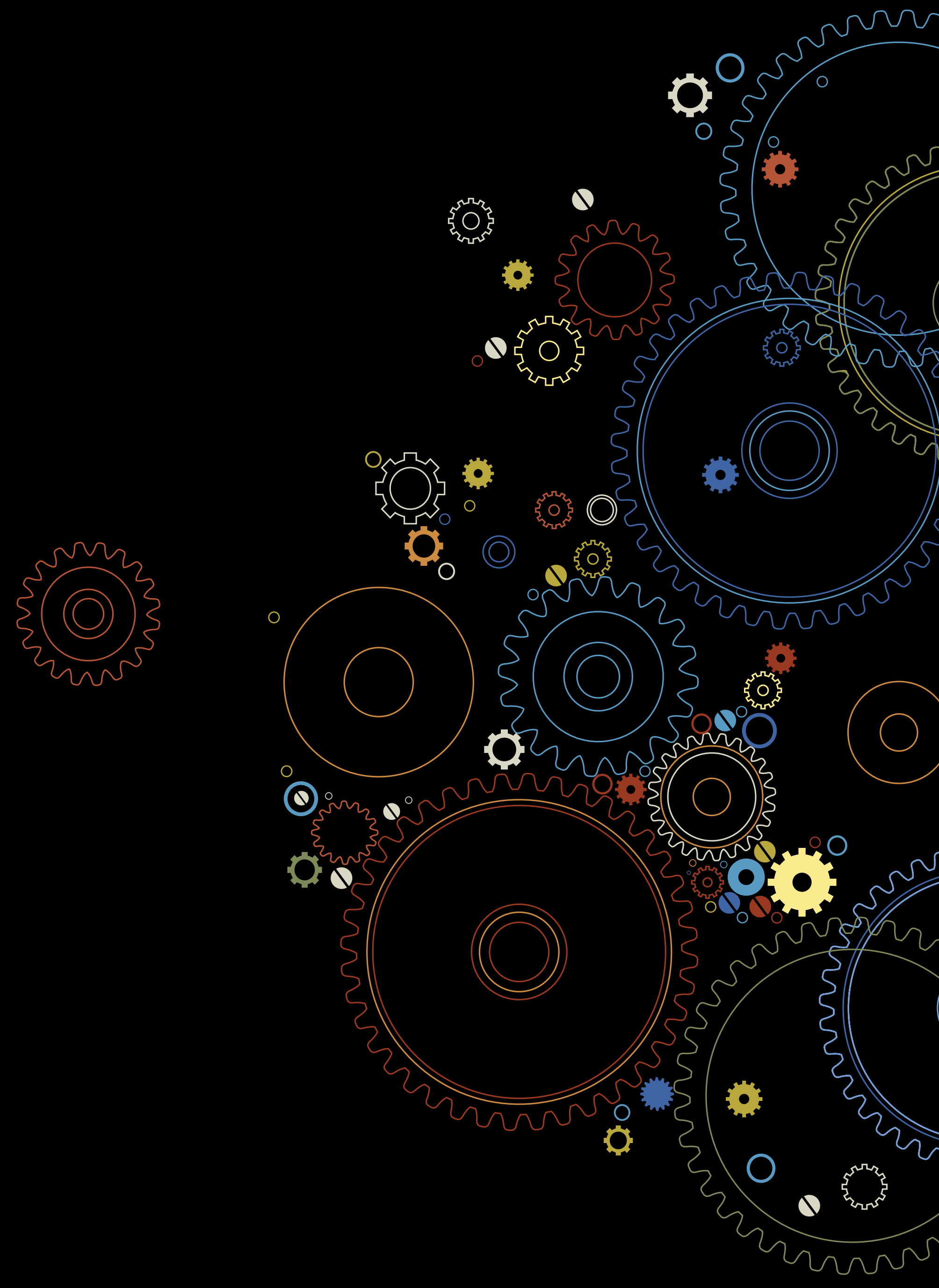

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