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GSFC NEWS

tech transfer

—PHOTO BY NASA

Global Precipitation Measurement (GPM)

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GPM

Nona Cheeks

[FROM THE *Chief*

From the Chief

Regular readers of the *Tech Transfer News* are aware that each issue typically highlights a NASA Goddard mission, technology, or capability. The featured subjects are examined from multiple perspectives, including technological achievement, collaboration, and societal benefit – both in terms of the science goals of its original mission, as well as potential impact when adapted for terrestrial applications.

The subject of this issue, the Global Precipitation Measurement (GPM) mission, combines many of these important themes. GPM is a collaboration between NASA Goddard and JAXA, our sister space agency in Japan. NASA Goddard assembled and tested the GPM Core Observatory, which was successfully launched from Japan's Tanegashima Space Center on February 28, 2014. The GPM Core Observatory is part of a larger constellation of satellites, operated in cooperation with space agencies in India and Europe. Truly a global collaboration!

The importance of GPM's scientific mission can scarcely be overstated. Few topics receive more popular press these days than the changing climate; many believe it is one of the most important topics we as a society must understand and address. GPM observations will provide essential data that will help scientists monitor and analyze the impact climate change is having on ecosystems across the Earth. Changes in precipitation will likely have important implications for our future needs in terms of agriculture, health, and safety. These are critical issues that we are only now just beginning to understand, but must be fully prepared for. GPM will play a central role in this process.

GPM may also represent a commercial opportunity for businesses, especially when evaluated in conjunction with Earth Science data recorded by other missions such as LDCM/Landsat 8 (see the Summer 2013 issue of the *Tech Transfer News*). The data produced by GPM can be valuable to industries such as commodity trading, food production, insurance, health care, and others who have a vested interest in the potential effects of changes in precipitation in critical geographic areas.

In this issue, we briefly review the GPM mission. We discuss GPM goals, and the development of the mission's instrumentation. To gain an "insider's" perspective, we speak with two key members of the GPM team to share their experiences on how they and their colleagues collaborated with other innovators, both inside and outside NASA Goddard, to ensure the mission's success. And in keeping with the theme of technology transfer, we also describe some of the new technology developed specifically for GPM, such as flight software. Although these technologies were created with GPM in mind, they also offer potential value for commercial satellite applications, among others. These examples provide additional proof of how public investment in space research can pay important dividends here on Earth, both in terms of societal benefit as well as economic opportunities.

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

GPM

OVERVIEW OF THE *Global Precipitation Measurement (GPM)*

Overview of the GPM

The Global Precipitation Mission (GPM)

—IMAGE BY NASA

A new era of 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. Known as the Global Precipitation Measurement (GPM) Core Observatory, the satellite begins an era of unprecedented national cooperation to measure global precipitation from space and advance human understanding of weather and the earth's water cycle.

The Mission

GPM is a joint mission between NASA and the Japan Aerospace Exploration Agency (JAXA) and will be part of a "constellation" of existing and future satellites that will gather data on global precipitation in near real time. While each constellation member has its scientific or operational objectives, they all contribute microwave measurements to the GPM mission.

GPM builds on the success of TRMM, the Tropical Rainfall Measuring Mission launched in 1997 and designed to measure moderate to heavy tropical rain. TRMM carried the first space borne precipitation radar and was also a joint project between NASA and JAXA. TRMM provided the very first three-dimensional images of storm systems giving scientists the chance for novel and innovative weather analysis. However, the TRMM satellite only monitors moderate to heavy rain precipitation over tropic and subtropic regions (approximately 35º North Latitude to 35º South Latitude, or the Mediterranean Sea to the southern tip of Africa). GPM Core Observatory will expand this view from the Arctic circle to the Antarctic circle, 65º North Latitude to 65º South Latitude. GPM also adds the ability to measure light rain and frozen precipitation.

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 scientists study the internal structure of these storms throughout their life cycles, including how they change over time. Such data will help scientists understand storm behavior better, and explain why some storms change in intensity as they transition from the tropics to the mid-latitudes.

The Global Water Cycle

Scientists study moisture and precipitation in the atmosphere 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 with even less information available on precipitation in earth's oceans. Satellite observations can provide that missing data and more.

This expanded view and data collection capability is a result of a "constellation" of satellites (9 in all, including the GPM Core Observatory) that together provide global precipitation data in near real time; data from the constellation will update every three hours. Combined, the constellation will provide scientists with data such as precipitation intensity and variability within a storm, 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 will help scientists improve climate and weather forecast models (including forecasts of hurricanes, floods, droughts and even landslides) as well as help them better design integrated hydrologic models of watersheds.

GPM Microwave Imager - GMI

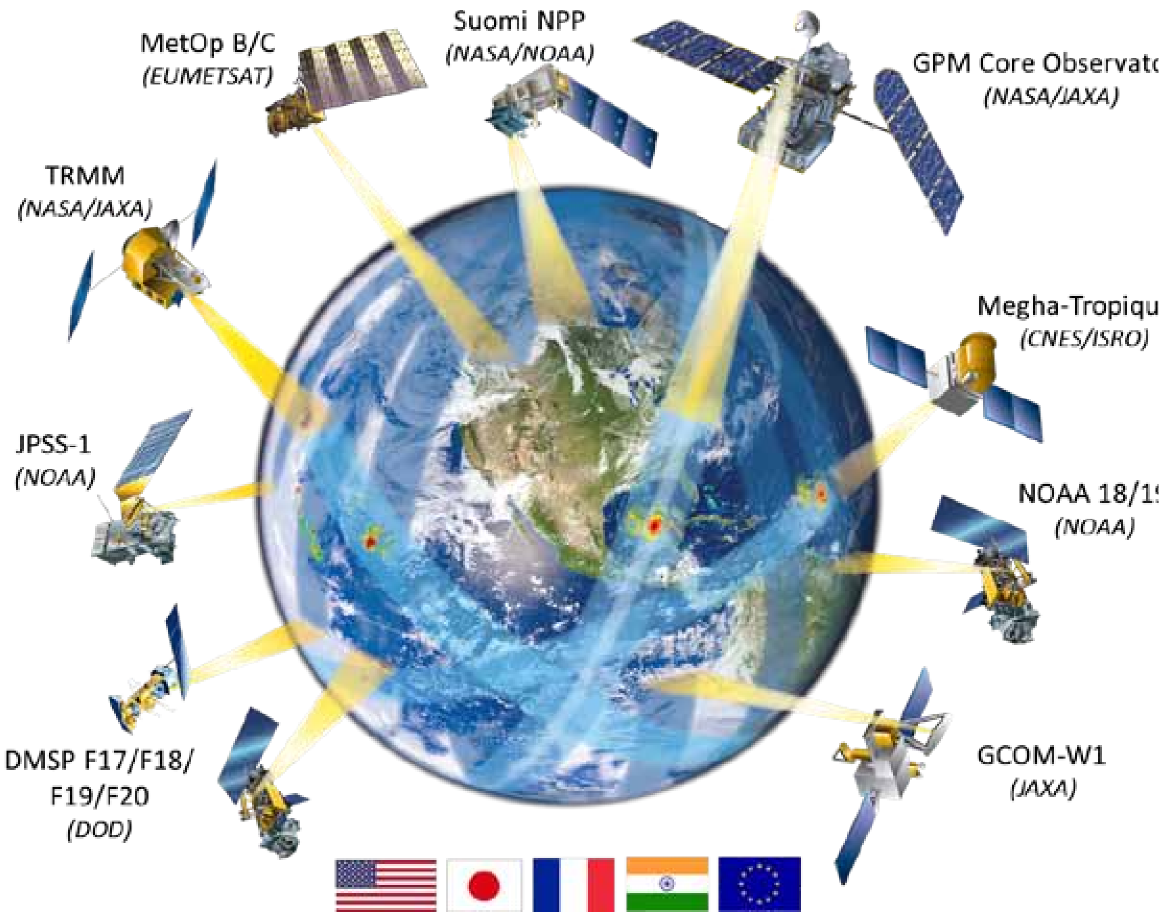
GMI is a multichannel microwave radiometer. The 13 "channels" provide GMI with unparalleled access to all cloud layers and the ability to detect total precipitation from light through heavy rain, ice, and snow. Each channel measures a different range of the intensity of microwave radiation emitted from the atmosphere and earth's surface. Where one frequency channel may only see light rain, another sees heavy rain, and yet another sees light snow. Combined, these channels give GMI a much broader range of precipitation types for analysis that has ever been available to scientists.

DPR – Dual-frequency Precipitation Radar

DPR is the next generation space borne precipitation radar, improving on the data currently collected by TRMM. It will make detailed three dimensional measurements of the rates and structures of precipitation events over nearly all of the earth's surfaces. The key to DPR's improved measurement is the dual band radar: Ku-band radar measures heavy to moderate rainfall at 13.6 gigahertz (similar to the instrument on TRMM) while Ka-band measures light rain and frozen precipitation at 35.5 gigahertz. Where the bands overlap, data on particle size distribution will be generated and scientists will be able to see, for example, how many raindrops of various sizes are in a cloud layer, and exactly what their distribution is throughout the storm. This data helps scientists understand storms better, including their behavior, and is expected to help improve future estimates on rain and snowfall.

The Core Observatory

The DPR and GMI are the two main technologies on the Core Observatory, which provides them power, communications, and data storage. The Core Observatory also houses a variety of subsystems such as a solar array drive and deployment, thermal control, navigation and control, and several others. It orbits above the earth at 407 kilometers (253 miles) while the two major instruments continuously scan a 120-885 kilometer (75-550 mile) "swath" or path of the earth's surface in an orbit completed every 93 minutes. Where the Ka and Ku bands overlap, important data on precipitation size and distribution will be generated. In addition, the Core Observatory



The Global Precipitation Mission Comstellation Status.

—IMAGE BY NASA

houses an advanced radar/radiometer system that serves as a reference standard to unify precipitation measurements from the entire constellation.

Ground Systems

The GPM Mission ground systems operate and command the Core Observatory, and manage/ distribute the data received from the constellation.

Data from the Core Observatory is transmitted nearly continuously from the GMI instrument and twice an orbit from the DPR, while data from the constellation is sent from the mission's partner agencies via their own respective data facilities. Goddard's Precipitation Processing System, or PPS, processes all of this data except for the initial DPR data which is sent to JAXA for initial processing and then sent along to PPS for integration into the complete data set. This data will be publicly available within six months of the launch, or around the end of August, 2014, from NASA at pps.gsfc.nasa.gov.

Ground validation and calibration is a critical component of the overall GPM mission, helping to continuously improve the data produced by the Core Observatory and the constellation. To provide this calibration and validation, NASA scientists collected data from ground based instruments and radar and compared them to data collected by aircraft and satellite instruments. This validation effort helps scientists improve the way the satellites estimate precipitation.

GPM

NEW TECHNOLOGY *Reporting*

NTR

As we explain in a separate article, data from the GPM mission is currently being used to monitor global precipitation. This data will improve climate, weather, and hydrological predictions through more frequent and more accurate measurement of precipitation worldwide. The mission architecture consists of a Core Observatory, a Low Inclination Observatory, Mission Operations Ground System, and a Precipitation Processing System (PPS).

According to Deputy Project Manager Candace Carlisle, GPM, while a Class B mission, truly benefits from a multitude of technologies that Goddard developed for, and used on, prior missions, technologies like the demisable fuel tank and reaction wheels, and the GPM Navigator. However, during the mission's development, there were some new technologies, such as flight software, validation technology, and simulator technology that were developed and used for this mission.

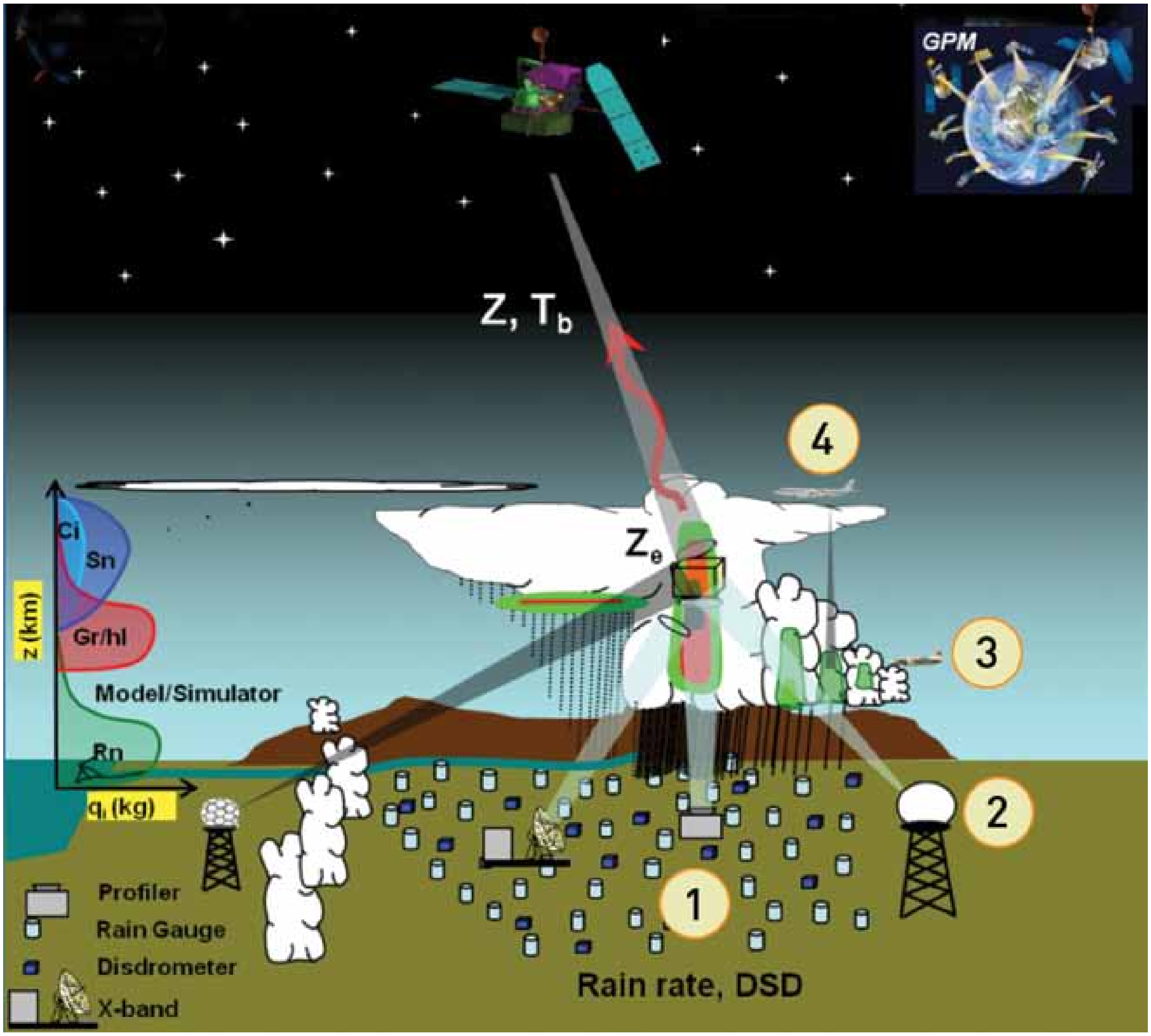
Flight Software

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

The Global Precipitation Measurement (GPM) spacecraft (S/C) flight software (FSW) controls and coordinates all aspects of the spacecraft's operation in nominal and anomalous conditions. It distributes commands to, and collects data from, all spacecraft subsystems and the science instruments. The FSW controls high gain antenna pointing to Tracking and Data Relay Satellite System satellites and manages communications with the ground controllers in real time to receive commands (during S-Band Single Access contacts) and send housekeeping telemetry data during S-Band Single Access and Multi-access contacts. It sends science data using the Class-2 Consultive Committee for Space Data Systems File Delivery Protocol (CFDP). The Flight Software also monitors the health of most orbiter subsystems and takes corrective actions when necessary.

Other critical roles performed by this software include controlling a variety of functions such as: the pointing of the spacecraft/instruments to the earth's surface, the orientation of the solar arrays to collect power, and the pointing of the high gain antenna to communicate with TDRSS. The FSW uses the propulsion system to perform orbit station keeping and re-entry when the mission is complete. It also implements a safehold controller and can perform "yaw maneuvers" to re-orient the spacecraft velocity vector by 180 degrees. The GPM FSW uses Goddard's Operating System Abstration Layer (OSAL) and the Core Flight Executive (cFE) software (we describe the cFE in more detail in the Tech Transfer News interview with Dave McComas). 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.

Currently there are multiple NASA centers using the CFS. For example, the Johnson Space Center used the 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. In addition, Johns Hopkins APL (Applied Physics Laboratory) and other commercial organizations are interested in it.



▶ *GPM Ground Validation technique of using overlapping field measurements to validate rain's physical properties*

—IMAGE BY NASA

Comparison Software

Global Precipitation Radar (GPM) space and ground radar comparison software (GSC-15469-1)

Global Precipitation Radar (GPM) space and ground radar comparison software was also designed by NASA scientists to support a prototype Validation Network for the GPM spaceflight mission. The current software version collects data from the Precipitation Radar instrument flying on the Tropical Rainfall Measuring Mission (TRMM) spacecraft. It also collects ground radar data from the 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.

Global Precipitation Mission (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 Precipitation Radar instrument. 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.

Simulation Technology

Simulation software is critical to the GPM mission and the Flight Software group simulated a variety of conditions in the flight software lab before launch. However, the group can only "verify" as much as the flight simulation allows, making this work extremely challenging. Some technologies developed in this regard are the GO-SIM core software and GO-SIM instrument simulation software.

Global Precipitation Measurement (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.

Global Precipitation Measurement (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 two instruments on board the GPM spacecraft). The simulations purpose are to 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. These instrument simulations are software-only and can run as a standalone application on windows. Further, the simulations do not affect the execution of the flight software.

Other Technology (GSC-16810-1)

Intercalibration of Measurements from Microwave Sensors for TRMM and GPM Using a Well Validated Radiative Transfer Code

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 Global Precipitation Measurement (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 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. The library 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 ANSI C.

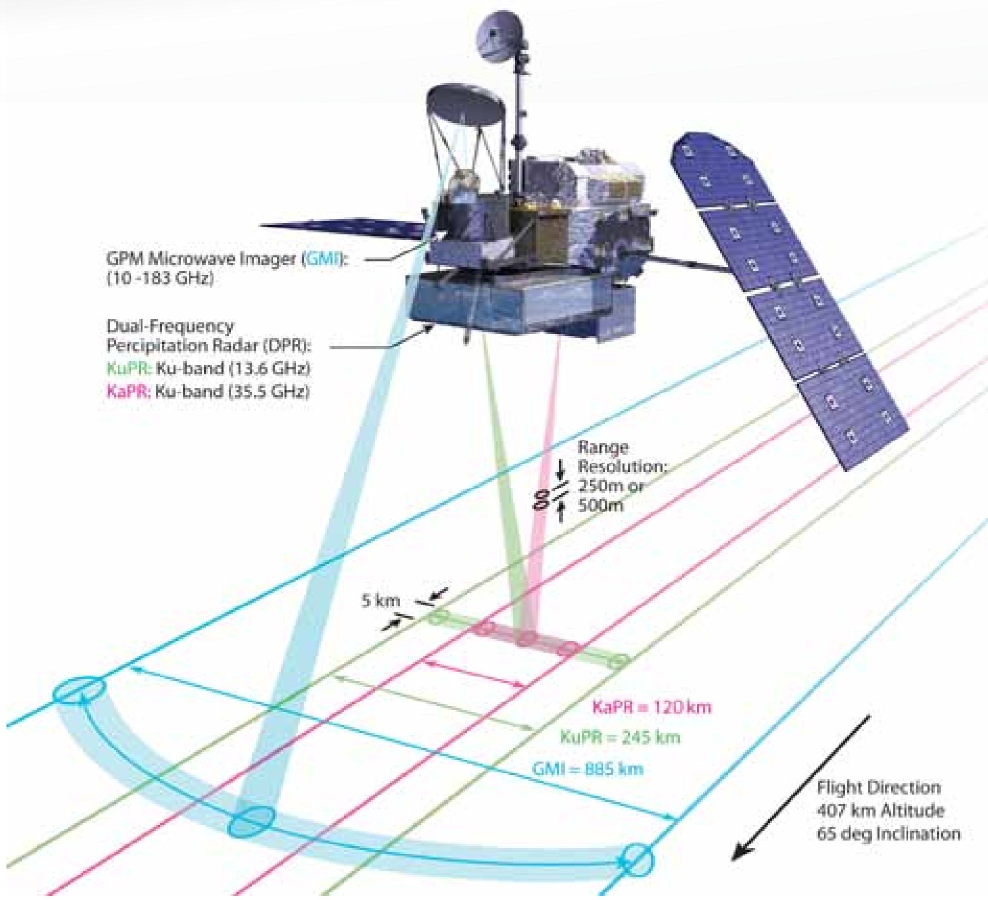
EEPROM File System (GSC-16852-1)

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.

GPM

INTERVIEW WITH Candace Carlisle and Dave McComas

GPM Interview



▶ *The GPM Swath Diagram 2013*

—PHOTO BY NASA

The Global Precipitation Mission (GPM) is an international effort to monitor precipitation across the Earth. The mission, launched from Tanegashima Space Center in Japan in February 2014, collects precipitation measurements from nearly every populated are of the world.

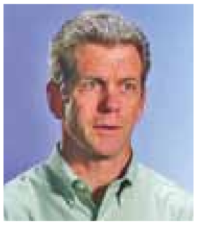
In this interview, we speak with two key members of the GPM team, Candace Carlisle (Deputy Project Manager) and Dave McComas (Flight Software Systems Branch Head).

Q. *Please give us a brief overview of the Global Precipitation Mission.*

Candace Carlisle: The Global Precipitation Mission, or GPM, is a joint mission between NASA and the Japan Aerospace Exploration Agency or JAXA. It involves the use of nine U.S. and international satellites (the "constellation") which combined will provide global data on precipitation. GPM will provide global data, which is refreshed every three hours, to organizations such as the National Weather Service who can use it to improve weather forecasting, watch hurricanes and other storms in real-time, and so on.

The GPM satellite itself sees its own 120-885 kilometer “swath” of Earth with an orbit of 93 minutes. Each of the other constellation satellites orbits the Earth on a different axis -- some are polar orbiters, one is an equatorial orbiter -- looking at its own “swath.” Combined, the constellation can observe 90% of the Earth over a period of 3 hours or so.

Q. *What is your role in GPM?*



Dave McComas

Dave McComas: I am the Branch Head of the Flight Software Systems Branch/Code 582. We provide the on-board, embedded software products that enable spacecraft hardware, science instruments and flight components to operate as an integrated on-orbit science observatory. Essentially this means that we take the requirements for the mission and spacecraft and develop the subsystem software requirements, and then design and implement the actual software. We’re involved from mission requirements through spacecraft Integration & Test, launch and early orbit checkout. In fact our involvement continues during operations and we have a dedicated team of FSW Sustaining Engineers (FSSE) who maintain the FSW for several operational spacecraft.

Candace Carlisle: As Deputy Project Manager, my role is to oversee the development of the spacecraft and ground systems. The project operates the mission for the first 90 days, and then hands it over to the Earth Science Mission Operations Project. ESMO will operate GPM over the lifetime of the mission. GPM has a three-year design life and more than five years of fuel on board. After three years, the mission can be extended by Headquarters and the extra fuel can make that possible. Other missions have lasted much longer than their original design life, such as the Tropical Rainfall Measuring Mission. The TRMM mission is still operating 16 years after launch, far outliving its original design life but still providing important rainfall data to researchers worldwide.

Q. *Why is the GPM mission so important?*

Candace Carlisle

Candace Carlisle: For the first time, scientists will be able to see storms as 3-dimensional structures and in real time. Right now there aren’t many on-orbit precipitation radar instruments available (the TRMM and GPM are the only two) and the data provided by this mission will allow scientists an unprecedented level of access to a storm’s structure and behavior. With this data, scientists can watch how a storm tracks and changes in its severity in real time, helping them understand the factors that influence storm behavior and resulting in better prediction models. The data should also help global scientists better predict droughts and floods as well as gain a more complete understanding of the global water cycle.

Q. *What NASA Goddard technologies are on board GPM?*

Candace Carlisle: GPM is a Class B/Category 1 mission based on NASA standard definitions of Risk Classification and Life Cycle Cost. As such, GPM makes use of many of the technologies previously developed by NASA Goddard over the years. Class B missions require technologies on board that are developed to a point beyond TRL-6, beyond a prototype demonstration. This mission is a technical success story because it uses many technologies developed at NASA Goddard and used for other missions.

For example, triple junction solar cells are one NASA Goddard technology used on GPM. These solar cells were advanced technology when they were used on the ST5 mission that launched in March of 2006 to test and validate new technologies for future space missions. GPM uses these cells and thus benefits from the prior development effort. GMSEC, established in 2001 to coordinate ground and flight system data systems development and services at NASA Goddard, is another. [See also the Spring 2011 issue of the NASA Goddard Tech Transfer News] GPM uses ground system technologies that have been used on several other missions and developed at NASA Goddard.

A more recent strategy at NASA Goddard is the "design-for-demise" approach with the goal is to make space mission technology "demisable." This calls for space components to be susceptible to melting, vaporizing, and/or otherwise disintegrating during re-entry of the spacecraft into the atmosphere of the Earth, so as not to pose a hazard to anyone or anything on the ground. The GPM itself was originally designed to be fully demisable; but the engineers found that was not totally possible. The mission does, however, incorporate demisable components where it can.

One such component is the propulsion tank system which is often made of titanium because it is a safety critical component. In the GPM mission, a composite overwrapped aluminum pressure vessel tank (GSC-16525-1) is being combined with an aluminum propellant management. This propellant management tank is designed to be fully demisable. A smaller, similar system was used in a prior mission (Lewis), and NASA Goddard was involved with its development and moved that technology beyond the TRL-6 necessary for use on GPM. *[See also the Winter 2012 issue of the NASA Goddard Tech Transfer News]*.

Dave McComas: The Flight Software Systems Branch recognized that a hardware-neutral software architecture would benefit missions because it would be mission-independent, cost effective and could provide reusable core assets. As a result, the branch developed the Core Flight System (CFS). The CFS includes the core Flight Executive (cFE) which is an open source, layered architecture that supports the development of additional applications that can be used for all missions or specific ones. The CFE has the computational efficiency to support low and high performance radiation-hardened hardware platforms and thus can be used on a wide range of missions from major science missions to low-cost technology demonstrations.

The architecture of the CFS creates a framework for the development of an "applications" store. Applications such as a "scheduler," "memory manager," and "limit checker," which checks system health, have all been developed along with others for a total of eleven mature applications. New ones continue to be developed and can be customized for each mission. The product line of applications has grown over the years because there are a number of core functions that we do for every mission. And it's not just used at NASA Goddard. The CFS is now used agency wide at NASA centers including Ames, Glenn, Johnson Space Center, Kennedy Space Center, and Marshall Space Flight Center. In fact, the layered architecture of the CFS was originally developed to promote collaboration among NASA Goddard projects and to save costs, and it has broadened to become a NASA-wide collaboration and is seen as an important resource for cost savings.

An important future mission, the Magnetospheric Multiscale (MMS) mission, will also use the CFS with these applications to study the Earth's magnetosphere and its role in "space weather." The LADEE mission developed by AMES also used the CFS. It launched from Wallops and recently intentionally crashed into the moon.

We really are at a pivotal point for the CFS because it started as a grassroots effort and in the past few years it has been widely accepted across NASA and some commercial entities. Multiple Space Act Agreements are in the works.

Candace Carlisle: Another NASA Goddard technology onboard the GPM mission is the demisable reaction wheel assembly (RWA) (GSC-14845-1). The unique design combines materials, parts, and a design that come together for complete demisability during descents at the end of mission life. The RWA is constructed of aluminum so the flywheel has a low melting temperature, ensuring its demise. These wheels were developed in-house at NASA Goddard and were flown on a prior mission, and are now being used on GPM.

The GPM navigator is another technology, developed over several years, that was first used in a Hubble Space Telescope servicing mission in 2009. It's now aboard GPM and is used operationally for the mission. The GSFC Components and Hardware Systems Branch established a technology transfer agreement with BroadReach Engineering (later acquired by MOOG) for the electronics and software designs.

Dave McComas: The GPM Navigator is also using a software package called GEONS (GPS–Enhanced Onboard Navigation System) (GSC-14687-1) which is a tech transfer effort and Navigator is also being used by MMS.

Q. *Did the SBIR program play any role in the development of these technologies?*

Candace Carlisle: The NASA SBIR program was involved in funding the development of D3R, Dual-wavelength, Dual-polarized Doppler Precipitation Radar. In this project, Remote Sensing Solutions, NASA Goddard, and Colorado State University worked together to develop an innovative solid state radar system that will serve as the ground validation radar system for the GPM mission. D3R will simultaneously monitor Ku and Ka band wavelengths superior ground-based data for comparison with GPM's DPR instrument precipitation observations.

Q. *Can any of the technologies developed for GPM be adapted and leveraged for terrestrial use? If so, what industries might be interested in these technologies?*

Dave McComas: Since the CFE is really a generic product for an embedded system; it's now running on Raspberry Pi, which is a low cost credit card sized single board computer that has become very popular among the educational and hobbyist communities. It uses a standard keyboard and mouse, and allows all types of people to learn programming and explore computing. In fact, one of our branch members, Alan Cudmore, has developed what he calls "PiSat" using Raspberry Pi.

This computer is offered by the Raspberry Pi Foundation, which is a nonprofit organization dedicated to providing small, low cost computers for children all over the world. We think there are opportunities for the CFE in a broader university audience as well.

Q. *Is GPM data made available to the public?*

Candace Carlisle: Six months after launch, late August, 2014, the data collected by the constellation will be made publicly available. Early adopters, such as science team members and the National Weather Service, are receiving data now. Also, the precipitation processing system is online now and there is a public web site where the precipitation information will be available after the six-month mark. Anyone can access the data and tools for analyzing the data collected.

Q. *Can companies build a business around making products from GPM data or other technology developed for the mission?*

Candace Carlisle: Companies could use the data to develop products designed to better predict weather, especially severe storm events because the data from GPM will provide such an expanded degree of access to the structure and behavior of large storms. In addition, products for predicting floods and landslides could be developed. These features could be combined into a product that would be valuable to many people.

Dave McComas: Because of its layered architecture, the CFE can be used with many different operating systems. There was a project at the Johnson Space Center where the CFE was used in a small helicopter. It's possible that there could be an application in remote control toys of all types, such as the ARDrone 2.

Q. *Anything else we haven't covered?*

Candace Carlisle: While GPM is a Class B mission, it is benefiting from many technologies developed by NASA Goddard over the years. In a very large sense, this mission is truly a technical success story.

SBIR Success Story

As we've mentioned elsewhere in this issue of NASA Goddard Tech Transfer News, the GPM mission is the first to coordinate a network of international satellites (current and planned) to produce the next generation of data on global precipitation. The star of the mission is the GPM Core Observatory, launched in February of 2014. It carries an advanced radar/radiometer system and serves as a reference standard that will unify precipitation measurements from the constellation. To do this, technology had to be developed that could link the data from the GPM Core Observatory to ground based measurement systems, validate the data they produced, and calibrate them continually. That technology is D3R.

The NASA Dual-frequency Dual-Polarimetric Doppler Radar (D3R)

—PHOTO BY NASA

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

Remote Sensing Solutions received a Phase I and Phase II SBIR award to develop the D3R or Dual-wavelength, Dual-polarized Doppler Precipitation Radar specifically 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 GSFC's cloud and precipitation measuring mission (the GPM mission).

The company leveraged this novel waveform and transceiver design and in a Phase III SBIR project, worked with Colorado State University and GSFC to complete the design of D3R. The radar simultaneously acquires dual-polarized Doppler and reflectivity precipitation volume backscatter measurements in the Ka and Ku band wavelengths with sensitivity close to traditional tube-based precipitation radar but eliminates the blind region.

The design provides the Ku-band ((14 GHz) and Ka-band (35 GHz) channels to receive data from GPM Core Observatory and provide the calibration and validation, or calval, necessary to continually modify the data collection from the constellation. The antenna is a key technology element for this mission as the calval ability allows the mission to constantly update its own performance. Further, acquiring data in Ku and Ka band wavelengths creates a system with multiple "channels" that can see precipitation in clouds from low level rain to high level snow and ice. The multiple channel approach to precipitation measurement is one of the reasons the GPM mission can more precisely quantify precipitation, yielding unprecedented data on global precipitation. It also creates a system that can use improvement algorithms for space-borne and long range ground-based cloud and weather radars (this is the calval component of the system).

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.

Networking and Outreach

▶ *Innovative Technology Partnerships Office (ITPO) staff member Lara Zitterkopf talks with a student at the 5th Annual Donna Edwards College and Career Fair.*

—PHOTO BY NASA

5th Annual Donna Edwards College and Career Fair

(OCTOBER 19, 2013, OXON HILL, MD)

NASA Goddard's Innovative Technology Partnerships Office (ITPO) hosted a table at the 5th Annual Donna Edwards College and Career Fair at Oxon Hill High School in Oxon Hill, Maryland. This annual event provides an opportunity for high school and middle school students, and their parents, to plan for future success by meeting and talking with experts from the U.S. Dept. of Education, representatives from colleges and universities, training centers, and other various government agencies. The ITPO talked with attendees about technology transfer and demonstrated NASA'S massively multiplayer online (MMO) game Moonbase Alpha, which was designed to encourage an interest in space exploration in school children.

▶ *A student at the 5th Annual Donna Edwards College and Career Fair plays NASA's massively multiplayer online (MMO) game Moonbase Alpha*

—PHOTO BY NASA

Innovation 2 Commercialization 2013: Making Tech Transfer Count

(OCTOBER 24, ROCKVILLE, MD)

Innovative Technology Partnerships Office Chief, Nona Cheeks, speaks at the 2013 Innovation 2 Commercialization conference in Rockville, Maryland.

—PHOTO BY NASA

NASA Goddard's Innovative Technology Partnerships Office (ITPO) participated in the Innovation 2 Commercialization: Making Tech Transfer Count conference held at the Universities at Shady Grove and hosted by the Montgomery County Department of Economic Development. This annual conference features exhibits from federal and academic tech transfer offices, business resources, educational programs, and funding resources. The conference also offered panels on Innovation, Commercialization, and Financing. ITPO Chief, Nona Cheeks, spoke during the Commercialization Plenary Panel about the role NASA Goddard's ITPO plays in technology transfer and commercialization. ITPO staff members were on hand to speak with attendees and give information on working and partnering with NASA.

Innovative Technology Partnerships Office Technology Manager, Enidia Santiago-Arce talks with students at the 2013 Noche de Ciencias (Science Night).

—PHOTO BY NASA

Noche de Ciencias at USPTO

(NOVEMBER 21, 2013, USPTO, ALEXANDRIA, VA)

On November 21 the Society of Hispanic Professional Engineers (SHPE) hosted Noche de Ciencias (Science Night) at the U.S. Patent and Trademark Office in Alexandria, VA. This annual event is held to introduce students and families to science and engineering through hands-on activities and exposure to college and career information in science, technology, engineering and mathematics (STEM). NASA Goddard's Innovative Technology Partnerships Office (ITPO) was on hand to talk with students and attendees about pursuing careers in science, demonstrate science related activities and promote the NASA OPTIMUS PRIME Spinoff Contest.

Innovative Technology Partnerships Office staff member Lara Zitterkopf demonstrates a science activity for attendees at the 2013 Noche de Ciencias (Science Night).

—PHOTO BY NASA

Technology Disclosures

Disclosures

- **SNAPSHOT GPS RECEIVER**

  William Bamford, Tyler Lulich, Penina Axelrad

- **HIGH DATA RATE COMPACT LOGGER**

  Maciej Stachura, Jack Elston, Eric McIntyre

- **A COMPACT IN SITU SENSOR FOR MEASUREMENT OF ABSORPTION AND BACKSCATTERING IN NATURAL WATERS - SIMULATION AND DESIGN CONCEPT**

  Wayne Slade, Curtis Mobley, Yogesh Agrawal

- **DETECTION OF UNAUTHORIZED COMPUTER ACCESS AND OTHER ANOMALOUS COMPUTER ACTIVITIES VIA COMPARISON OF MULTIPLE INDEPENDENT SPATIAL-TIME DATA SETS FROM END-USER DEVICES AND SUPPORTING INFRASTRUCTURE**

  Joshua Krage, Paul Westmeyer, Russell Wertenberg, Jack Riegel

- **A COMET SURFACE SAMPLE RETURN PROBE**

  Philip Chu, Kris Zacny, Stephen Indyk

- **JAMES WEBB SPACE TELESCOPE PROJECT REFERENCE DATABASE SUBSYSTEM TOOLKIT (PRDS TOOLKIT)**

  Fred Romelfanger, Jesse Doggett, Steven Handy, Andy Groebner

- **EXTENDED FAULT DETECTION AND ISOLATION FILTER**

  Jason Speyer, Emanuell Murray, Wei Huang

- **MODULATION METHOD FOR MAGNETOMETER PROBE LASER**

  David Hovde, Dmitry Budker

- **SYSTEMS ENGINEERING EDUCATION AND DEVELOPMENT (SEED) WEB APPLICATION**

  Donya Douglas, Carmel Conaty, Gregory Wood

- **QEMU MODEL FOR DEC21143 (TULIP) PCI ETHERNET CARD**

  Steven Seeger

- **INTERFACE BETWEEN STAR-CCM+ AND 42 FOR ENHANCED FUEL SLOSH ANALYSIS**

  Eric Stoneking, David Benson

- **GOES-R FLIGHT SOFTWARE**

  Scott Nguyen, Michael McKenzie, Lisa Sevcik, Sean Sommer

- **MAGNETICS TEST SITE APPLICATION**

  Joseph Gurganus, Malinda Hammond

- **BAR CODE SCANNER TO SUPPLEMENT NASA GSFC PROPERTY INVENTORY PROCESS**

  Kenneth Li

- **SPACE OPERATIONS LEARNING CENTER (SOLC) KIDS ZONE 4**

  Malinda Hammond, Daniel Binebrink, Heng Kuok

- **ULTRA LOW HEAT LEAK HTS CURRENT LEADS**

  Christopher Rey

- **THE FIRST JFET-BASED SILICON CARBIDE ACTIVE PIXEL SENSOR UV LMAGER**

  Leonid Fursin

- **IN-SITU OPTICAL FIBER TAPERING**

  Alireza Marandi, Robert Byer, Charlie Rudy, Konstantin Vodopyanov

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- **IMPROVED MINIMAL TEMPERATURE RESPONSE OF A BANDGAP REFERENCE CIRCUIT**

  Sampath Venkatesan, James Hofmeister

- **FINAL FIBER COUPLED PULSE SHAPER FOR SUB-NANOSECOND PULSE LIDAR**

  Tony Roberts, Gregg Switzer, Philip Battle

- **NON-COMPETITIVE PROMOTION PROCESS (NCPP) SYSTEM**

  Stephen Waterbury, Malinda Hammond

- **NDVI SENSOR SUITE**

  Maclej Stachura, Jack Elston, Raymond Oung, Albin Gaslewski

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- **MODULAR RECONFIGURABLE MATCHED SPECTRAL FILTER SPECTROMETER (PHASE I SBIR)**

  Elizabeth Schundler

- **GODDARD OPPORTUNITIES BULLETIN BOARD SYSTEM (GOBBS) 2.0**

  Malinda Hammond

- **IMPROVED WHITE MOLECULAR ADSORBER COATING SYSTEM (MAC-W)**

  Nithin Abraham, Mark Hasegawa, Sharon Straka, John Petro

- **GOES-R SIMULATION SOFTWARE**

  Josh Davidson, Ryan Guitreau, Andrew Wobido

- **RESONANCE-ACTUATION OF MICROSHUTTER ARRAYS (2013)**

  Yiting Wen, Mary Li, Liqin Wang, S. Harvey Moseley

- **CLEAR HIGH OPTICAL POWER LINKS**

  Charles Dupuy

- **LIGHTWEIGHT SUPERCONDUCTING MAGNETS FOR LOW TEMPERATURE MAGNETIC COOLERS**

  Welbo Chen, Nicholas Kattamis

- **MOBILE PASSIVE SPECTROSCOPIC IMAGER**

  Qizhi Zhang, Yingyin Zou

- **HIGH-RESOLUTION SILICON-BASED PARTICLE SENSOR WITH INTEGRATED AMPLIFICATION**

  Subhashree Ramadoss, Mark Hammig

- **A LIGHT WEIGHT, MINI INERTIAL MEASUREMENT SYSTEM FOR POSITION AND ATTITUDE ESTIMATION ON DYNAMIC PLATFORMS**

  Kenyon Zitzka, Agamemnon Crassidis

Patents Issued

- **NON-SCANNING LASER 3D IMAGER**

  Michael Krainak

Provisional Patents

- **GATED CHOPPER INTEGRATOR (GCI)**

  Gerard Quilligan, Shahid Aslam

Space Act Agreements

COMPANY	AGREEMENT TYPE	PARTNERSHIP ABSTRACT
Broad Reach Engineering Company	*Space Act Agreement*	*The purpose of this SAA is to have Broad Reach integrate the Express Logistic Carrier (ELC) Ethernet design into their Mirideon Rad Hard CPU Board for use as the Single Board Computer (SBC) for the Neutron Star Interior Composition ExploreR (NICER) Main Electronics Box (MEB).*
DigitalGlobe Incorporated	*Space Act Agreement*	*The purpose of this Agreement is to define and enable the responsibilities and procedures for DigitalGlobeâ€™s utilization of Conjunction Assessment (CA) screening services to be provided by NASA-funded Orbital Safety Analyst (OSA) staff within the Joint Space Operations Center at Vandenberg Air Force Base in California.*

COMPANY	AGREEMENT TYPE	PARTNERSHIP ABSTRACT
The United States Strategic Command	*Interagency Agreement*	*The United States Strategic Command (USSTRATCOM) utilizes the Goddard Space Flight Center (GSFC) Communications Center (GCC) for distribution of Two Line Elements (TLEs) to the Space Track website, timely distribution of launch support and other critical messages to users, and maintenance of router listservs used to distribute real-time updates to approved Orbital Data Request (ODR) customers.*
Google, Inc.	*Space Act Agreement*	*NASA and Google wish to study the effects of space weather on data center operations and to explore mitigation concepts. NASA will collect data from multiple, geographically dispersed Google data centers and at Google's headquarter facilities in Mountain View, CA.*
The Saylor Foundation	*Space Act Agreement*	*NASA GSFC and Saylor wish to develop a series of video lectures addressing various topics within the discipline of space systems engineering. Topics covered will include: Teamwork, System Engineering Project Lifecycle, Concept of Operations, Requirements, Trade Studies. GSFC will utilize the video lectures for internal training purposes. Saylor will host the video lectures on their Website, where they will be freely available to the public.*

—IMAGE BY NASA

NASA Goddard Tech Transfer News [http://itpo.gsfc.nasa.gov]

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Send suggestions to Robert.S.Leonardi@nasa.gov.

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