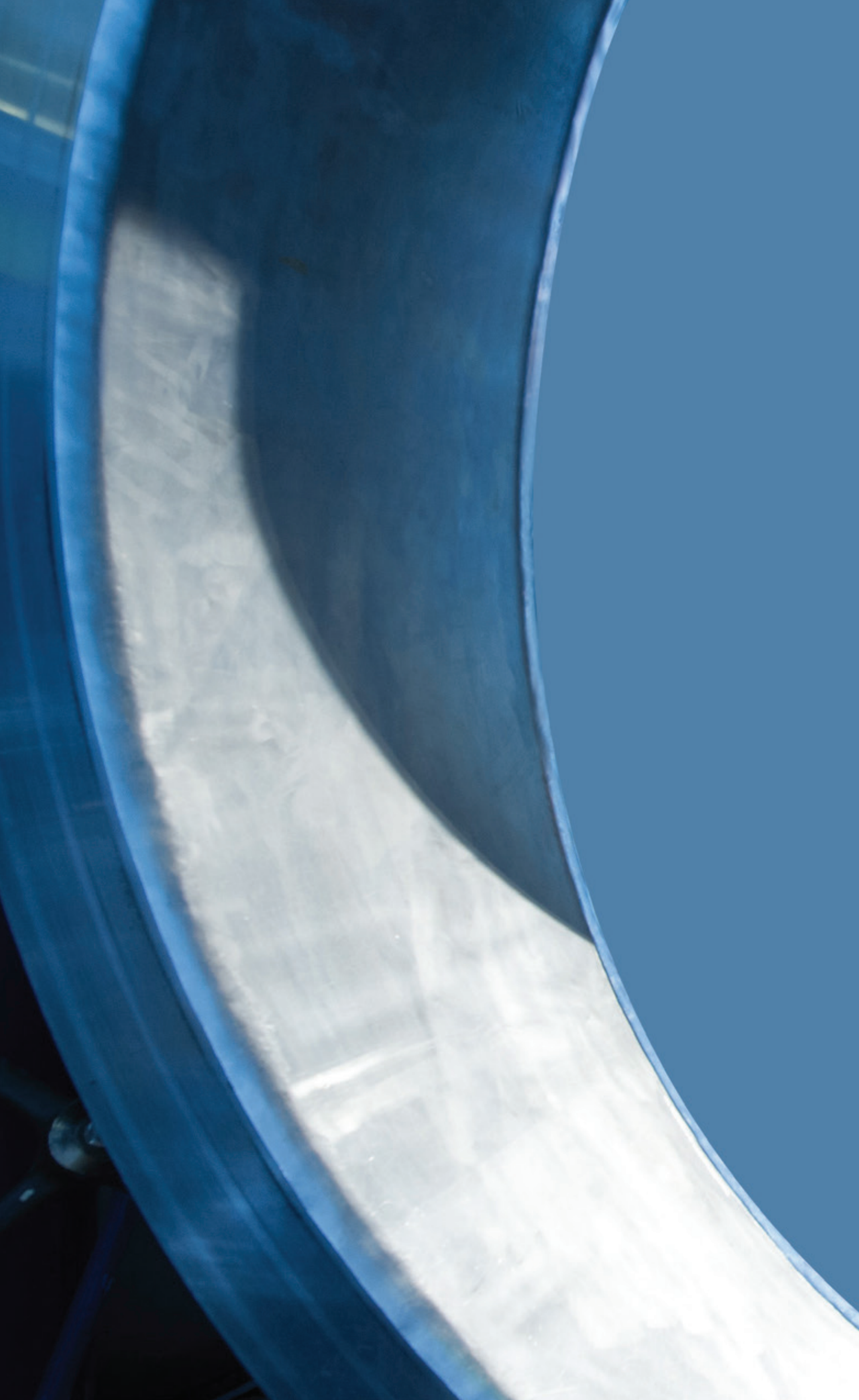
National Aeronautics and Space Administration

Partnering for TOMORROW

GODDARD SPACE FLIGHT CENTER'S | INNOVATIVE TECHNOLOGY PARTNERSHIPS OFFICE | **ACCOMPLISHMENTS REPORT 2015**



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Partnering for TOMORROW

From the Chief

Versatility and value – these two words describe the many innovations developed at NASA Goddard and made available to the public, and they comprise one of the underlying themes for the Innovative Technology Partnerships Office's 2015 Accomplishments Report. Versatility is represented by the broad spectrum of capabilities our technologies encompass, and value by the countless benefits these technologies can provide to Earth-based applications.

In past Accomplishments Reports, we've often focused on specific missions and the technologies developed to support them. We continue this tradition by reviewing the Magnetospheric Multiscale (MMS) Mission. We examine the innovations behind the MMS, and how these can be leveraged to terrestrial applications.

In addition, this Accomplishments Report focuses on three major cross-cutting NASA Goddard capabilities: advanced electronics, CubeSats, and software. Each in its way embodies the dual concepts of versatility and value. For example, our science missions require electronics that are small, light, energy efficient, and highly reliable – all while being able to withstand the harsh environments of space. The Earth-bound applications in which these electronics could be of high value are probably too numerous to count. The software programs we've developed over the years in support of our missions touch upon nearly every aspect of project development, operation, and support. And our continued efforts in evolving CubeSats into an industrial-grade, robust platform offers academia and industry an entry point into space orders of magnitude less expensive than previous options.

It's not difficult to imagine how these capabilities can be "mixed and matched" in highly advantageous ways. For example, imagine you're an entrepreneur for a space technology startup company. You can incorporate NASA Goddard electronics into your system design. You can browse the NASA Software Catalog for code that supports every aspect of the project, from system design, project management, hardware control, and testing. And you can take advantage of a CubeSat platform to launch your technology into space at greatly reduced cost.

This is of course only a very simple and generic example. The actual applications to which these NASA Goddard innovations can be leveraged to advantage are many and varied, limited only by imagination.

Our goal in the 2015 Accomplishments Report is to help spark your collective imaginations, by presenting some of the available NASA Goddard innovations the ITPO office has helped push to market during the past 12 months. The versatility of these technologies ensures there's something here for everyone; their value will encourage interested parties to learn more. Please read on, and enjoy!

Nona Cheeks

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

President Park Geun-hye of South Korea Visits NASA Goddard — 2015 NASA

NASA Goddard Tech Transfer

2015 IN REVIEW

Throughout 2015 the NASA Goddard Innovative Technology Partnerships Office (ITPO) continued its mission to help ensure all innovations developed at NASA Goddard are made available for technology transfer to the public. These technologies – and the broad array of applications to which these technologies can potentially be applied – are too numerous to describe in detail in a single publication.

In the 2015 Accomplishments Report, we briefly review just a few examples of the innovations with which the ITPO has worked during the past calendar year. These include:

Advanced Electronics

It probably goes without saying that electronics are ubiquitous in all NASA Goddard missions – and in today's society in general. The electronics developed for space missions can often be adapted to the requirements of non-NASA applications. A recent example of this is SpaceCube (GSC-15760-1), an electronic computer processing module designed for use in small spacecraft and sounding rockets.

Magnetospheric Multiscale Mission (MMS)

The MMS is one of the most sophisticated and ambitious missions ever undertaken by NASA Goddard. Several innovations developed to support MMS and its science instruments are now publically available for potential use in Earth-based commercial and educational applications.

CubeSat

NASA Goddard has played a critical role in the evolution of CubeSat to SmallSat, from purely experimental and educational projects to a robust platform upon which real science and commercial application can be built.

A recent example is Dellingr (GSC-17152-1), a new 6U CubeSat designed and built by NASA Goddard to demonstrate CubeSat's ability to perform space science research.

Software

Similar to electronics, software is a near-universal component of modern technology. Over the years, NASA Goddard has developed software to support numerous missions and capabilities. This code is captured via the New Technology Report and Software Release process, and made available to all interested parties through the NASA Software Catalog.

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Advanced Electronics

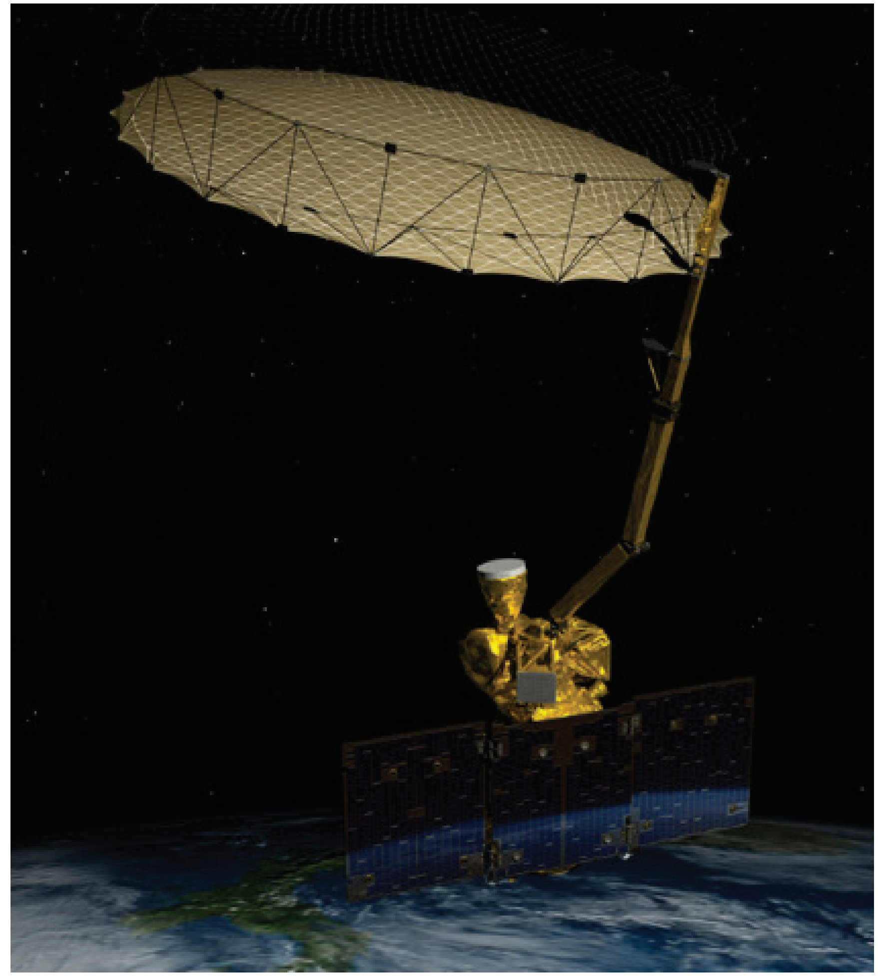
Introduction

It’s difficult to imagine an aspect of modern society that does not involve electronics in some way. If you are reading this report online, an example is literally staring you in the face. And a look around the room should reveal many others. Suffice to say electronics are virtually everywhere.

This is especially true at NASA Goddard. At the heart of every mission, science instrument, and core capability are electronic components. Many of these represent cutting-edge innovations, developed to meet highly demanding requirements. These include small size and weight, extreme precision, and energy efficiency – all while withstanding the harsh environments of outer space.

The characteristics and specifications to which these technologies have been developed make them ideal for certain Earth-based applications where traditional electronics are too bulky, inefficient, or delicate. For example, the Soil Moisture Active and Passive (SMAP) mission depends on taking ultra-sensitive microwave measurements, which are subject to Radio Frequency Interference (RFI). To meet this challenge, NASA Goddard has developed novel RFI-mitigation strategies that may benefit ground/space communications and radar. Another mission, the Deep Space Climate Observatory (DSCOVR), provides early warning of solar storms. And thanks to its location in deep space, the mission also collects information on how electronics are affected by radiation in deep space. Commercial applications for the resulting “space weather” reports range from the airlines to power grid operators.

In this section, we look at several examples of NASA Goddard developed advanced electronics. We also review a few potential non-NASA applications these technologies could provide substantial benefits.



SMAP (Artist Conception) — NASA

Advanced Electronics Overview

It is difficult to overestimate the impact space exploration has had on the development of modern electronic technology. The heavy, power-hungry, vacuum-tube based electronics of the 1940s and 1950s were unsuitable for the demands of space flight, and the very limited space, power, and weight budgets available in early satellites and missiles. This challenge led directly to the development of transistor based miniature electronic systems and integrated circuits. As a result, many types of electronics that have become ingrained into everyday life were first developed to support space missions. Perhaps the most famous of these is the microcomputer (forerunner of today's personal computer and its hand-held relatives) although many other examples abound.

This tradition is alive and well at NASA Goddard, where engineers continue to serve as leaders in advanced electronics development in support of missions such as Soil Moisture Active and Passive (SMAP). Innovators are constantly pushing the state of the art forward to obtain timely and precise scientific results possible within the still-limited space, weight, and power budgets available in today's spacecraft. These same requirements are equally important in consumer electronics, where lightweight and mobile devices reign supreme.

In addition to developing new technologies that may form the basis of tomorrow's products, NASA Goddard performs a potentially critical service to the electronics world. Our increasing reliance on modern technology comes at a certain risk: if our communication, navigation, and power delivery systems were ever compromised, many facets of society could be profoundly impacted. Among these potential risks is the possibility of a solar event damaging satellites in space and/or power grids on the ground. A better understanding of these events – and ideally, sufficient warning before they occur to enact protective measures – could be an enormous advantage. NASA Goddard missions such as the Deep Space Climate Observatory (DSCOVR) and Magnetospheric Multiscale (MMS) missions are designed to help us better understand, anticipate, and potentially predict space weather events that could endanger our critical electronics-based systems.

In this article, we look at two missions that took flight in 2015: SMAP and DSCOVR. The first is an example of NASA Goddard's ongoing efforts to develop new and better-performing advanced electronics. The second represents a mission designed to help protect the electronics-based infrastructure on which the world has come to rely.

Soil Moisture Active and Passive (SMAP)

On January 31, 2015 the Soil Moisture Active and Passive (SMAP) reached orbit and began its three-year mission to create global high-resolution maps of moisture in the top five centimeters of soil. The goal is to fill a significant gap in knowledge of how near-surface groundwater is distributed. This data will be valuable to a wide range of applications in agriculture, meteorology, climate science, and hydrology. SMAP instruments will update these maps every two to three days throughout the mission, providing unprecedented data on seasonal and year-to-year changes in soil moisture and mapping how the moisture freezes and thaws. This is expected to allow prediction of significant events including floods and droughts, and will also improve climate change models.

SMAP is equipped with a radiometer for detecting moisture in Earth's soil via naturally occurring microwaves. The radiometer, which was developed at NASA Goddard, measures the "brightness temperature" of the soil. This is a combination of surface temperature and soil moisture. By factoring out the temperature with the help of computer models, scientists can calculate the wetness of the soil. Researchers have worked for decades on interpreting radiometer data in terms of soil moisture, and the results are very accurate.

Protecting this instrument from radio frequency interference (RFI) presented a significant technical challenge. Although the 1400-1427 MHz band in which the SMAP radiometer operates is reserved for scientific use by international law, out-of-band emissions from neighboring transmitters (and possibly illegally operating emitters) is often present. This interference can be significant enough to impact the success of the mission. Therefore NASA Goddard has implemented an aggressive mitigation solution, including special flight hardware and ground software capabilities for RFI detection and removal.

In addition, the high resolution moisture maps delivered by SMAP also have a broad range of potential applications. These include weather and climate forecasting, prediction of droughts and wildfires, early warning of floods and landslides, agriculture, human health and national security.

DSCOVR

The DSCOVR mission (which has its earliest origins in the Triana mission) lifted off from Cape Canaveral Air Force Station on February 11, 2015, propelled by a Space-X Falcon 9 rocket. The spacecraft achieved a Lissajous orbit at the Sun-Earth L1 Lagrangian point on June 8 and began transmitting near-real time images of Earth shortly afterward.

From its vantage point in deep space, DSCOVR will provide early warning of solar storms, which can have significant effects on spacecraft and ground based electronic systems. It will also carry out a series of earth-and space-science observations.

DSCOVR's instruments include a Solar Wind Plasma Sensor and Magnetometer (PlasMag) and associated Faraday Cup, which NOAA will use to measure solar wind velocity distribution and the magnitude and direction of the solar wind magnetic field. These are the primary instruments which will be used to predict solar storms.

NASA Godddard engineers ready the Deep Space Climate Observatory (DSCOVR) spacecraft for shipment to Cape Canaveral. — PHOTO BY NASA

Satellite capture of a developing U.S. storm system. — NASA

NOAA will distribute solar storm warnings and observations through the Space Weather Prediction Center (SWPC) in Boulder, Colorado. Potential users include power grid operators, airlines, and satellite navigation engineers who would be impacted by geomagnetic storms. NASA will be responsible for Earth and Space Science instrument data, which will be processed at NASA Goddard and made available to the public through the Atmospheric Science Data Center at NASA's Langley Research Center.

Conclusion

The SMAP and DSCOVR missions represent only two examples of many in which NASA Goddard continues to further the advancement of cutting-edge electronics. In fact, virtually every NASA Goddard mission involves the development of new and novel technologies that could be transferred into the public domain to form the basis for new applications and products. In the following article, we describe several examples of these available technologies.

DSCOVR clean room — Photo by NASA

Advanced Electronics Tech Transfer Opportunities

Today's NASA-developed technologies created in the name of space science can be leveraged into tomorrow's consumer electronics products. In this article, we look at three examples of NASA Goddard advanced electronics that are now available to the public.

RFI Mitigation (GSC-17030-1)

As we mentioned in the preceding article, the SMAP mission encountered a significant problem with RFI affecting its radiometer. To address this issue, a NASA Goddard engineering team developed a "multidomain" approach to RFI mitigation. This involves digital signal processing on both on the spacecraft and on the ground. The on-board system uses an innovative on-board digital detector backend with digital signal processing algorithms to characterize time, frequency, polarization, and statistical properties of received signals.

This technology has many potential terrestrial uses. For example, an application in the communications and signal processing arena can benefit from RFI mitigation. This includes signals intelligence involving detecting buried signals in noise. Another potential application could be cell phones and other low-power radios. The communications and radar communities could find significant benefits in this technology, since it helps ensure the integrity of the signal.

Science-defined Signal Processing Module (GSC-16502-1)

This innovation functions similarly to a smart phone that users can customize by adding apps to it. The Science-defined Signal Processing Module allows users to perform a similar process by implementing custom instrument signal processors.

At its core, this system is an electronics module consisting of one common digital electronics board, customizable daughter-cards that plug into it, and customizable "apps" called FPGA designs that have been organized into a NASA center-wide library. The module is designed in a small form-factor, enabling it to fit in a variety of spacecraft. It is customizable for a wide variety of science instruments, including portable radiometers, energetic particle detectors, planetary and earth altimeters, multispectral imagers, plasma wave spectrometers, and electric and magnetic field monitoring instruments. In each case, the module can be configured to replace the custom electronics that would otherwise be designed for each instrument.

SpaceCube 2.0 (GSC-15760-1)

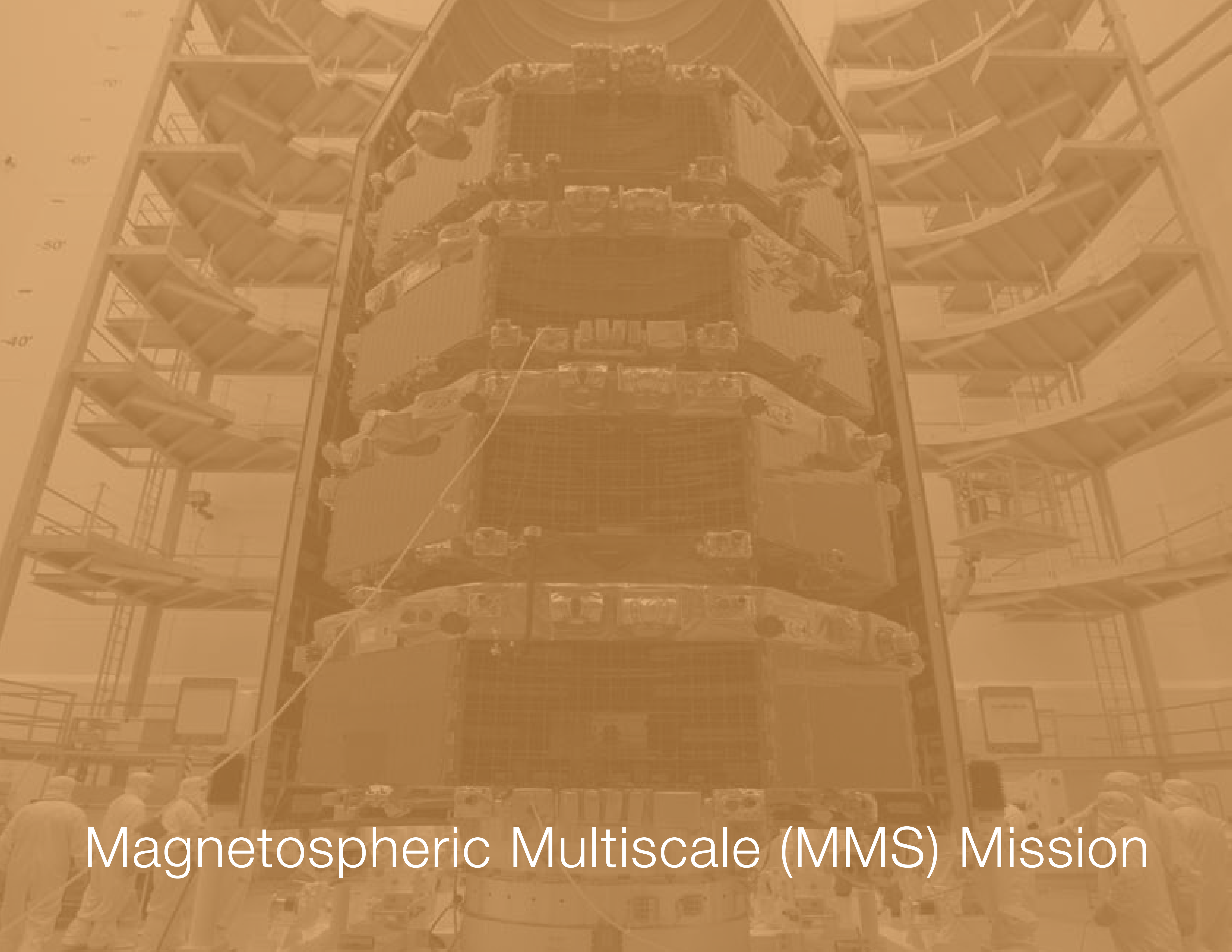
The SpaceCube 2.0 flight design builds on nine years of experience with past SpaceCube processors, which have been flight proven in five applications including:

- On-board image processing during Hubble Space Telescope Servicing Mission 4.
- Software mitigation of radiation induced electronic upsets aboard the International Space Station (ISS).
- Multi-function avionics package aboard the joint NASA-DoD Small Rocket/Spacecraft Technologies (SMART) sounding rocket.
- Central avionics for the Space Test Program (STP) on ISS.
- SpaceCube 2.0 Engineering Model on ISS advancing prior technology demonstrations.

The SpaceCube program is in the process of delivering three additional units for a follow-on Space Test Program ISS payload and one unit for a GPS sounding rocket demonstration.

Conclusion

These are just three examples of the many NASA Goddard advanced electronics currently available for technology transfer. For more information on these and all other NASA Goddard technology transfer opportunities, please contact the NASA Goddard Innovative Technology Partnerships Office (http://itpo.gsfc.nasa.gov/index.html).



Magnetospheric Multiscale (MMS) Mission

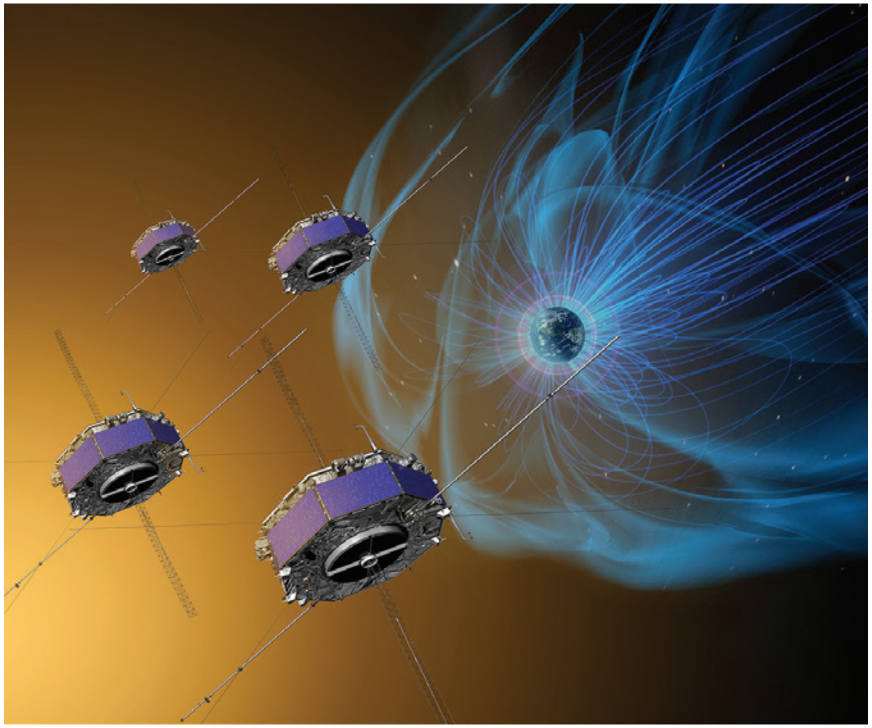
Introduction

NASA Goddard's Magnetospheric Multiscale (MMS) Mission launched on March 12, 2015 and transitioned to Operations on September 1, 2015. The purpose of MMS is to study the "magnetic reconnection," the interaction between magnetic fields from the Earth and the Sun. MMS is a highly complex and complicated system, comprising four separate spacecraft flying in tandem and carrying over 100 scientific instruments.

This data is critical for understanding the impact space weather can have on space-borne assets, both governmental and commercial. Communication satellites, the GPS system, satellites performing science, governmental, and military applications, and even the terrestrial power grid are all potentially susceptible to space weather events. The impact on society resulting from one or more of these systems being compromised would likely be profound. The MMS provides data that will help us better protect these systems.

The technologies developed for MMS can also be leveraged to applications here on Earth. These innovations include spacecraft positioning, data acquisition and processing, and others. For example, one component of the MMS is the digitally steered antenna array. This system uses innovative technology to detect GPS signals despite the fact that the MMS spacecraft fly far above the current limit of GPS positioning.

In this section, we briefly review the MMS mission and the science and technology behind it. We also look at several innovations developed to support MMS, including the Navigator and others, and how they can potentially be adapted to terrestrial uses.



Artist concept of the Magnetospheric Multiscale, or MMS, mission to study how magnetic fields release energy in a process known as magnetic reconnection. — NASA

MMS Innovations

Few NASA Goddard missions have been as ambitious as the Magnetospheric Multiscale (MMS) Mission. In this article we review some of the innovations that made MMS one of the most challenging endeavors ever undertaken by NASA Goddard.

The Challenge: Studying the Earth's Magnetic Reconnection

Obtaining reliable data about the magnetic reconnection has historically eluded scientists. This energy is stored and released through magnetized plasma, which has never been closely studied due to the high level of difficulty in capturing the right data. The electron diffusion region (EDR), where reconnection occurs, is thin, fast moving, and largely unpredictable. The EDR is also three dimensional, which necessitated innovative flight dynamics and a novel tetrahedral array of the four MMS spacecraft. While NASA spacecraft have encountered the phenomenon before, instruments were not sufficiently fast to record sufficient data for study.

One of the many advantages of MMS is its ability to capture data at speeds 100 times faster than previous missions. Instruments on the MMS spacecraft are tasked with measuring electric and magnetic fields, fast plasma, energetic particles, and hot plasma composition of the Earth's magnetosphere. For the first time, scientists will have data that will help explain the phenomenon of magnetic reconnection in the electron diffusion region, which will lead to a better understanding of the dynamics and processes of space weather.

Measuring magnetic and electric fields requires a spacecraft that is very electrostatically and magnetically "clean." The process developed for fabricating the MMS resulted in the cleanest spacecraft ever built by NASA Goddard. This process can now be applied to future missions.

The MMS solar arrays were specially designed to ensure all components were grounded and the cells did not create any islands of charge. This required a special grid over the cells. The magnetic signature of the spacecraft also had to be extremely low, with static buildup minimized.

Special advanced electronics needed to be developed for this application. This required a combination of materials selection, design process, and testing. For example, some materials were prohibited due to their unfavorable magnetic properties. NASA Goddard innovators designed the electronics to minimize current loops, electric field, and magnetic moments. Tests were conducted at the board and component level to ensure no charge was collecting.

All this effort appears to have been successful; measurements obtained from the MMS indicate a magnetic field even lower than expected.

One of the primary challenges facing the MMS involved formation flying. In order to collect data from the thin but 3D space of the electron diffusion area, the MMS spacecraft fly in formation using broadly tetrahedral forms. The MMS is NASA's first attempt to fly four satellites in simultaneous formation, resulting in unique flight dynamics. This required launching the spacecraft in proper orbital position, an extremely sensitive operation.

A number of innovations were developed to enable the four satellites to fly as close as 10K. To address this, MMS employs a NASA Goddard-developed navigation system that receives GPS signals from above the GPS "constellation." MMS is now the highest altitude spacecraft receiving GPS signals; its navigation system provides positional accuracy to within 5 meters. This allows the MMS formation to fly four separate (but very similar) orbits.

To record data, the MMS must fly through magnetic reconnection events very quickly (less than a second) taking measurements at up to about 1000 times per second. Certain events cause a trigger indicating significant data has been taken; a scientist back on Earth can then override the spacecraft software and decide which data to downlink.

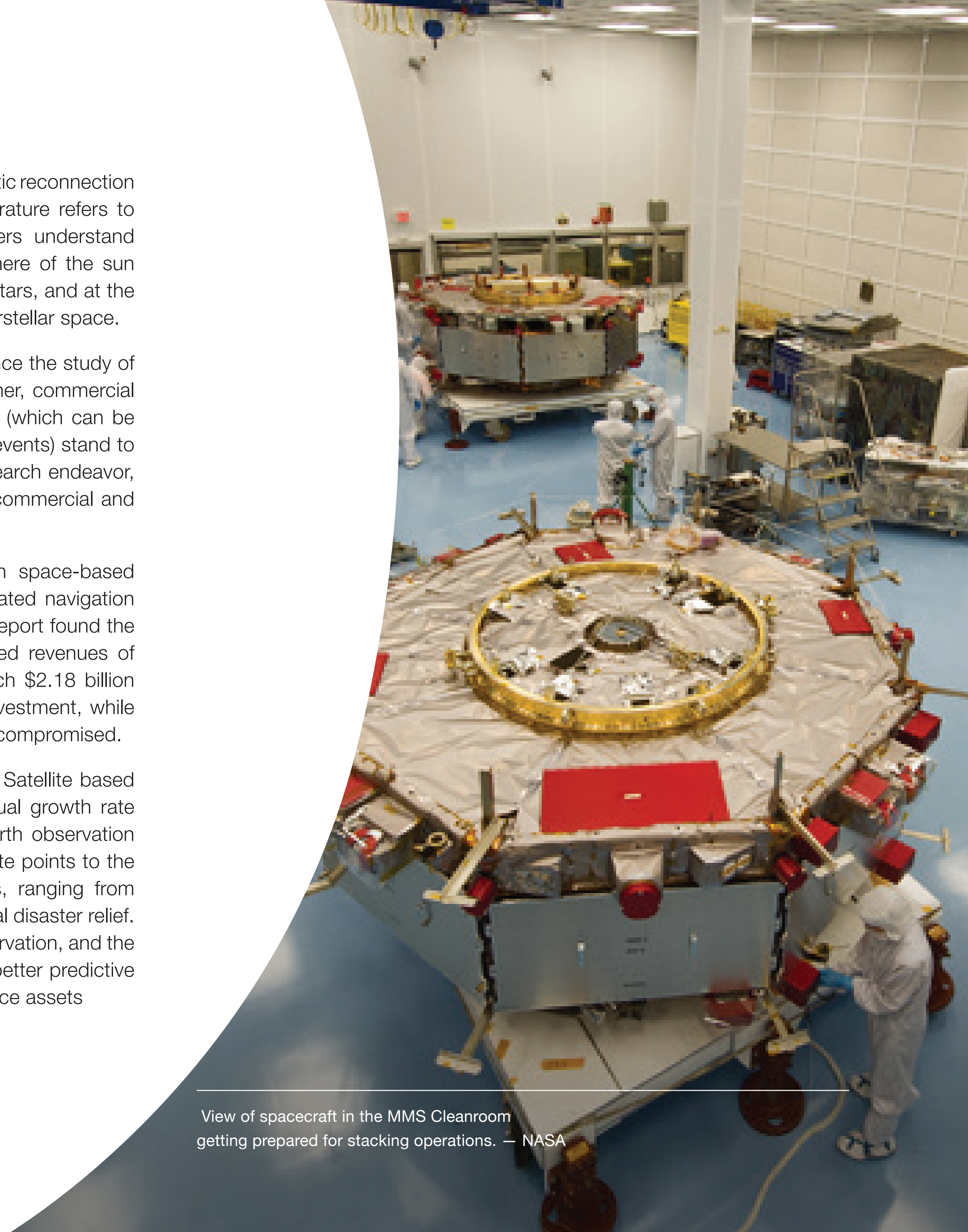
Conclusion: Doing Science
(and Protecting Space-Based Assets)

The primary purpose of MMS is science. By studying magnetic reconnection in the Earth's magnetosphere (which NASA Goddard literature refers to as a "local, natural laboratory"), MMS helps astronomers understand reconnection elsewhere as well, such as in the atmosphere of the sun and other stars, in the vicinity of black holes and neutron stars, and at the boundary between our solar system's heliosphere and interstellar space.

At the same time, MMS provides a critical side benefit. Since the study of the magnetic reconnection offers insight into space weather, commercial and governmental markets concerned with space assets (which can be damaged or even rendered inoperable by space weather events) stand to benefit from the mission. So while MMS is primarily a research endeavor, its technologies also have important implications for the commercial and defense communities.

For example, as military operations rely increasingly on space-based technology, automated weapons systems need sophisticated navigation for missile and artillery guidance. A 2014 Frost & Sullivan report found the Military Global Navigation Satellite Systems market earned revenues of $1.98 billion in 2013, and estimates that number to reach $2.18 billion by 2022. Data provided by MMS can help protect this investment, while helping to ensure the U.S. defensive readiness remains uncompromised.

According to a press release on Reuters.com, the Global Satellite based Earth Observation market will grow at a compound annual growth rate of 11.34% during 2013-2018, with an estimated 258 Earth observation satellites launched from 2014-2029. The strong growth rate points to the importance of observation data for multiple applications, ranging from agriculture to defense, and resource management to natural disaster relief. NASA Goddard is already a leader in the field of Earth Observation, and the data collected during the MMS Mission will help develop better predictive models for space weather that threatens satellites and space assets



View of spacecraft in the MMS Cleanroom getting prepared for stacking operations. — NASA

Key MMS Technologies

A mission as complicated and unprecedented as MMS requires the development of new and unique technologies. These innovations are now available for technology transfer. In this article, we look at a few examples of technologies developed to support MMS, and how they could be leveraged to non-NASA applications.

Navigator (GSC-14793-1)

The NASA Goddard built Navigator is an example of an MMS technology that has already been successfully licensed and commercialized. The Navigator extends GPS-level positional accuracy into space. To do this, the Navigator detects GPS data at a higher altitude than has ever been achieved before. On-board propulsion, controlled by flight dynamics personnel on the ground, is also enabled by the Navigator, along with flight dynamics and high-precision thruster maneuvers with a precision accelerometer process running in a closed loop. This capability can now be applied to future space missions, along with other commercial applications.

Optical Bench Assembly (OBA) (GSC-17127-1)

To achieve the goals of MMS, a suite of instrumentation had to be developed and assembled, identically on all four spacecraft. One of the challenges to completing this task was managing manage thermal performance. To do this, a novel Optical Bench Assembly (OBA) was designed to ensure operating temperature limits on the spacecraft. The temperature limit of some of the instruments is lower than the average temperature of the spacecraft, so it is critical that heat transfer is managed and that the instruments are conductively isolated and radiatively insulated from the spacecraft. The Optical Bench Assembly instruments provide navigation for orbit raising and attitude maneuvers.

MMS Spacecraft Flight Software (GSC-16471-1)

The MMS Spacecraft Flight Software consists of command, data handling, and attitude control. Along with spacecraft commanding and telemetry, the software also performs attitude determination and control. A key component of the software system is the communication between ground and spacecraft operations. The ground system sends commands to the spacecraft, which will then carry out configuration changes to the onboard software and/or hardware. Command handling and routing, telemetry handling and routing, attitude determination and control, File Delivery Protocol, and custom interfaces management are all features and benefits of the Spacecraft Flight Software.

SWM76 Launch Window Analysis Tool for MMS (GSC-17339-1)

Due to the multiple factors determining optimal orbital and flight patterns, a sophisticated analytic tool was needed to plan the precise launch window for MMS. The SWM76 Launch Window Analysis Tool for Magnetospheric Multiscale Mission enabled the MMS team to correctly identify the exact conditions and parameters for launch. This technology will clearly be useful for future missions, and also has commercial potential in the growing market of space assets. Not only does the SWM76 excel in analytic efficiency, but it also produces graphical results that helped the MMS team evaluate which launch windows would be most impacted by the various mission requirements, and how best to predict the most successful launch opportunity.

Closed-Loop Automated Ground Data System for Support of the MMS Constellations (GSC-14476-1)

Automation of all routine operations is an excellent means of cutting costs and saving both time and energy in the command center. Previous missions have automated several key functions, but the MMS team has gone a step further by developing a way to solve "closed-loop" automation across all shifts. By using mostly legacy software, the Closed-Loop Automated Ground Data System for Support of the MMS Constellations can dramatically improve mission operations through software architecture that does not require building a system from scratch. A comprehensive systems automation tool of this type could have substantial benefits for future missions, and have commercialization potential for applications that have yet to integrate multiple systems with a single closed-loop solution.

MMS Magnetometer Data Processing and Preliminary Calibration Software (GSC-17353-1)

MMS-specific software applications were developed to facilitate magnetometer data. The MMS Magnetometer Data Processing and Preliminary Calibration Software uses an innovative calibration format to produce, update, and exchange data between the various institutions collaborating on the MMS Mission. The software runs autonomously and the calibration algorithms are specially adapted for use on slow-spinning spacecraft, providing magnetic field data in a timely manner to support various aspects of MMS operations. While current use is limited to the subset of MMS data users, there is potential for future re-engineering for other NASA missions. Furthermore, the development of such a technology is a true collaborative effort, demonstrating NASA Goddard's ability to incorporate multiple institutions into a single mission.

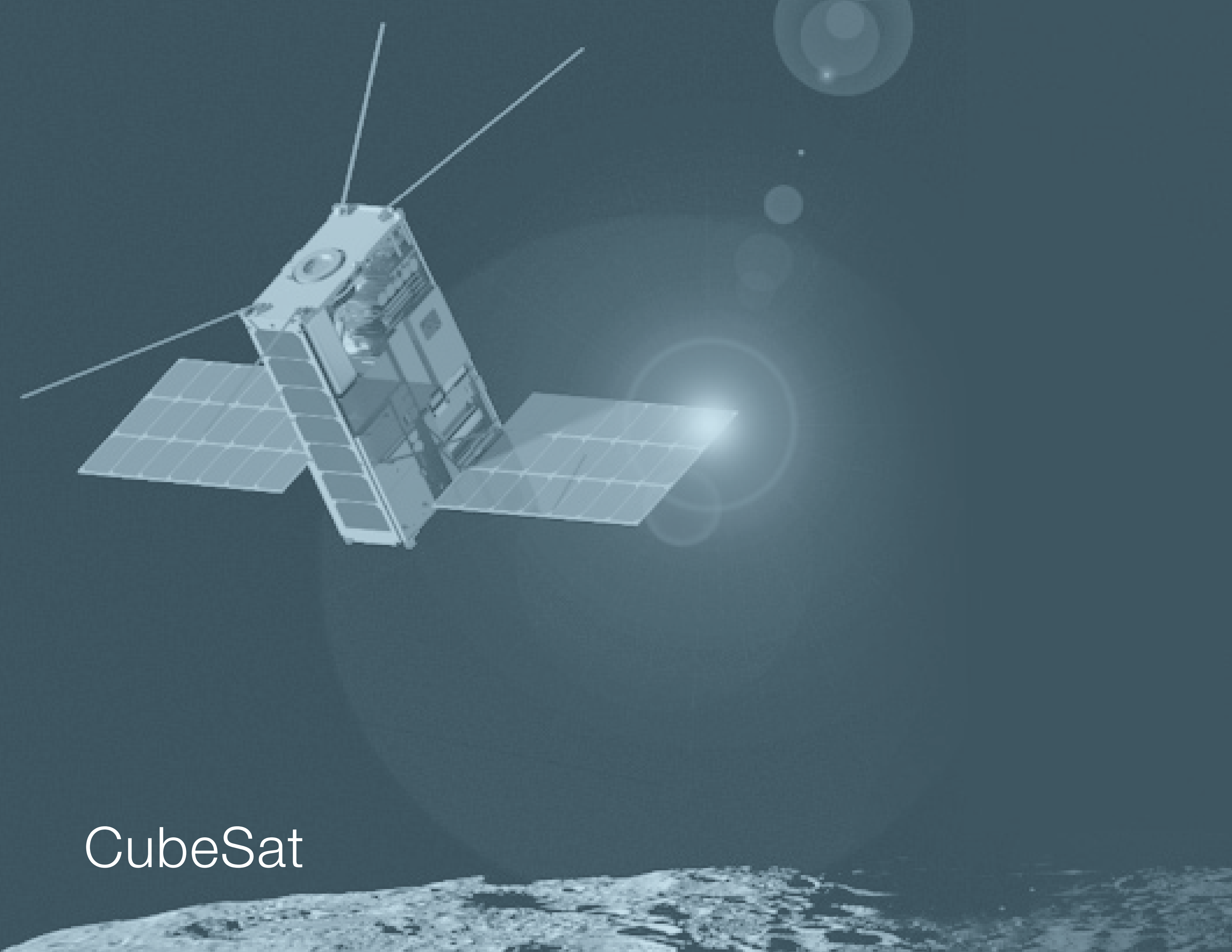
Command and Data Handling subsystem (GSC-17223-1)

Before the data produced by the MMS Mission is sent to the ground, the Command and Data Handling subsystem provides the computing power necessary to execute stored or uplinked commands and distribute those commands to the Instrument Suite (IS) and other spacecraft components. This subsystem is tasked with spacecraft command and telemetry, time management and distribution, analog data acquisition, and interfacing with the IS and other hardware components. There is also a built-in redundancy feature to ensure spacecraft operations and mission integrity.

Discrete Cosine Transform (GSC-17237-1)

Finally, a new compression algorithm based on an advanced Discrete Cosine Transform predictive coder is being developed by NASA Goddard to increase the lossless data compression ratios of natural, high resolution, color, or gray-scale images. By compressing UV, visible, IR, and multispectral space science images, the Discrete Cosine Transform Minimum Mean Square Error Predictive Coder (DMPC) can improve data throughput from MMS instruments. With data being captured much faster than traditional missions due to the transitory nature of the electron diffusion region, the ability to compress images for ground transmission will save both time and power, augmenting performance of the spacecraft and instruments over the duration of the mission.

Beauty pass showing the MMS spacecraft flying on the nightside. — NASA


CubeSat

Introduction

NASA Goddard is playing an important role in CubeSat's evolution from a purely academic tool for students to practice and learn rudimentary satellite design, into a robust platform upon which important science can be conducted (and commercial applications can be built).

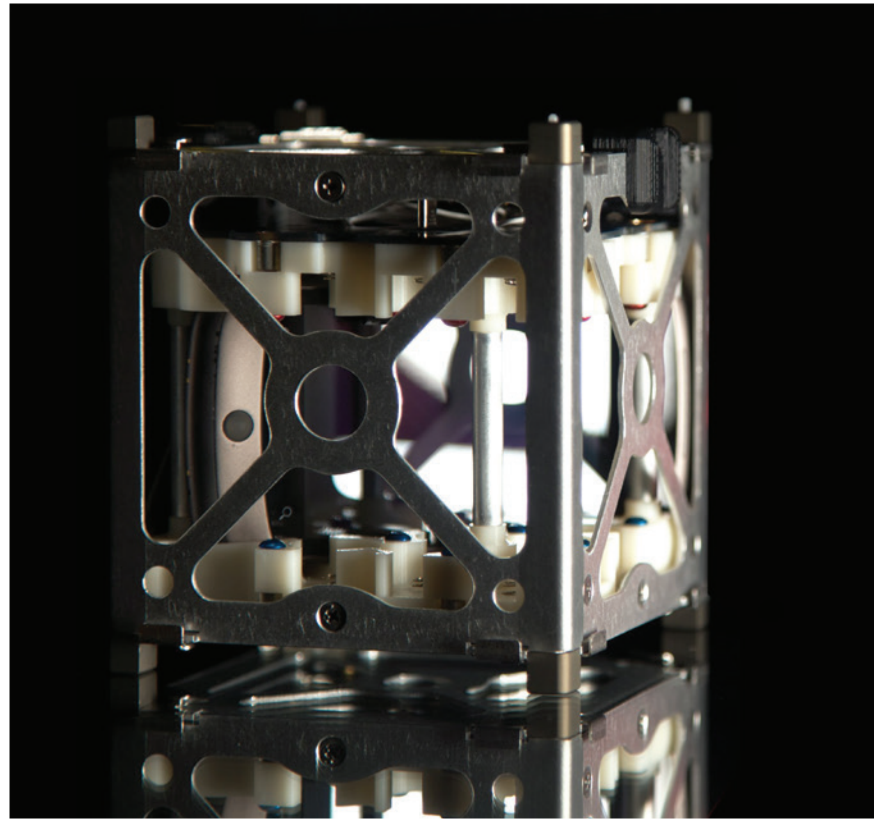
We have featured NASA Goddard's ongoing involvement in CubeSats in previous Accomplishments Reports, as well as in three issues of our quarterly publication, the NASA Goddard Tech Transfer News. Our frequent coverage of this topic reflects NASA Goddard's ongoing commitment to CubeSats, and how vital we consider this platform to be to the future of space science and exploration.

In this section, we provide an update to the Center's latest accomplishments in this area. This includes the Dellingr mission, a new 6U CubeSat designed and built by NASA Goddard. Dellingr demonstrates the capabilities of the CubeSat platform to meet the requirements of a space science project; its initial application is heliophysics research. The goal of this mission is to prove CubeSats can provide a smaller, more efficient, and a less costly option for accommodating NASA space science mission needs.

We also present a high-level overview of CubeSats, their history, and current development. We provide a few examples of the broad spectrum of CubeSat-related technologies developed at NASA Goddard. These include:

- SpaceCube Mini, a high-performance data processor small enough to be used on CubeSat missions
- Advanced CubeSat Ejector (ACE)
- Diminutive Assembly for Nanosatellite deploYables (DANY) Miniature Release Mechanism
- Thermal Control Louvers

…and others. We also review some of the potential applications for CubeSats, including commercial market opportunities.



Phonesat 1.0 CubeSat. — NASA

CubeSat at NASA Goddard

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. Initially, volume was confined to a 10 cm cube, with a mass not to exceed 1.33 kg (this is now referred to as a "1U" CubeSat). The specification has subsequently been amended to include larger devices.

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.

NASA Goddard is actively helping CubeSat technology evolve into a more robust platform suitable for applications outside the classroom. For example, Tom Johnson (Launch and Flight Operations) and others at 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" (Low Earth Orbit) applications

Dellingr

One recently developed NASA Goddard project (under the direction of Project Manager Chuck Clagett) is the Dellingr CubeSat (GSC 17152-1). The goal of Dellingr is provide relatively quick and cost-effective access to space compared to larger missions, which may take five to six years and millions of dollars to build.

Dellingr measures about 12 inches long, nearly 8 inches wide and 4 inches high, and is constructed from readily available off-the-shelf commercial components. Its ultimate goal is to serve as an innovative, compact platform for performing inexpensive space science missions. Once successfully demonstrated, NASA Goddard plans to make Dellingr's design available to any U.S. organization interested in using it.

SpaceCube Mini

Another NASA Goddard effort is SpaceCube Mini (GSC-16223-1), a miniaturized version of the SpaceCube 2.0 (GSC-16700-1) high-performance data processor small enough to be used on CubeSat missions.

SpaceCube Mini enables a mission to process raw data in real-time and only store processed data or extracted information. This could yield significant savings in on-board storage and downlink bandwidth, and enable 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.

Propulsion

NASA Goddard is also working on innovative ways to launch CubeSats into space, including non-rocketry based propulsion technologies. These include high-altitude balloons. For example, the High Altitude Student Payload (HASP) has launched a number of payloads, including missions over Antarctica. This platform is capable of reaching altitudes up to 15,000 to 130,000 feet, or above 99.9% of the Earth's atmosphere.

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 Flight Facility currently holds a record for the longest cannon-based launch of a particular diameter projectile without any propulsion on the projectile. The Facility is also looking at hosting a railgun that uses electromagnetic force to propel the payload. Although this technology is not considered capable of launching CubeSats into Earth orbit; it could possibly be used on the moon to launch payloads from the moon into deep space.

Other CubeSat Initiatives

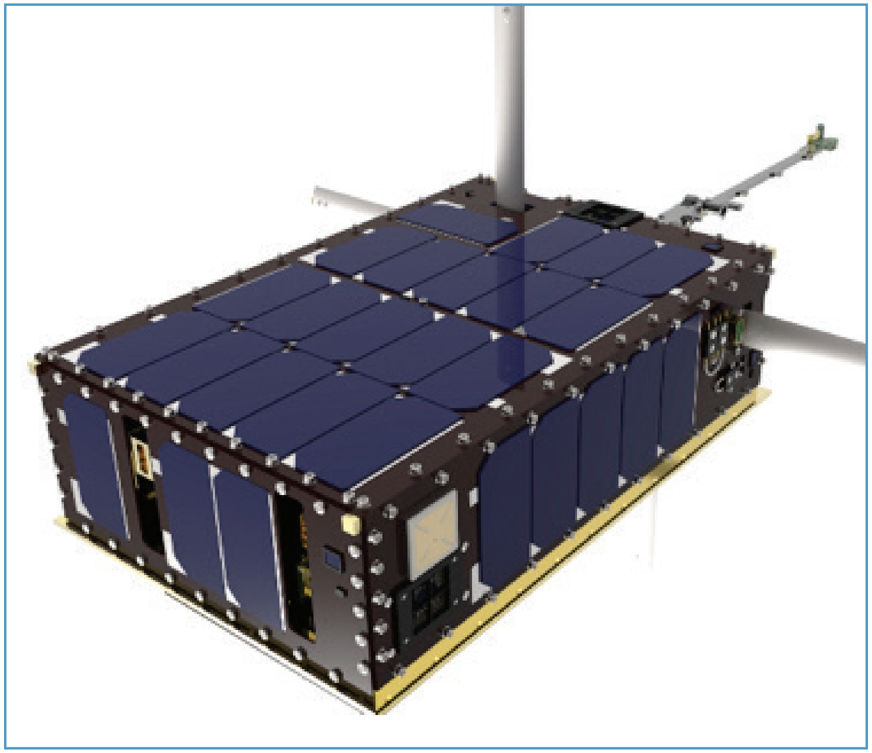
Beyond propulsion, a major limitation in the CubeSat standard's potential as a deep-space and long-duration "beyond LEO" science platform is its current lack of robustness and reliability. NASA Goddard is playing an important role in addressing this limitation. NASA Goddard is seeking to increase the reliability of the CubeSat platform through the development of a scalable, high reliability bus. NASA Goddard is working with universities, other government agencies, and private companies to identify who is (or can be) providing quality components that can be used on this bus.

In addition, NASA Goddard has developed:

- **Diminutive Assembly for Nanosatellite deploYables (DANY)** miniature release mechanism (GSC-16900-1). This provides a secure method to constrain CubeSats without using any internal space. DANY provides a secure interface for the items to be deployed.
- **CubeSat Form Factor Thermal Control Louvers** (GSC-17034-1). These use passive thermal control to significantly improve the internal thermal stability of small spacecraft, creating a difference of several watts in dissipated heat between open and closed louvers.
- **Advanced CubeSat Ejector (ACE)** (GSC-16795-1). This ejector system interfaces to the launch vehicle and functions to protect the primary payload from the nanosatellite, constrain the nanosatellite during launch, and perform a guided ejection afterwards.

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.

These represent a small sampling of NASA Goddard technologies developed to support the ongoing evolution of CubeSats. The Center remains committed to the CubeSat effort, serving as one of the leaders in ensuring CubeSats continue to mature from a standard for student experiments into a robust, fully developed space platform.



The Dellingr cubesat will help validate new hardware, new construction processes and expand Cubesat capabilities at Goddard. — NASA

CubeSat Commercialization Opportunities

As we noted earlier in the Accomplishments Report, CubeSats were originally created as a teaching tool to provide students with hands-on experience with basic satellite concepts. Their commercial potential was not initially a primary concern. Since that time, several trends have helped drive renewed focus towards developing CubeSats for more robust and demanding applications.

For example, CubeSats can be developed at relatively modest cost, a clear benefit to any institution or company with a limited budget. Increasing miniaturization of electronic components now provide the ability to expand CubeSats capabilities while retaining a small overall size. And advances in computing power and functionality offer the promise of multiple CubeSats working in concert, performing the tasks of a large mission at a fraction of the expense. These developments have led to CubeSats being given serious attention from commercial interests.

In this article, we look at some potential product and market opportunities that may be developing around the CubeSat platform.

CubeSat Components as an Industry

One of the first commercial markets associated with CubeSats involves the production of components suitable for CubeSat missions. In recent years the number of CubeSat missions and applications has expanded significantly. This has in turn created small but growing niche market for CubeSat-compliant components. For instance, CubeSat.org web site lists a number of vendors who sell CubeSat parts (see http://www.cubesat.org/index.php/collaborate/suppliers). Although this market has yet to achieve the multi-billion dollar level required to interest large suppliers of electronics, it has evolved to the point where smaller players find it attractive.

One important consumer of CubeSat components is NASA Goddard itself. NASA Goddard innovators continue to push the boundaries of CubeSat capability into deep space and "beyond LEO" Earth orbits. In doing so, they have created a corresponding need for highly reliable CubeSat components. Building a CubeSat project quickly requires reliable electronic components. Suppliers of these electronics can find CubeSats to be a relatively easy entry point for doing business with NASA Goddard. In return, CubeSats provide an excellent way for new technology and capabilities to be infused into NASA Goddard.

CubeSats and Proving Space Readiness

CubeSats provide opportunities for low-cost testing and validation of components and systems within the harsh environments of space. Engineers can design a CubeSat mission for demonstrating proof-of-concept for all kinds of systems and instruments, and then observe how the technology performs. In this way, a CubeSat can serve as a "laboratory in space," helping to validate a technology. A number of CubeSat projects have been designed for this purpose, testing technology both for NASA and the private sector.

By providing quick access to the space environment, NASA Goddard can help the CubeSat platform become more reliable. In its early days as a largely academic tool, CubeSats often proved unreliable, with up to half the missions failing. Improving on this record requires more reliable components; however the development of these new technologies can be a challenge for universities. In addition to providing a space platform for testing these new components, NASA Goddard also has the resources and expertise to help develop these new technologies in-house. Areas in which the Center can provide special value include electronics miniaturization and environmental testing. NASA Goddard has a large and diverse technology development resources devoted to these areas.

Potential CubeSat Commercial Applications

As new components and technologies continue to make CubeSats more robust, these small satellites can eventually be adapted to numerous commercial applications. These could include satellite servicing, vehicle examination, space station inspection, and removal of space debris. The last is a particularly interesting possibility – a CubeSat device could be designed to track and attach itself to an unwanted satellite that has fulfilled its useful life, and propel the satellite back into the atmosphere to be destroyed.

Other possible commercial applications for CubeSat missions include remote sensing and surveillance, such as launching CubeSats from an aircraft to observe a region of interest. CubeSats may also be useful for applications include defense, search and rescue, and disaster management.

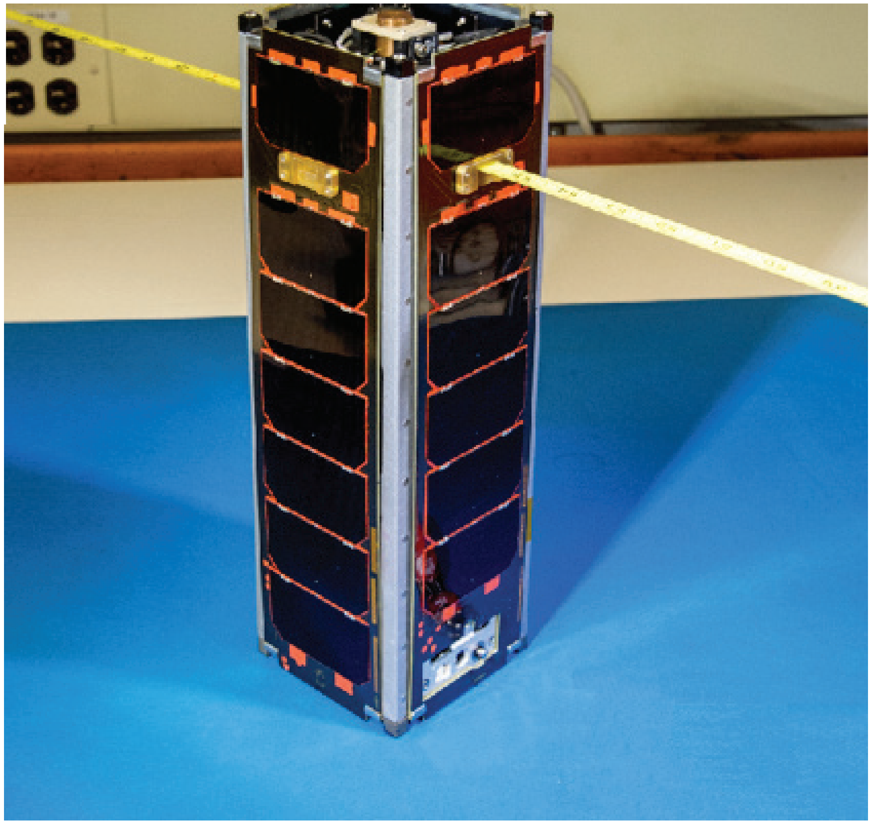
NASA Goddard's ongoing CubeSats work also opens up potential future applications far beyond the platform's current capabilities. For example, CubeSats could be developed to fly constellations of satellites. They could be part of a hybrid mission involving a large "mothership" satellite and a number of smaller CubeSats. The smaller satellites can be controlled by the main satellite to perform tasks that may be difficult or risky.

One potentially important NASA Goddard technology in development is SpaceCube Mini, a miniaturized version of the SpaceCube 2.0 high-performance data processor small enough to be used on CubeSat projects. SpaceCube Mini is designed to increase the data processing power of a CubeSat mission by one or two orders of magnitude. This technology may also offer value in terrestrial applications. SpaceCube Mini could be useful for other high-data systems, providing both data reduction and onboard awareness. SpaceCube Mini allows for autonomous operations, which could be valuable in applications where instruments collaborate with each other, such as a sensor web.

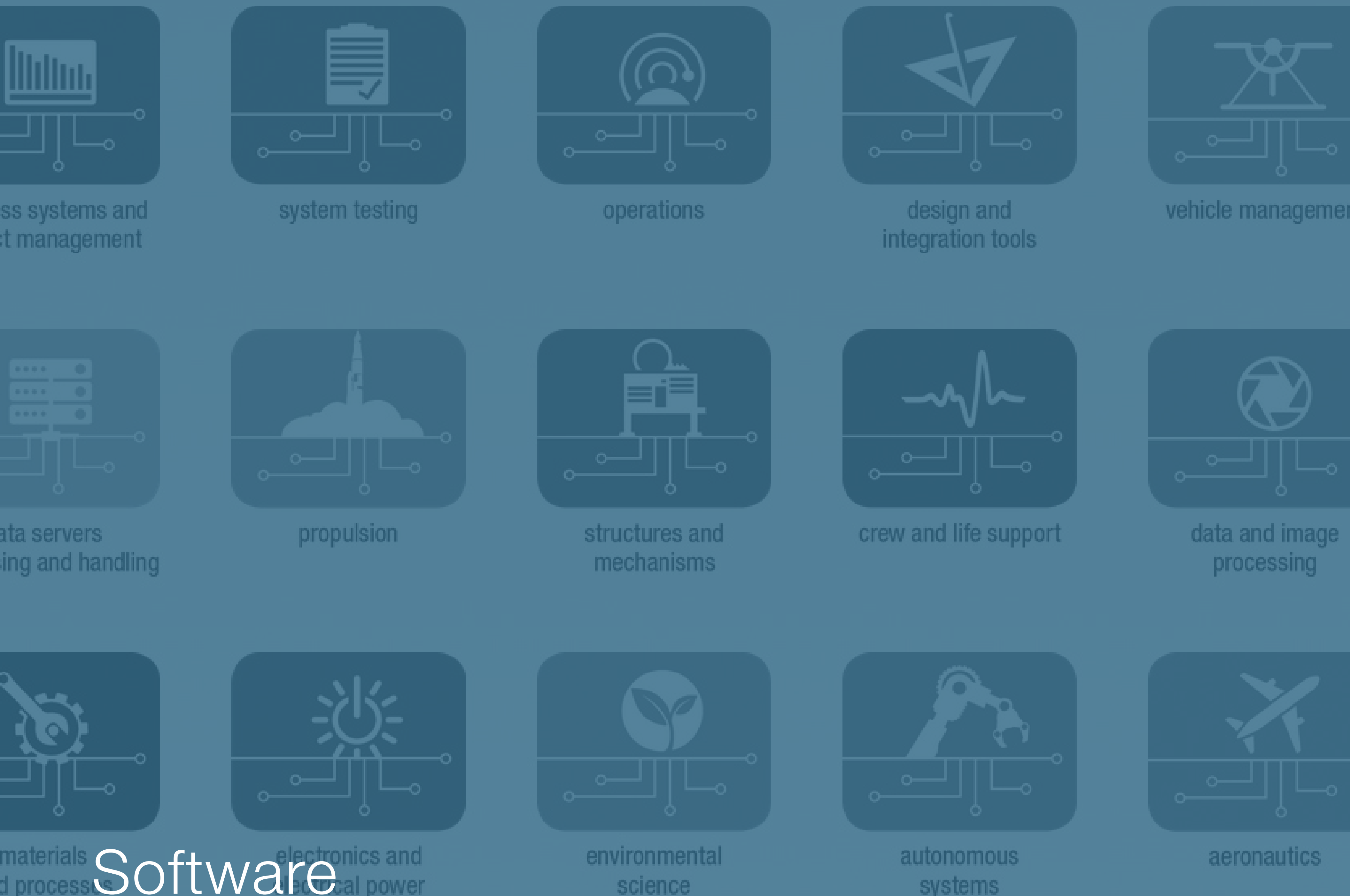
Other technologies in development address the "3 Ps" – propulsion, positioning, and power – whose availability would significantly strengthen CubeSats as a robust, versatile platform. For example, Wallops Flight Facility has the capability to launch sounding rockets from many different locations. It may be possible to marry this capability to CubeSat launches. Although sounding rockets are currently limited to sub-orbital flight, they may eventually evolve to the point where they can launch CubeSats into orbit. This would remove the need for CubeSats to "hitch hike" on launches primarily dedicated to larger missions.

Conclusion

As we've seen, NASA Goddard is playing a critical and growing role in helping extend CubeSats 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 CubeSats from a teaching tool to a robust platform for contributing to the advancement of Earth and space science.



Developed at NASA Goddard, the Firefly small satellite mission is to study the relationship between lightning and huge bursts of gamma rays called terrestrial gamma ray flashes. — NASA


system testing
operations
design and integration tools
propulsion
structures and mechanisms
crew and life support
data and image processing
electronics and electrical power
environmental science
autonomous systems
aeronautics

Software

Introduction

From the very beginning software development has been critical to NASA Goddard's success. From project management, design and integration, materials and processes, structures and mechanisms, propulsion, data and image processing, aeronautics, system testing, and many other critical applications; software plays a vital role – indeed, it may be a challenge to find a NASA Goddard mission or capability that does not involve software in some way.

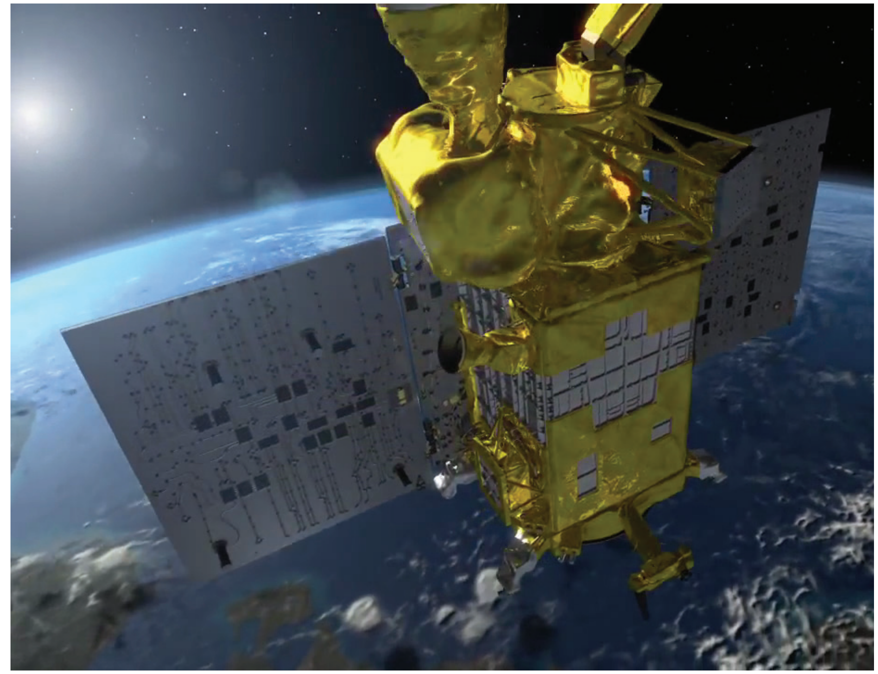
Some of this code was developed for a highly specific purpose. However, much of it can be adapted and applied to other applications. To ensure this valuable code is captured, NASA has implemented the Software Release process (NPR 2210.1C). This is a formal method for recording all code within NASA Goddard and ensuring it is made available for reuse as appropriate.

NASA codes are available via the Software Release process. Most released codes are available to the public via the NASA Software Catalog. Developers can browse the Catalog and search for software of interest. Most software is available via Open Source and can be immediately downloaded and put to use. Other software may require the developer to provide additional information before gaining access.

In this section, we review the Software Release process and the Software Catalog. We explain the function and purpose of Software Release. We also present a quick overview of the Software Catalog and its features. We then look at several examples of NASA Goddard-developed software, including:

- "42," a tool for simulating every feature of the space environment, including orbit, gravity gradient torque, and others.
- GEONS, a solution for onboard orbit determination.
- Hilbert-Huang Transform 2.0 (HHT2), an update to the Hilbert-Huang Transform data analysis algorithm.

We also examine a few potential non-NASA applications for which this software could be of significant benefit.



SMAP in Earth Orbit — NASA

The NASA Software Release Process and Software Catalog

The NASA Software Release Process and Software Catalog

Virtually every area of NASA Goddard expertise is supported by software. Innovators have developed (and continue to develop) software to enable a broad spectrum of capabilities, including navigation, propulsion, monitoring, sensor control, remote sensing, image analytics, and many others. This diverse body of code represents one of the most comprehensive and versatile resources within NASA Goddard.

This article introduces the Software Release process. We explain the purpose of the process and how it works. We conclude with an overview of the Software Catalog, and how you can use it to access NASA software you can apply to your own applications and requirements

Software Release: Capturing NASA software

The main venue through which the public can learn about software developed at NASA Goddard (and all other Centers) is the NASA Software Catalog. To become part of the Catalog, all NASA software must go through a formal Software Release process defined in NPR 2210.1C. According to the NPR, its purpose is to establish

"…procedures and responsibilities for the reporting, review, assessment, and release of software created by or for NASA. These procedures ensure that NASA software is reported and released according to law and NASA policies, with appropriate restrictions on the use and redistribution of the software."

The NPR goes on to state that the requirement applies both to new software that has not yet been reported, as well as previously reported software to which (1) new functionality and enhancements have been made, and/or (2) additional innovators have become involved in the development process. Each report records information about the software, including:

- The names of all individuals involved in the conceptualizing, design, and coding
- Whether the software is a new innovation, or an update to existing code
- Whether any part of the software is proprietary, owned by a non-Federal entity, or Open Source

According to NASA Goddard Software Release Authority Alternate Enidia Santiago-Arce, if software was originally developed for limited release (a specific mission, NASA internal use, and so on) access is very limited; the

NASA Software Catalog home page

process for releasing this type of code is streamlined and requires very little paperwork. On the other end of the spectrum is software to be released as Open Source and is therefore available to everybody; this process requires a great deal of paperwork.

Ms. Santiago-Arce is a member of the Software Release Authority Working Group, which meets monthly to help ensure the process remains current and flexible enough to accommodate the ever-evolving nature of software development.

Software Catalog: Making code available to the public

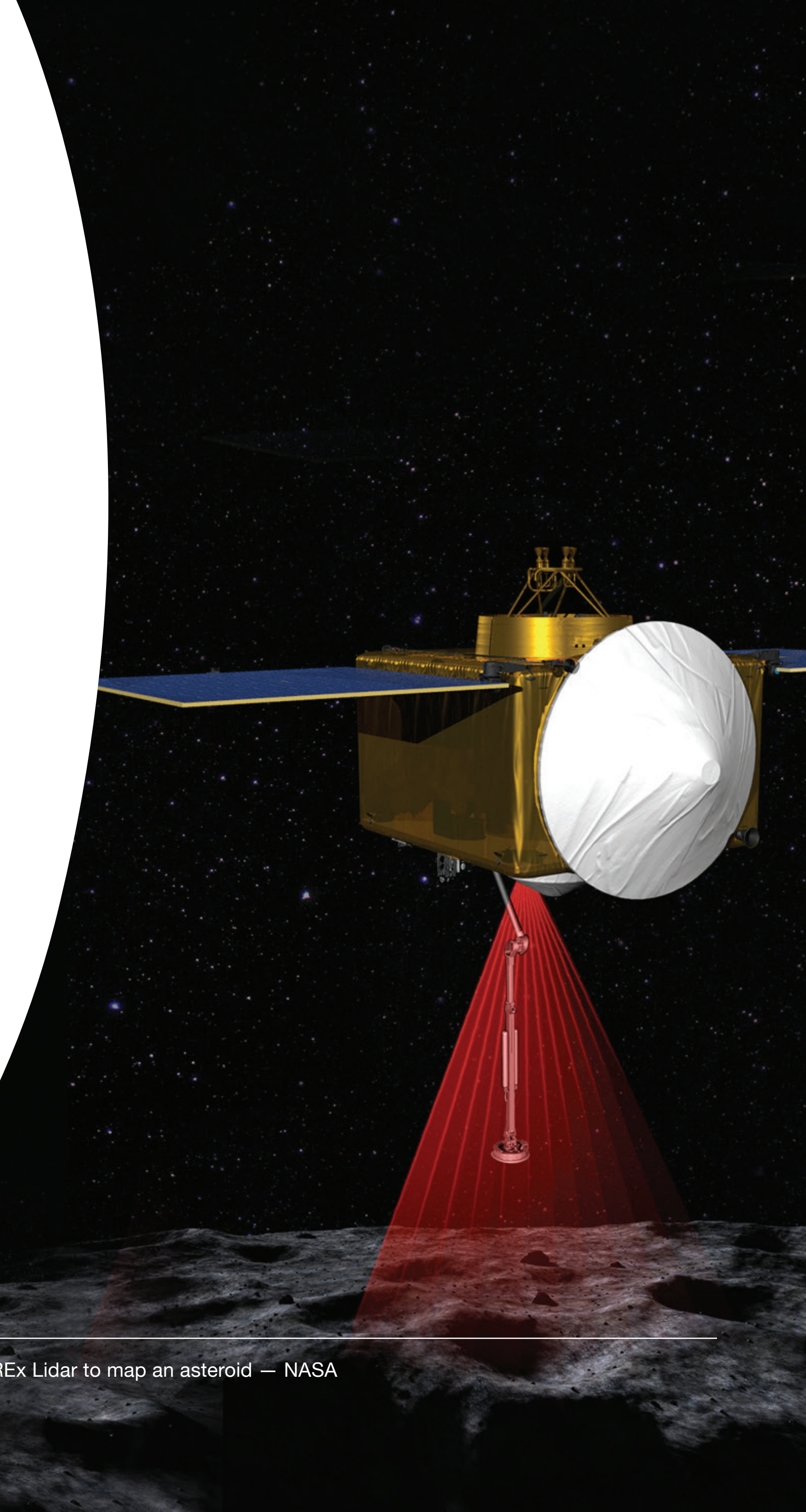
The ultimate "product" resulting from the Software Release process is the NASA Software Catalog (see https://software.nasa.gov/ to view online, you can also download the entire Catalog in PDF format from this site). The Software Catalog, which is continuously updated to include all the latest code that has gone through the Software Release process, provides the following information for each entry:

- Title
- Product ID number (known internally as the NASA case number)
- Short description. In some cases, this incudes links to additional information or downloading options.
- Release type (General Public, U.S. Government Purpose, Open Source, and so on)

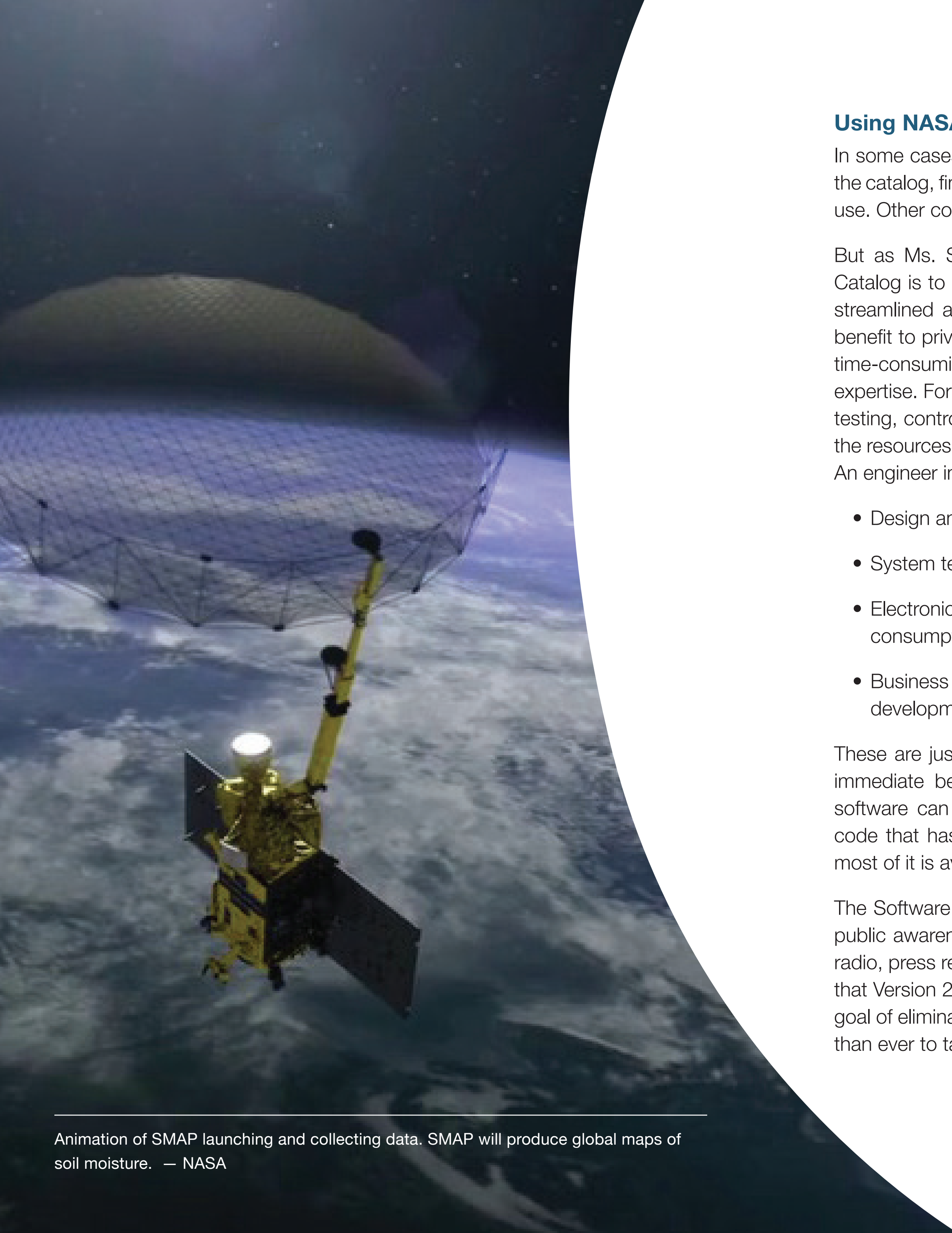
An important usability feature of the Software Catalog is the "one button" ability to search for programs that apply to a specific application. This enables potential users to quickly identify and browse all NASA code associated with their particular business or area of interest.

For example, clicking on the "data and image processing" button displays a list of the approximately 100 available programs in the Catalog related to this application:

This list can also be downloaded for future reference and sharing.



OSIRIS-REx Lidar to map an asteroid — NASA



Animation of SMAP launching and collecting data. SMAP will produce global maps of soil moisture. — NASA

Using NASA code

In some cases, code can be accessed instantly – users can simply browse the catalog, find the code of interest, and download it for their own immediate use. Other code may require a more formal technology transfer process.

But as Ms. Santiago-Arce points out, the ultimate goal of the Software Catalog is to make the transfer of NASA software into the public sector as streamlined and painless as possible. This in turn can provide significant benefit to private industry. Software development is often an expensive and time-consuming process, especially when it falls outside a company's core expertise. For instance, hardware engineers often need support software for testing, controlling, and communicating with their technology; but may lack the resources necessary to develop this code concurrent with the hardware. An engineer in this situation could instead browse the Software Catalog for:

- Design and integration tools for helping develop hardware
- System testing tools for testing prototypes
- Electronics and electrical tools for managing the hardware's power consumption
- Business systems and project management tools for ensuring the development project runs smoothly

These are just a few of the available software categories that could be of immediate benefit to a technology developer. In many instances NASA software can be adapted to such applications, providing the public with code that has already been developed, tested, and proven reliable – and most of it is available free of charge!

The Software Release Authority Working Group is actively working to raise public awareness of the Software Catalog through media such as articles, radio, press releases, and brochures. In addition, Ms. Santiago-Arce reports that Version 2.0 of the Software Catalog is already in development, with the goal of eliminating all paperwork from the process – thereby making it easier than ever to take advantage of this highly versatile and valuable resource.

Examples of NASA Goddard Software: GEONS, HHT2, &"42"

A single peek at the NASA Software Catalog (see the preceding article) reveals a long and varied list of available code. Any one of these can potentially be put to non-NASA use, and adapted to applications far removed from the space science for which it was initially developed.

In this article we briefly review examples of NASA Goddard software. Although these three programs perform very different functions, they all exemplify the versatility of NASA Goddard software, and the important value they can provide to programmers developing their own applications.

"42" Simulation Tool (GSC-14817-1)

This code (whose name derives from the Hitchhiker's Guide to the Galaxy series of books by Douglas Adams) is designed to simulate every feature of the space environment, including orbit, gravity gradient torque, and so on. To do this, 42 takes an "outside in" approach. The software started by simulating the external framework, such as planets and orbits. And once it had established this framework, it simulated the spacecraft within it – attitude, orbital dynamics, interaction with the environment.

Typically, simulations tend to be designed for a specific spacecraft. Building a framework from the outside in from the start makes it much easier to adapt 42 to different missions, because the simulation of the space environment is the same regardless of the spacecraft.

42 has helped design a number of missions, including Fermi, MMS, OSIRIS-REx, Constellation, and others. 42 has been used as the central simulation tool, and also for spot simulations.

For example, design engineers for the OSIRIS-REx mission were concerned about fuel sloshing; a potentially significant problem since it can disturb the motion of the spacecraft. NASA Goddard innovators created "glueware" that allows 42 to integrate with a commercial software product that calculates the forces generated by the sloshing fuel; 42 takes this information and simulates the effects these forces will have on the spacecraft's motion.

Another way 42 has evolved is in the types of simulations it can perform. For example, a Mars lander needs to simulate the conditions associated with landing a spacecraft on the surface of a planet. To accommodate this, 42 was enhanced to simulate contact with an object's surface. It can now simulate landing, standing, and moving around – basically simulating a robot's environment.

42 is available to the public as Open Source software and can be downloaded by anyone interested in simulate a generic space environment. In addition to the source code, the 42 package includes documentation, overview slides, and several spacecraft models. It also includes a simple sample demonstration, and a template for creating simulations. This can be very useful to the commercial satellite industry. In addition to the typical attitude control system design effort, 42 can also support proximity operations, for example cargo missions which requires one satellite to maneuver in close quarters with another. And 42 can be especially valuable to CubeSat developers, who may not otherwise have sophisticated simulation resources available.

GPS-Enhanced Onboard Navigation System (GEONS) aka Goddard Enhanced (GSC-14687-1)

Earlier we discussed the Magnetospheric Multiscale (MMS) mission, in which four identical satellites fly in a very precise formation. This type of positional accuracy requires the precision provided by the Global Positioning System (GPS). Other satellite applications such as autonomous navigation, course planning, and close-proximity maneuvering also share this requirement. Unfortunately, extending GPS capability into space has historically been a challenge.

The GPS-Enhanced Onboard Navigation System (GEONS) has been developed at NASA Goddard to meet this challenge. The goal of GEONS is to provide navigation capabilities to satellites with limited GPS visibility, such as high-Earth and geosynchronous missions.

The original innovation that led to GEONS was technology funded by a Small Business Innovation Research grant and developed at NASA Goddard in the late 1980s. This technology evolved over the next decade; by 2000 GEONS enabled the first public demonstration of satellite formation flight between EO-1 and Landsat-7. Further developments and enhancements include adding technology developed to support the TERRA mission, as well as an optical sensor. These enhancements are now being applied to MMS and other potential missions that involve formation flying.

To provide accurate absolute and relative navigation solutions in real time, GEONS processes data from several sources, including standard GPS receivers, attitude sensors, and onboard communication systems. This allows GEONS to provide high-quality solutions in environments with fewer than four available GPS satellites. Among GEONS advantages over previous navigational systems are accuracy, reliability, reduced costs, and reduced computing requirements.

Due to the efforts of the ITPO, GEONS is currently widely used both within and outside NASA. GEONS is freely available (source code included) to all US Government programs, including contractors. It is also available for commercial applications via licensing.

Potential applications include satellite servicing, where precision positional awareness and autonomous navigation can be critical requirements. A similar application may be removing non-functional spacecraft and other space debris from orbit. GEONS can also be valuable in science research and defense applications.

Hilbert-Huang Transform 2 (HHT2) (GSC-17219-1)

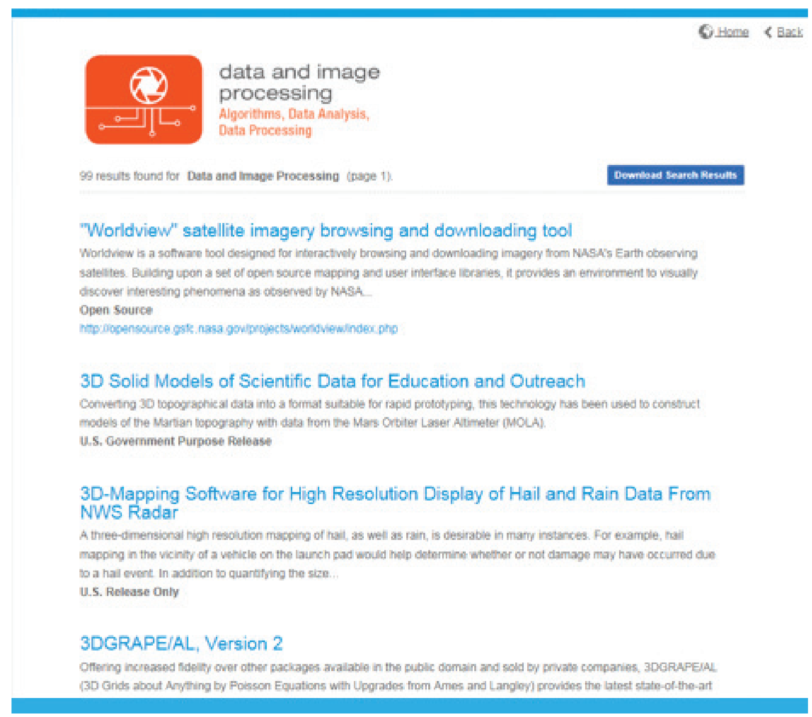
Another software technology developed at NASA Goddard is the Hilbert-Huang Transform (HHT). This is highly efficient, adaptive, and user-friendly set of algorithms used to analyze, encode, or modulate signals or data sets for a multitude of applications. HHT was originally developed as part of NASA's ongoing research into ocean waves.

To enhance the capability of HHT, Semion Kizhner and other NASA Goddard innovators have recently developed the HHT2. Although the original HHT algorithm is very versatile, it is limited to "one dimensional" data. The HHT2 algorithm is designed to work with data in two dimensions, enabling the fast processing of images, thus significantly broadening the range of applications to which this software can be applied.

HHT2 has been used to process signals contaminated by RFI the SMAP radiometer (described in an earlier article). It has also been used for fringe patterns decomposition analysis and image synthesis.

Conclusion

These are just three examples of "success stories" involving NASA Goddard software. The NASA Software Catalog lists hundreds of additional programs, each available to the public (at no cost) for download and use. Collectively, these comprise an important resource for researchers and private enterprise – and represent a tangible example of how public money spent on space exploration can also provide major benefits here on Earth.



Data and image processing results page

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 2015 fiscal year, generating seventeen patents, ten partnerhsips, forty SBIR/STTR Phase I awards and 209 New Technology Reports (NTRs).

31st Annual Space Symposium

(April 13 – 16, 2015, Colorado Springs, CO)

The NASA Goddard Innovative Technology Partnerships Office (ITPO) hosted a booth at the 31st Annual Space Symposium held in Colorado Springs, Colorado. This annual meeting brings together space leaders from around the world to discuss, address and plan for the future of space. With over 11,000 attendees, the Space Symposium has become widely known as the premier U.S. space policy and program forum and as the “must attend” opportunity for information on and interaction among all sectors of space. NASA Goddard ITPO staff were on hand to talk with visitors about Goddard’s partnership, licensing, and technology transfer opportunities.

Outreach

High School category winners of the 2014-2015 NASA OPTIMUS PRIME Spinoff Challenge share a moment with actor Peter Cullen in-between takes while filming their PSA video at NASA's Goddard Space Flight Center.

NASA Goddard OPTIMUS PRIME Spinoff and InWorld Challenge

2014-2015

Tying in with the theme of this year's Accomplishments Report, Partnering for Tomorrow, the ITPO is encouraging students to do just that in thinking of a way NASA technology can make the world a better place through spinoffs. Students from across the country did this as part of the 2014-2015 OPTIMUS PRIME Spinoff and InWorld Challenge by submitting videos and demonstrating their understanding of NASA spinoff technology in addition to identifying a unique spinoff opportunity that was not already available. High school students continued on with the challenge by entering in the InWorld Phase of the competition. In this phase, teams created models of the original spinoff and their newly designed spinoff technology in InWorld, a 3D multi-user virtual world setting. College and graduate engineering students mentored the teams during the design process.

Contest winners came to Goddard Space Flight Center for a 3 day workshop and awards ceremony where they had a behind-the-scenes look at Goddard; met actor Peter Cullen, voice of Hasbro's TRANSFORMERS character, OPTIMUS PRIME; and designed and created their own public service video announcement.

Looking at tomorrow, the contest will be changing in 2016 in a way that will allow students to creatively explore NASA spinoff technology and come up with ways to help humankind for not only today, but tomorrow through a new platform. The ITPO will "roll out" a new look, format and name-calling the contest, NASA's OPTIMUS PRIME Spinoff Promotion and Research Challenge (OPSPARC).

For more information on OPSPARC, go to:
itpo.gsfc.nasa.gov/opsparc/index.php

ITPO staff members Dennis Small and Dale Clarke speak with an attendee at the annual Code 600 SED New Year's Poster Party.

8th Annual Sciences & Exploration Directorate New Year's Poster Party

January 28, 2015, Greenbelt, MD

NASA Goddard's Innovative Technology Partnerships Office (ITPO) participated in the 8th Annual Sciences & Exploration Directorate (SED) New Year's Poster Party, held in NASA Goddard's Building 28 atrium. This annual event brings together Goddard's Earth and space scientists, along with invited presenters from the Applied Engineering and Technology Directorate (AETD), to display their posters from 2014 meetings. ITPO staff members spoke with attendees about partnerships, licensing, New Technology Reporting (NTR) benefits and SBIR/STTR successes.

ITPO Senior Technology Manager Darryl Mitchell speaks with an attendee at the 2015 ARPA-E Energy Innovation Summit.

ARPA-E Energy Innovation Summit

February 9-11, 2015, National Harbor, MD

NASA participated in the 2015 ARPA-E Energy Innovation Summit at the Gaylord National Hotel and Convention Center in National Harbor, MD on February 9 - 11, 2015. Goddard's Innovative Technology Partnerships Office was on hand along with representatives from NASA Glenn Research Center, Johnson Space Flight Center, Kennedy Space Center and NASA Ames Research Center. The ARPA-E Energy Innovation Summit is an event dedicated to transformative energy solutions, bringing together thought leaders from academia, business, and government to discuss cutting-edge energy issues and facilitate relationships to help move technologies into the marketplace. There were approximately 3,000 summit attendees who provided a steady stream of showcase attendees. NASA received several inquiries in specific areas such as electronics, AeroPod technology, solar energy, and batteries, to name a few.

Association of University Technology Managers (AUTM) Annual Meeting

February 22-25, 2015, New Orleans, LA

NASA Goddard's Innovative Technology Partnerships Office (ITPO) attended the annual meeting of the Association of University Technology Managers (AUTM) in New Orleans, LA. This year's meeting saw more than 1,900 technology transfer professionals from around the world and featured networking, professional development, and sessions with national and international experts on trends in technology transfer. AUTM's members represent intellectual property managers from more than 300 universities, research institutions, teaching hospitals, businesses, and government agencies.

Keynote speaker, Dr. Zaven Arzoumanian, discusses how his company uses star mapping technology.

22nd Annual New Technology Reporting Program Event

November 10, 2015, Goddard Space Flight Center

On Tuesday, November 10, 2015, Goddard's Innovative Technology Partnerships Office hosted its 22nd Annual New Technology Reporting Program, an event to celebrate Goddard's technologists who have submitted new technology reports within the fiscal year. Dr. Zaven Arzoumanian, Goddard's own technologist and President of Wild Me was the keynote speaker at the event. He discussed how his company uses technology from the Hubble space telescope to track endangered whale sharks and other animal species through the mapping of distinctive marks on the animals. Sixty-five guests attended the event.

2015 Patents Issued

An Apparatus for Ultrasensitive Long-Wave Imaging Cameras
U.S. Patent 8,912,494
Ari Brown, Dominic Benford, James Chervenak, Edward Wollack

Solderless Circularly Polarized Microwave Antenna Element
U.S. Patent 8,912,974
Cornelis Du Toit, David Green

Apparatus, Method, and Computer Program for a Resolution-Enhanced Pseudo-Noise Code Technique
U.S. Patent 9,081,096
Steven Li

Discrete Fourier Transform in a Complex Vector Space
U.S. Patent 9,075,749
Bruce Dean

Method of Making Lightweight, Single Crystal Mirror
U.S. Patent 9,075,188
Vincent Bly

System and Method for Nanostructure Apodization Mask for Transmitter Signal Suppression in a Duplex Telescope
U.S. Patent 8,963,068
James Butler, Stephanie Getty, John Hagopian, Jeffrey Livas, Ron Shiri, June Tveekrem

Apparatus and Method to Enable Precision and Fast Laser Frequency Tuning
U.S. Patent 9,065,242
Jeffrey Chen, Kenji Numata, Stewart Wu, Guangning Yang

Reducing Sensor and Readout Circuitry Noise in Digital Domain Using Reference Pixels
U.S. Patent 8,913,844
Dominic Benford, Thomas Flatley, Katherine Heinzen, Semion Kizhner, Max Pinchinat

System, Apparatus and Method for Emittance Control and Suppressing Stray Light
U.S. Patent 8,976,362
Stephanie Getty, John Hagopian, Manuel Quijada

Miniaturized High-Speed Modulated X-Ray Source
U.S. Patent 9,117,622
Zaven Arzoumanian, Keith Gendreau, Steve Kenyon, Nick Spartana

System, Apparatus and Method Employing a Dual Head Laser
U.S. Patent 8,958,452
Barry Coyle, Demetrios Poulios, Paul Stysley

Impedance Matched to Vacuum, Invisible-Edge Diffraction Suppressed Mirror
U.S. Patent 9,012,008
John Hagopian, Patrick Roman, Ron Shiri, Edward Wollack

Hilbert-Huang Transform Data Processing Real-Time System with 2-D Capabilities
U.S. Patent 9,013,490
Semion Kizhner

Autonomic and Apoptotic, Aeronautical, and Aerospace Systems, and Controlling Scientific Data Generated Therefrom
U.S. Patent 8,983,883
Michael Hinchey, Roy Sterritt

Autonomic and Apoptotic Systems in Computing, Robotics, and Security
U.S. Patent 8,983,882
Michael Hinchey, Roy Sterritt

Integrated Genomic and Proteomic Information Security Protocol
U.S. Patent 8,898,479
Brian Gosselin, Harry Shaw

High Precision Metal Thin Film Liftoff Technique
U.S. Patent 9,076,658
Ari Brown, Amil Patel

Partnerships

Rolls-Royce corporation
Type: Space Act Agreement Amendment
Partnership Title: Development of Joint Performance Prediction Method for Brazed Structures

National Nuclear Security Administration
Type: Interagency Agreement
Partnership Title: Asteroids and Planetary Defense

National Nuclear Security Administration
Type: Interagency Agreement
Partnership Title: Single-Event Effect Tests of IBM Circuits at the NASA GSFC Radiation Effects Facility

Materion Corporation
Type: Space Act Agreement
Partnership Title: Development of Iron based metal matrix composite

The Boeing Company
Type: Space Act Agreement Amendment
Partnership Title: Conjunction Assesment Risk Analysis (CARA) Support

YYESIT, LLC
Type: CRADA
Partnership Title: Joint Technology Development for Monitoring and Tracking Quality and Safety

Department of Defense - SpaceTest Program
Type: Interagency Amendment
Partnership Title: Integration of SpaceCube 2 experiment into Space Test Program- Houston 4 (STP-H4) payload

Millennium Space Systems, Inc.
Type: Space Act Agreement
Partnership Title: Goddard Mission Services Evolution Center (GMSEC) Software and Engineering Support

United States Air Force Space Command Space and Missile Systems Center
Type: Umbrella Agreement/Annexes
Partnership Title: Goddard Mission Services Evolution Center (GMSEC) Software and Engineering Support

United States Air Force Space Command Space and Missile Systems Center
Type: Interagency Umbrella Agreement/Annexes
Partnership Title: GMSEC Update Project

Technology Transfer

The ITPO Technology Transfer program promotes the transfer of GSFC-developed technology to the private sector, including managing GSFC's invention portfolio. 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. New Technology Reports (NTRs) are a key element in that process – they disclose that a new technology is available.

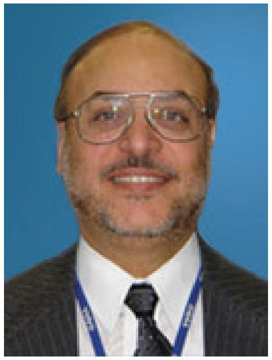
Tech Manager Distribution by Code for NTR Cases

Ted Mecum
Senior Technology Manager

GSFC CODES
300-ALL
550
553
580
590-ALL
800-ALL

Darryl Mitchell
Senior Technology Manager

GSFC CODES
100-ALL
400-ALL
408
552
670-ALL
690-ALL



Hossin Abdeldayem
Technology Manager

GSFC CODES
551
554
555
560-ALL
660-ALL

Dennis Small
Technology Manager

GSFC CODES
200-ALL
540-ALL
581-589
610-619
700-ALL

Enidia Santiago-Arce
Technology Manager

GSFC CODES
180-ALL
580
587
600
601-606
610-619

SBIR/STTR

SBIR/STTR Introduction

The ITPO is also responsible for Goddard's Small Business Innovation Research (SBIR) and Small Business Technology Transfer (STTR) 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. The ITPO manages a very competitive SBIR/STTR award system which provides qualified small hi-tech businesses and not for profit organizations with opportunities to propose innovative ideas that meet NASA Goddard's specific research and development needs.

Similar to other agencies, NASA's SBIR/STTR programs generally have three phases: Phase I (6-month study on scientific, technical, and commercial feasibility), Phase II (24-month development, demonstration, and delivery of the innovation), and Phase III (reaching successful commercialization – no SBIR/STTR funds). 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. Additionally, NASA provides Post Phase II initiatives, such as Phase II-Enhancement (II-E), Phase II-Expanded (II-X), and Commercialization Readiness Program (CRP), to assist small businesses in pursuing commercialization and partnership opportunities past their Phase II.

Detailed guidelines are available at:
http://sbir.nasa.gov/content/post-phase-ii-initiatives

Success Story

Michigan Aerospace Corporation (MAC)'s Tunable Fabry-Perot interferometer (or etalon) is an enhancement of a prior design with all-new digital etalon controller that is more capable than its analog predecessors. It allows discrete, repeatable adjustment of the plate-gap distance as required by the mission and has been flight qualified multiple times for airborne use and launch conditions. The CATS etalon will be used to reject most of the molecular backscatter signal at 532 nm so that the LIDAR system can measure the aerosol extinction unambiguously at that wavelength. The overall system will provide range-resolved profile measurements of atmospheric aerosol and cloud distributions and properties at three wavelengths.

The system was launched to the International Space Station (ISS) in January 2015 and was mounted externally on the Japanese Experiment Module in February. MAC is already selling similar etalons to the scientific and engineering community, both as stand-alone items and as part of MAC's Doppler wind LIDAR systems. Other etalons form key sensing elements in MAC's line of direct-detection ultraviolet Doppler atmospheric LIDAR systems, Optical Air Data Systems (OADS), and various derived technologies.

Aprille Ericsson

SBIR/STTR Program Manager

Ramsey Smith

SBIR/STTR Deputy Program Manager

SBIR/STTR Activities

2015 SBIR Phase I

Advanced Space, LLC
Boulder, CO
Improved Navigation for Highly Dynamic Environments

AOSense, Inc.
Sunnyvale, CA
Stabilized Portable External Cavity Laser (SPECL)

Applied Material Systems Engineering, Inc. (AMSENG)
Schaumburg, IL
Innovations for the Affordable Conductive Thermal Control Material Systems for Space Applications

Biospherical Instruments, Inc.
San Diego, CA
14-Decades Calibration in Airborne Detectors for Environmental Science (14DeCADES)

Composite Technology Development, Inc.
Lafayette, CO
Electric Potential and Field Instrument for CubeSat (EPIC)

CoolCAD Electronics, LLC
Takoma Park, MD
Large Area Silicon Carbide Photodiode Active Pixel Sensor

Creare, LLC
Hanover, NH
A High Efficiency 30 K Cryocooler with Low Temperature Heat Sink

ElectroChem, Inc.
Woburn, MA
Advanced Onboard Energy Storage Solution for Balloons

EM Photonics, Inc.
Newark, DE
A Scheduling-Based Framework for Efficient Massively Parallel Execution

Emergent Space Technologies, Inc.
Greenbelt, MD
World-Class Visualizations in GMAT

Energy Research Company
Plainfield, NJ
Compact High Performance Spectrometers Using Computational Imaging

Fibertek, Inc.
Herndon, VA
3D Imaging Cubesat Lidar for Asteroid and Planetary Sciences

Freedom Photonics, LLC
Santa Barbara, CA
Compact Ultrasensitive Erbium-doped Waveguide Optical Gyros

Honeybee Robotics, Ltd.
Brooklyn, NY
Miniaturized System-in-Package Motor Controller for Spacecraft and Orbital Instruments

Incom, Inc.
Charlton, MA
Curved Microchannel Plates for Spaceflight Mass Spectrometers

Innoflight, Inc.
San Diego, CA
Software Redundancy Framework for COTS SoC FPGAs

Intelligent Automation, Inc.
Rockville, MD
Scalable Architectures for Distributed Beam-Forming Synthetic Aperture Radar (DBSAR)

Intelligent Fiber Optic Systems Corporation
Santa Clara, CA
Innovative Fiber-Optic Gyroscopes (FOGs) for High Accuracy Space Applications

LoadPath
Albuquerque, NM
High heat flux Enhanced Acquisition and Transport system for Small spacecraft

Mesa Photonics, LLC
Santa Fe, NM
Cloud Droplet Characterization System for Unmanned Aircraft

Nuvotronics, LLC
Radford, VA
Robust Microfabricated Interconnect Technologies: DC to THz

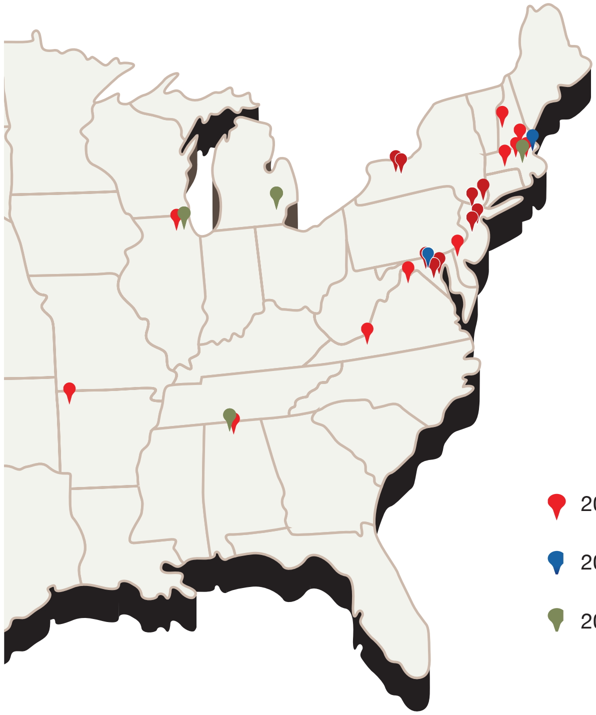
Optimax Systems, Inc.
Ontario, NY
Freeform Optics: A Non-Contact "Test Plate" for Manufacturing

Optimax Systems, Inc.
Ontario, NY
Manufacture of Monolithic Telescope with a Freeform Surface

Ozark Integrated Circuits, Inc.
Fayetteville, AR
Highly Scalable SiC UV Imager for Earth & Planetary Science

Princeton Lightwave, Inc.
Cranbury, NJ
High-Power Tunable SeedLaser for Methane LIDAR Transmitter

QmagiQ
Nashua, NH
Antimony-Based Focal Plane Arrays for Shortwave-Infrared to Visible Applications



SBIR/STTR Program at a Glance

NASA'S SBIR/STTR PROGRAM INFUSED **$3.87 MILLION** INTO THE U.S. SMALL BUSINESS ECONOMY **FOR THE 2015 PHASE I CYCLE**

2015 Phase II

The 2015 Phase II selection announcement is available at http://sbir.nasa.gov

2 Awards — Post Phase II

Phase II-E encourages the advancement of innovations and Phase II-X helps establish partnerships with other NASA projects developing new technologies of innovations for future use.

3 Awards — Phase III

Phase III is the commercialization of innovative technologies, products, and services resulting from either a Phase I or Phase II. This includes further development of technologies for transition into NASA programs, other Government agencies, or the private sector.

1 Award — CRP

The Commercialization Readiness Program (CRP) helps enable technology maturation for infusion and commercialization.

Silicon Space Technology Corporation

Austin, TX

Radiation Hardened ARM Micro Controller Module

SPIRITUS, INC

Huntsville, AL

SparkRS - Spark for Remote Sensing

STARA Technologies, Inc.

Gilbert, AZ

Precision Guided Parafoil System For Sounding Rocket Recovery

Superconducting Systems, Inc.

Billerica, MA

Shielded 3T HTS ADR Magnet Operating at 30-40 K

Systems & Processes Engineering Corp

Austin, TX

Miniature HD6D Navigation and Rendezvous LIDAR & Software

Twinleaf, LLC

Princeton, NJ

Space-Qualified Compact Optical Magnetometer

2015 SBIR Select Phase I

Intelligent Automation, Inc.

Rockville, MD

GNSS Reflectometer Instrument for Bi-static Synthetic Aperture Radar (GRIBSAR) Measurements of Earth Science Parameters

Optra, Inc.

Topsfield, MA

New Lamellar Grating Interferometer for Spectroscopy

Paul Finkel Consulting

Redwood City, CA

Commercialization of a Laser Heterodyne Receiver for Measuring Greenhouse Gasses in an Atmospheric Column

2015 STTR Phase I

CFD Research Corporation

Huntsville, AL

Improved Forecasting of Solar Particle Events and their Effects on Space Electronics

Michigan Aerospace Corporation

Ann Arbor, MI

Improved Forecasts of Solar Particle Events using Eruptive Event Generators based on Gibson-Low and Titov-Demoulin Magnetic Configurations

NOUR, LLC

Wilmette, IL

Design and Fabrication of Strain-Balanced nBn Dual-Band LWIR/LWIR Focal Plane Arrays Based on InAsSb/InAsType-II Superlattices

Predictive Science, Inc.

San Diego, CA

A Coupled System for Predicting SPE Fluxes

Q-Peak, Inc.

Bedford, MA

Compact Laser for In-Situ Compositional Analysis

“It is difficult to say what is impossible, for the dream of yesterday is the hope of today and the reality of tomorrow.”

— Robert H. Goddard

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and Space Administration
Goddard Space Flight Center

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