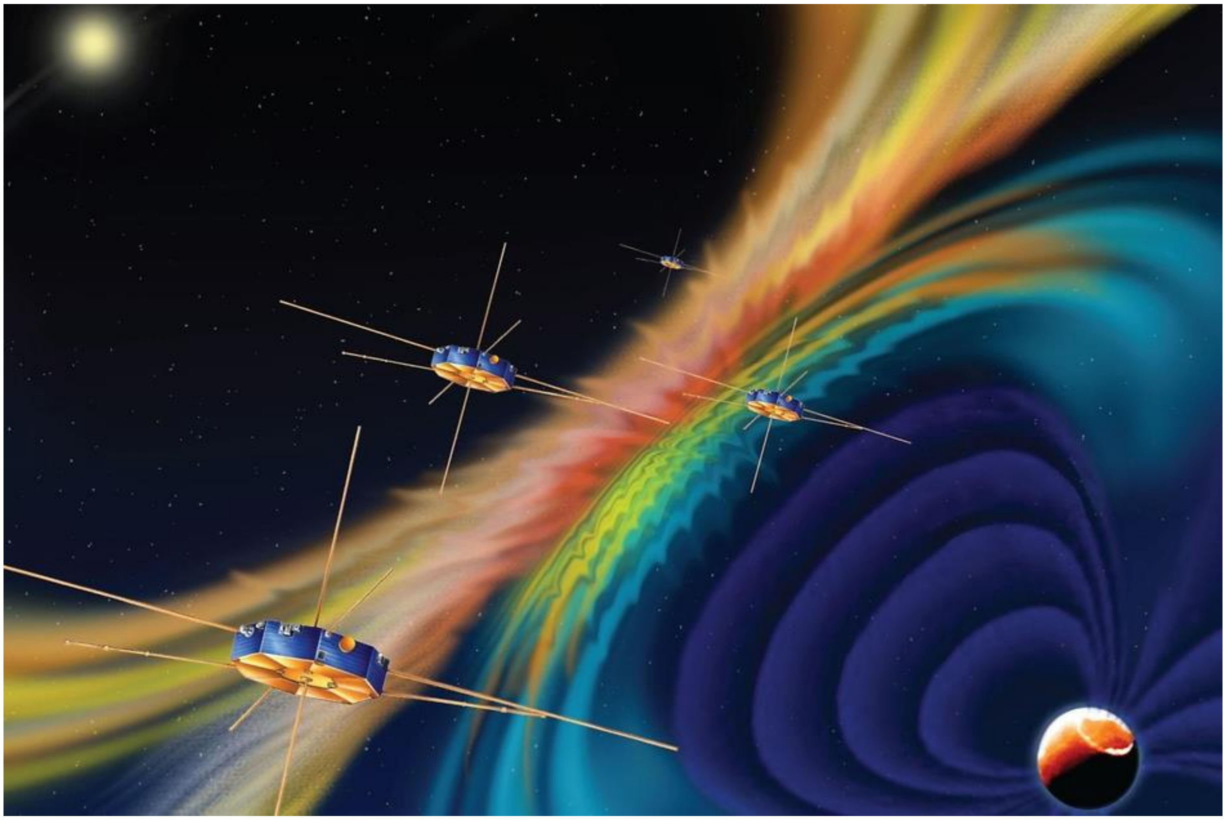
National Aeronautics and Space Administration

Mission Guide
Magnetospheric Multiscale Mission



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MMS Quick Facts

Mission focus:
The Magnetospheric Multiscale, or MMS, mission provides the first three-dimensional view of gigantic explosions in space that release energy and fast-moving particles, a process called magnetic reconnection.

MMS uses four identical spacecraft to observe reconnection directly in the magnetic space environment, or magnetosphere, surrounding Earth. By studying reconnection in this nearby, natural laboratory, MMS helps us 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.

Launch Vehicle: ATLAS V 421 Launch Vehicle
Launch Site: Cape Canaveral Air Force Station, Florida
Scheduled Launch Date: March 12, 2015

Dimensions:
At launch, with a full load of propellant, each observatory weighs approximately 2,998 pounds (1360 kg). This is about the weight of a compact car.

Each MMS observatory is in the shape of an octagon, roughly 11 feet across and 4 feet high. When stacked together in the launch vehicle, the four MMS observatories are over 16 feet tall. In space, with axial booms and wire booms extended, each observatory grows to be about 94 feet tall and 369 feet wide; a span that would stretch across most of Fenway Park.

Orbit:
Over its two-year prime mission, MMS will travel in two different highly elliptical, Earth orbits. Each orbit is designed to pass through two separate areas of magnetic reconnection in near-Earth space. During the first 1.5 years MMS will fly through the dayside boundary where Earth's magnetic fields meet up with those from the sun. During the last six months, MMS will focus on the night side of Earth, flying through reconnection sites in Earth's magnetic tail.

The first phase of the mission has an orbit that reaches 1,600 miles (2,550 km) altitude at its closest approach to Earth and extends out to 43,500 miles (70,080 km) at its farthest. For the second mission phase, the closest approach remains the same, but the orbit will extend out to 95,000 miles (152,900 km) at its farthest point from Earth – this is about 41 percent of the distance to the moon.

Organization:

MMS involves a number of institutions in the United States, as well as partners in Europe and Japan.

MMS is the fourth NASA Solar Terrestrial Probes Program mission. Goddard built, integrated, and tested the four MMS spacecraft and is responsible for overall mission management and mission operations. The Southwest Research Institute in San Antonio, Texas, leads the Instrument Suite Science Team, with the University of New Hampshire leading the FIELDS instrument suite. Science operations planning and instrument command sequence development will be performed at the MMS Science Operations Center at the University of Colorado's Laboratory for Atmospheric and Space Physics in Boulder.

Introduction to MMS

In March 2015, NASA plans to launch the Magnetospheric Multiscale, or MMS, mission. MMS consists of four identical spacecraft that will orbit around Earth, traveling through the dynamic magnetic system surrounding our planet to study a little-understood phenomenon called magnetic reconnection.

Reconnection occurs when magnetic field lines explosively realign and release a gigantic burst of energy. It is a fundamental process throughout the universe that taps energy stored in magnetic fields and coverts it into heat and the energy to cause particles to speed up to nearly the speed of light. Magnetic reconnection is a phenomenon unique to plasma -- that is, the mix of positively and negatively charged particles that make up the stars, fill space, and account for an estimated 99 percent of the observable universe. Magnetic reconnection occurs naturally in near-Earth space where MMS can access it, offering the first chance to study this phenomenon directly instead of observing it from afar.

MMS will travel directly through areas near Earth known to be magnetic reconnection sites. On the sun-side of Earth, reconnection can link the sun's magnetic field lines to Earth's magnetic field lines, allowing material and energy from the sun to funnel into Earth's magnetic environment. On the night side of Earth, reconnection helps trigger auroras, also known as the Northern or Southern lights.

The four MMS observatories will travel in an adjustable pyramid formation to gather a three-dimensional snapshot of their environment. This will help scientists determine if any given event occurs in an isolated spot, across a wide area simultaneously, or moves through space.

Several spacecraft, such as NASA's Time History of Events and Macroscale Interactions during Substorms, or THEMIS, mission and the European Space Agency and NASA's Cluster, have previously gathered tantalizing data when they happened to witness a magnetic reconnection event in Earth's magnetosphere. MMS, however, is the only mission dedicated to the study of this phenomenon.

The Magnetosphere and Magnetic Reconnection

Because Earth has a magnetic core, it behaves much like a giant magnet in space. A small bar magnet, the kind you could hold in your hand, for example, produces a set of magnetic field lines around itself. These point from the north magnetic pole of the bar to the south one and guide the movement of any electrically conducting or magnetized material nearby. A pile of iron filings for example would align themselves along these otherwise invisible lines, corralled into place by the magnetic structure. The iron filings also become a powerful way to see that magnetic structure.

The magnetic lines around Earth are much more extensive and more complicated – but the basic laws of physics are the same. Known as the magnetosphere, the magnetic structures around Earth point from the south pole to the north pole and keep magnetized material, such as the electrically charged plasma particles that fill space, constrained to move along those field lines. Just as with the iron filings, by tracking those particles, scientists can "see" the field lines of the magnetosphere.

Earth's magnetic fields are also greatly affected by other magnetized structures in space. The sun, for example, sends out a constant stream of what's called the solar wind, which travels with an embedded magnetic field. The solar wind helps mold the shape of the magnetosphere, so that it looks somewhat like a comet: snub and rounded at the front with a long tail trailing behind. Giant eruptions of solar material called coronal mass ejections, or CMEs, can also travel toward Earth, compressing the front of the magnetosphere.

When the magnetic field of the solar wind is aligned just right, this onrush of solar material can link up with Earth's magnetosphere – the hallmark of a magnetic reconnection event. The magnetic field lines within plasmas are choosy about breaking or merging with other field lines and only do so under certain conditions: If the field lines in the solar wind are pointed in the opposite direction of those in the magnetosphere, then the entire pattern changes. Everything realigns into a new configuration.

The amount of energy released by magnetic reconnection can be formidable. It taps into the stored energy of the magnetic field, converting it into heat and kinetic energy that sends particles zooming off, penetrating further into near-Earth space than usual. Even more powerful and explosive realignments can occur on the night side of Earth in the magnetotail, the long tail of the magnetosphere that points away from the sun.

During reconnection, the particles continue to follow the rules of electromagnetism. They are still constrained to travel along the magnetic field lines, but have been heated and accelerated by what amounts to a huge pump in the sky. Reconnection can channel this movement into new directions, especially downward toward Earth. Particles and electromagnetic energy flow down toward the polar regions and cause a flash of light when they collide with atoms and molecules in the atmosphere. This is an aurora.

This inrush of particles and energy can also cause other changes in the magnetosphere, such as causing the radiation belts – two giant donuts of radiation surrounding Earth – to intensify and swell.

What's Important to Science

While humans rarely witness magnetic reconnection on Earth, it is a fundamental process that occurs throughout the universe. Being able to peer directly into the heart of this phenomenon, as it occurs, will improve our understanding of how it affects our solar system, our sun, the stars in our galaxy, and even black holes.

Scientists want to know exactly what conditions -- what tipping points -- set off magnetic reconnection. Much of what we currently know about the small-scale physics of magnetic reconnection comes from theoretical studies and computer models. True understanding requires observing magnetic reconnection up close, as MMS will be able to do in Earth's magnetosphere.

Reconnection occurs wherever conducting gases, called plasma, are magnetized. Plasma fuels stars and fills the near vacuum of space. Plasma behaves unlike the gases we normally experience on Earth because they are tightly linked to their own set of magnetic fields entrapped in the material. Changing magnetic fields affect the way charged particles move and vice versa, so the net effect is a complex, constantly adjusting system that is sensitive to minute variations. Magnetic reconnection is one possible side effect of these complex realignments.

Near Earth, the reconnection sites are so small that MMS will fly through them in under a second, so the MMS sensors have been built to be exceptionally fast. As the spacecraft fly through such a site, they will measure the magnetic and electric fields present as well as the movement of particles.

Armed with this data, scientists will have their first chance to watch magnetic reconnection from inside the critical layers where it is controlled, right as it's occurring.

What's Important to the World at Large

Understanding magnetic reconnection is also crucial for better understanding of the catalysts of space weather: Reconnection is at the heart of how eruptions on the sun can lead to changes in the shape of our magnetosphere and expose satellites in space to dangerous radiation.

Take, for example, the events that rocked near-Earth space in October 2003. On Oct. 28, 2003, and again on Oct. 29, massive solar flares erupted on the sun, sending X-rays zooming through the solar system. Along with the flares, the sun expelled giant clouds of solar material in the form of CMEs. The CMEs slammed into Earth's magnetic field, making it agitate and funneling material and energy in toward Earth. This created what's called a geomagnetic storm.

The Halloween Storms, as they are now called, triggered brilliant auroras that could be seen over much of North America -- reaching as far south as Texas. But they also interfered with GPS signals and radio communications, and caused the Federal Aviation Administration to issue their first-ever warning to airlines to avoid excess radiation by flying at lower altitudes.

Every step leading to these intense storms -- the flare, the CME, the transfer of energy from the CME to Earth's magnetosphere – was ultimately powered or driven through space by magnetic reconnection.

By studying the small details of this little-understood process, scientists will better understand what happens on the much larger scales of space weather events, thus helping us predict space weather and protect our home planet Earth.

Spacecraft and Instruments

MMS relies on four spacecraft with identical sets of instruments. The four spacecraft fly in an adjustable, pyramid formation that enables them to observe the three-dimensional structure of magnetic reconnection. Four spacecraft give MMS the necessary observational perspectives to determine whether reconnection events occur in an isolated locale, everywhere within a larger region at once, or traveling across space.

Each MMS observatory is in the shape of an octagon, roughly 11 feet across and 4 feet high, built around a central cylindrical thrust tube. The majority of the science instruments and associated electronics are mounted on the underside of the top deck. The flight control hardware is installed on the upper side of the bottom deck. Each observatory is also equipped with six long electric antennas and two magnetometer booms with science sensors on the end as part of the science experiments.

Primary power is provided by eight solar arrays, with a secondary battery for energy storage and use during eclipses. The propulsion system consists of 12 thrusters and four hydrazine propellant tanks located within the central thrust tube. The MMS spacecraft are spin-stabilized, with a spin rate of three revolutions per minute. Attitude information is provided by four star cameras, two three-axis accelerometers, and two sun sensors. The thrusters are used for attitude and orbit adjustment maneuvers.

MMS is also equipped with a new navigator based on extremely sensitive GPS equipment to provide absolute position information. The observatories require such sensitive sensors because the satellites fly in an orbit higher than that of the GPS satellites; therefore, they must rely on the weaker signals from GPS satellites on the far side of Earth.

Instruments:

Each MMS observatory carries 11 scientific experiments, made up of 25 separate sensors. The instruments measure velocities of charged particles, the movement of plasma, and electric and magnetic fields, with unprecedentedly high – on the order of milliseconds -- time resolution and accuracy.

Most of the scientific instruments are mounted inside the observatory, underneath the top deck, but the two magnetometer booms and one of the two Fly's Eye Energetic Particle Spectrometers, or FEEPS, are mounted on the underside of the bottom deck; the second FEEPS is mounted on top of the top deck. The two 41-foot (12.5-meter) Axial Double Probe booms are stored in the thrust tube and will be deployed once in orbit. Placement of the instruments required careful design in order to make sure that each instrument had a full range of view and that the giant booms sticking out from the spacecraft would not interfere with any other instrument's line of sight or electromagnetic systems.

The instruments were made around the world at a variety of institutions.

The numerous MMS instruments are divided into three investigations or groups:

- Hot Plasma: to observe the nature of the charged gas, or plasma, present during reconnection
- Energetic Particles: to observe the fast-moving, energetic particles
- Fields: to observe electric and magnetic fields and waves

Hot Plasma Suite
During a magnetic reconnection event, the changing shape of the magnetic fields sends the local charged particles, or plasma, off with a great push, creating something like a giant rush of wind. The hot plasma suite measures that plasma – a concrete, physical entity unlike the more abstract magnetic fields themselves – to learn more about what's happening during reconnection. The hot plasma suite of instruments includes the Fast Plasma Investigation and the Hot Plasma Composition Analyzer.

Fast Plasma Investigation (FPI):

The Fast Plasma Investigation observes the fast-moving plasma. Incoming particles pass through a filter which cherry picks certain particle speeds and directions and allows them to pass through to a sensor plate. When an incoming particle hits the sensor plate, millions of electrons come out the other side, so the instrument can detect the event. The whole process takes several nanoseconds. By filtering for specific energies, FPI can count the number of particles entering the instrument at different energies during any given time span.

Past plasma detectors have relied on the spin of the spacecraft to gain a full view of its environment, but with only a journey of a fraction of a second through any given magnetic reconnection site, FPI must be much faster. Four sensors are used to detect the electrons and another four for the charged particles, known as ions. Each sensor is made of two spectrometers that each can scan through a 45-degree arc, resulting in a 90-degree field of view. Together the sensors can observe the entire sky. The box for each dual sensor and its components is as big as a small toaster oven, weighing in at about 15 pounds.

In combination, FPI – consisting of the four dual electron spectrometers, the four dual ion spectrometers, and one data processing unit -- will produce a three-dimensional picture of the ion plasma every 150 milliseconds and of the electron plasma every 30 milliseconds. These frame rates are similar to those used in video and a factor of 100 times faster than what has been accomplished before for electrons.

The dual electron spectrometers and the processing unit, or IDPU, were built at NASA Goddard. The dual ion spectrometers were built by Meisei Electric in Gunma, Japan, under the direction of the Institute of Space and Aeronautical Sciences, a part of the Japanese Aerospace Exploration Agency.

Hot Plasma Composition Analyzer (HPCA):

While FPI gathers millisecond observations of the presence of the plasma, along with certain salient details, the Hot Plasma Composition Analyzer is more concerned with detecting exactly which particles are present. It gathers more detailed measurements but at a slower rate.

When a particle hits the carbon foil at the front of the sensor, it knocks off an electron. The HPCA uses this electron to start a timer to measure the time it takes the original particle to hit a stop detector. This time measurement can be used to determine the particle's speed, and this speed is used to determine the mass of the original particle. The mass, in turn, is used to determine what particle it was.

The material in Earth's magnetosphere is dominated by a different set of atoms than the material streaming in from the sun with the solar wind: protons, singly charged helium and oxygen in the magnetospheric plasma; protons and doubly charged helium in the solar wind. Consequently, using the HPCA to observe what particles are present during any given event helps scientists determine which kind of plasma was involved, and assess the effects of different particles.

Unlike FPI, the HPCA needs only one sensor. The instrument relies on the spin of the spacecraft to view a sweep of the sky, gathering a set of observations every 10 seconds, the equivalent of half of the spacecraft's spin.

The HPCA also has a unique capability never before flown. There are usually so many solar wind protons compared to, for example, magnetospheric oxygen that mass spectrometers flown in the past were overwhelmed -- and the oxygen signal was masked. HPCA uses radio frequency oscillations to sweep the majority of solar wind protons away from the detector, without affecting the magnetospheric oxygen, resulting in a 10- to 100-fold improvement in detection.

The HPCA was developed and built by the Southwest Research Institute in Austin, Texas.

Energetic Particles Detector Suite (EPD)

Magnetic reconnection both causes a bulk flow of plasma – not unlike a blowing wind -- and also can pump up a small population of particles to incredibly high speeds and energies. The details of this latter process remain undetermined, although many theories having been suggested. The Energetic Particles Detector Suite will help distinguish between the theories and help determine whether this acceleration only works for electrons or also for heavier particles, the charged atoms known as ions. Short-term bursts of incredibly fast ions have been observed in the magnetic tail trailing behind Earth, and it is possible that these are due to magnetic reconnection as well.

EPD also remotely senses the structure of a large space environment surrounding reconnection sites, because it can observe particles coming in from far away. The instruments tracks ions that move along giant circles, often larger than 2000 miles in diameter, and very fast electrons that move up to 80% the speed of light.

EPD observes these high-speed particles through two instruments: the Fly's Eye Energetic Particle Sensor and the Energetic Ion Spectrometer.

Fly's Eye Energetic Particle Sensor (FEEPS):

The primary job of FEEPS is to obtain nearly instantaneous all-sky measurements of how many electrons of different energies and different arrival directions are present. The instrument relies on solid-state detectors made of silicon, a semiconductor, much like those used in computer electronic systems. Whenever a charged particle hits the detector, it initiates a current that can be used to measure the energy of the original particle. There are two FEEPS instruments per spacecraft, and together they provide 18 views in different directions simultaneously, giving rise to the "fly's eye" in the instrument's name. FEEPS has two sets of sensors, one for electrons and one for ions. The solid-state detectors within each of the electron "eyes" are covered by a 2-micrometer aluminum foil, which keeps out the ions. The detectors for the ion views, on the other hand, have no aluminum foil and are exceedingly thin so that electrons generally pass through without leaving a detectable signal.

FEEPS was developed by The Aerospace Corporation of El Segundo, California.

Energetic Ion Spectrometer (EIS):

The Energetic Ion Spectrometer also gathers all-sky measurements of the energetic ions, collecting information about their energy, their arrival direction and their mass. EIS can determine the mass of these particles by measuring their velocity and total energy. The mass information helps determine how many protons, helium ions and oxygen ions are present.

To measure the energy, EIS uses a solid-state detector like the one on FEEPS. Velocity is measured using two very thin foils and a microchannel plate sensor. When an ion travels through the first foil, it knocks a few electrons off. These electrons are deflected toward the microchannel plate, which can amplify the signal, sending 1 million electrons out the other side -- just like the detectors used in the plasma suite. The ion continues traveling to the second foil, where a similar process occurs. By determining the time of flight between electron detection at the first and second foils, the instrument can determine the velocity of the original incoming particle.

Combining the comprehensive ion measurements of EIS with the simpler ion measurements on FEEPS allows researchers to determine the ion properties at a faster rate of 1/3 of a spacecraft spin, a cadence that will sometimes be needed in the vicinity of fast-changing reconnection sites.

EIS development was led by the Johns Hopkins University Applied Physics Laboratory in Laurel, Md.

Fields Suite:

At the heart of magnetic reconnection lies the fact that magnetic fields change their configuration, so the Fields suite has the important job of observing the magnetic fields themselves. It also observes the key signatures of electric fields, which also change as part of the reconnection process. MMS will measure electric fields simultaneously in all three dimensions with better precision than any previous mission.

Because MMS will typically fly through a reconnection region in well under a second, the Fields suite can gather information more than 1000 times per second -- the highest time-resolution measurements on MMS. The Fields suite is made of six sensors: the Analog Fluxgate and Digital Fluxgate magnetometers, the Electron Drift Instrument, the Spin-plane Double Probe, the Axial Double Probe, and the Search Coil Magnetometer. The sensors all work together, in some cases providing confirmation measurements, but also to cross-calibrate each other, thus providing very precise measurements.

Analog Fluxgate (AFG) and Digital Fluxgate (DFG) Magnetometers:

The magnetometers provide two sets of similar measurements. The fluxgates carry a permeable material that changes properties in response to the presence of magnetic fields. Measuring how they change can be correlated to strength of the field down to a half a nanotesla – typical fields in the regions of interest will be about 50 nanotesla.

The AFG sensors were provided by the University of California in Los Angeles and the DFG instrumentation was provided by the Space Research Institute of the Austrian Academy of Sciences in Graz, Austria.

Electron Drift Instrument (EDI):

The Electron Drift Instrument measures both the electric and magnetic fields by tracking the path of electron beams through space. EDI sends a beam of electrons out into space using each of its two Gun Detector Units. In the presence of magnetic fields, electrons travel in orbits that are nearly circles, so over the course of about half a mile, the electron beam curves around on itself until it comes back in to the second Gun Detector Unit. By measuring how long it takes the electrons to circle back, one can calculate the strength of the magnetic fields through which the beam traveled.

When electric fields are present as well, then the electron beam will not make a perfect circle, but will drift in a predictable way as it returns. By measuring the size of that sideways drift, one can calculate the strength of the electric fields.

This technique of correctly capturing the electron beam was perfected for use on the joint European Space Agency/NASA Cluster mission. On MMS, the EDI will take faster measurements than on Cluster. Its strength, however, is not in its speed but in its precision, because knowing how much the particles are being displaced in space due to an electron field is crucial for accurate measurements by other instruments aboard MMS.

If needed, EDI can also be used solely as a detector, measuring all incoming electrons from space as opposed to just tracking its own specialized electron beam. In this case, EDI can make observations at rates of up to 1,000 times a second.

The EDI electric gun was developed at the Space Research Institute. EDI optics were developed at the University of Iowa. The sensitive detector, the controlling electronics, and the overall integration and operation of the EDI instrument is the responsibility of the University of New Hampshire in Durham.

The Spin-plane Double Probe (SDP) and the Axial Double Probe (ADP):

MMS carries two sets of double-probe instruments. Each measures the voltage between two electrodes to determine the electric field. Because the field changes are quite small, the electrodes must be set as widely apart as possible to provide a robust signal. Thus the double probes sensors reside at the ends of very long booms that deploy away from the main body of the observatory after it is launched.

The Spin-plane Double Probe, or SDP, consists of four 200-foot wire booms with spherical sensors at the end. These booms stick out of the sides of the observatory. The Axial Double Probe, or ADP, is aligned through the center of the observatory, along its spin axis. It is made of two 30-foot antennas.

Gathering accurate measurements while the spacecraft spins around is no small feat, and the accuracy of the probes is continually checked and calibrated against measurements made by EDI.

The SDP is the product of a collaboration between the University of New Hampshire, the Royal Institute of Technology in Sweden, and the University of Colorado in Boulder. The ADP was provided by the University of Colorado.

Search Coil Magnetometer (SCM):

The Search Coil Magnetometer provides direct measurements of changes in the magnetic fields, using something called an induction magnetometer. The magnetometer contains a coil of wire around a ferromagnetic material. It is a basic law of physics that a changing magnetic field near such a coil will induce a voltage. Measurements of the voltage, therefore, can be used to determine how the magnetic field changes.

The SCM was developed at the Laboratory for Plasma Physics in Paris, France.

FIELDS Central Electronics (CEB):

All the FIELDS measurements are coordinated, collected, and transmitted from a central electronics system. This set of electronics was the responsibility of the University of New Hampshire, the Royal Institute of Technology, the University of California in Los Angeles, the University of Colorado, and the Space Research Institute.

In addition to the basic science instrument suites, the payload includes:
Two Active Spacecraft Potential Control Devices (ASPOC): The ASPOCs neutralize the electrical potential of the spacecraft, limiting or eliminating spurious electric fields that can contaminate measurements. This allows observations of the more scientifically important low-energy ions and electrons. The ASPOCs were developed at the Institut fuer Weltraumforschung of the Austrian Academy of Sciences in Vienna.
Central Instrument Data Processor (CIDP): The CIDP provides the interface between the instruments and the spacecraft Command and Data Handling subsystem. The CIDP was developed at the Southwest Research Institute.

MMS Glossary

Aurora: An aurora is a natural display of light in the night sky that typically occurs in far northern and southern regions, in a rough oval known as the auroral zone. Auroras occur when incoming charged particles from the sun are channeled by Earth's magnetic field into the atmosphere. The particles strike oxygen and nitrogen about 60 to 200 miles up in Earth's atmosphere, releasing flashes of light and heat. Auroras are visible from the ground as the *aurora borealis,* or *northern lights,* and the *aurora australis*, or *southern lights.*

Coronal mass ejection or CME: Not to be confused with the intense burst of light that is a solar flare, a CME is a cloud of magnetized solar material that erupts from the sun's atmosphere, the corona, into interplanetary space. The details of how a CME starts are unknown, but magnetic reconnection is certainly a catalyst. At their largest, CMEs can contain 10 billion tons of matter, and they can move at speeds of a million miles an hour. Just after blowing into space, a CME cloud can grow as wide as 30 million miles across, 35 times the diameter of the sun. When a CME travels toward Earth, it can take anywhere from one to three days to reach our atmosphere, where it can create a type of space weather known as a geomagnetic storm.

Dayside: The side of Earth facing the sun.

Electrons: Negatively charged particles that can either exist as part of an atom or travel on their own. They can also hop from one atom to another, causing neutral atoms to become positive or negative particles -- known as ions -- depending on the particular interaction. Understanding how electrons and charged particles move and interact with each other, especially in the presence of magnetic fields, lies at the heart of understanding the plasmas around Earth.

Geomagnetic storm: Geomagnetic storms are disturbances in Earth's magnetic field. They are caused when energy from the sun -- in the form of CMEs or high-speed streams of solar wind -- meets up with Earth’s magnetic system, the magnetosphere, in an alignment that causes magnetic reconnection. Particles and energy are then transferred into the magnetosphere, typically over the course of many hours. Magnetic storms can degrade communication signals and cause unexpected electrical surges in power grids.

Heliosphere: The heliosphere is the sphere of the sun's influence, a bubble defined by the outflow of particles from the sun called the solar wind, streaming far past the outermost planets, six to nine billion miles away from the sun. Solar particles speed outward from the sun, pushing back the material in the rest of space, known as the interstellar medium. The boundary between the two defines the edges of the heliosphere.

Ions: Atoms that have either gained or lost electrons and have therefore become charged. A gas of hot ions is called plasma, and plasmas are subject to laws of electromagnetism – including the process of magnetic reconnection -- causing a complex system of motion unlike what is typically experienced with the mundane, non-charged particles on Earth.

Interplanetary magnetic field, or IMF: As the solar wind flows outward from the sun at several million miles per hour, it drags the sun's magnetic field with it. This magnetic field permeates the solar system and is known as the interplanetary magnetic field. While the IMF typically deflects around Earth's magnetic field, the IMF can sometimes connect with Earth's field through magnetic reconnection, allowing solar wind energy and particles to funnel directly into Earth's magnetosphere.

Magnetic field: A field of force that guides the motion of anything electrically charged. Earth and the sun and several planets have giant magnetic fields surrounding them, which roughly link north and south poles along lines of magnetic force, known as magnetic field lines.

Magnetic reconnection: Magnetic reconnection is the source of many of the energetic events throughout the universe, from solar flares and coronal mass ejections on the sun to space weather events near Earth that create auroras. Magnetic field lines normally cannot cross each other. Under special conditions, however field lines can connect and then reconfigure into a new alignment. This process provides huge amounts of energy as the magnetic fields rebound explosively into new positions, sending particles and plasma off into space.

Magnetosphere: The magnetosphere is the area in space formed by Earth’s magnetic field. It protects life on Earth by deflecting the incoming magnetic and particle energy that constantly streams from the sun. Created by the natural magnetism of the planet, the magnetosphere gets molded into a teardrop shape as the solar wind blows past. Sometimes, solar wind energy breaches the magnetosphere, leading to geomagnetic storms and other forms of space weather. Mercury and the giant gas planets also have magnetospheres.

Magnetotail: Earth's magnetotail blows out behind it – the tail of the teardrop-shaped magnetosphere. It extends over a hundred thousand miles behind Earth. Energy from the solar wind can be stored here, before being explosively released toward Earth or further down the tail through magnetic reconnection.

Night Side: The side of Earth facing away from the sun.

Plasma: Plasma is a state of matter just like gas, solid and liquid that is essentially a gas made up of charged particles. Much of the material in Earth's magnetosphere -- as well as the material in the sun and the solar wind -- are all plasmas. Plasmas are so incredibly hot that some electrons leave their atoms, making it a gas of charged particles called ions. The electrical charge strongly affects how the particles move, as the particles are simultaneously governed by, and constantly creating, magnetic fields. For example, in close-up images of solar activity, you can see the plasma very clearly following the magnetic field lines. Conversely, as plasma moves, it drags its own magnetic fields along for the ride. While uncommon on Earth, 99% of the matter we can observe in the universe is made of plasma.

Solar flare: A great burst of light and radiation due to the release of magnetic energy on the sun. The exact process of what initiates a solar flare is not yet known, but they are often rooted in magnetically complex spots on the sun and magnetic reconnection is certainly involved. Flares are by far the biggest explosions in the solar system, with energy releases comparable to billions of hydrogen bombs. The radiation from the flare travels at the speed of light, and so reaches Earth within eight minutes. The energy is generally absorbed by Earth's atmosphere, which protects humans on Earth, however, the energy can cause radio blackouts on Earth for minutes or, in the worst cases, hours at a time. Some, but by no means all, flares have an associated coronal mass ejection.

Solar wind: The solar wind is a constant stream of charged particles, a state of matter called plasma, flowing away from the sun at millions of miles per hour. It consists primarily of protons and electrons, with some ionized helium. As the solar wind travels through interplanetary space it carries along an embedded magnetic field.

Substorm: An explosive release of magnetic energy that originates in Earth's magnetotail, drawing on energy funneled there from the solar wind and other solar events. Substorms are quite common, occurring more often during solar maximum. The energy can be released via magnetic reconnection, releasing energy toward Earth, which then flows down magnetic field lines in Earth's northern and southern regions, causing auroras.

Acronyms and Abbreviations

ADP Axial Double Probe
AFG Analog Fluxgate
ASPOC Active Spacecraft Potential Control Devices
CEB FIELDS Central Electronics
CDR Critical Design Review
CIDP Central Instrument Data Processor
CME Coronal Mass Ejection
Co-I Co-Investigator
DFG Digital Fluxgate
EDI Electron Drift Instrument
EIS Energetic Ion Spectrometer
EPD Energetic Particles Detector Suite
FEEPS Fly's Eye Energetic Particle Sensor
FIELDS: *not an acronym,* name of MMS electric and magnetic field investigation
FPI Fast Plasma Investigation
FRR Flight Readiness Review
GDU Gun Detector Unit
GEONS GPS Enhanced Onboard Navigation System
GPS Global Positioning System
GSFC Goddard Space Flight Center
HEO Highly Elliptical Orbit
HPCA Hot Plasma Composition Analyzer
HQ Headquarters
JAXA Japanese Aerospace Exploration Agency
KSC Kennedy Space Center
MMS Magnetospheric Multiscale
MOC Mission Operations Center
NASA National Aeronautics & Space Administration
OBS Observatory

PI Principal Investigator
PS Project Scientist
Re Earth Radius
SCM Search Coil Magnetometer
SDP Spin-plane Double Probe
STP Solar Terrestrial Probes
STEREO Solar and Terrestrial Relations Observatory
SwRI Southwest Research Institute
THEMIS Time History of Events and Macroscale Interactions during Substorms
TIMED Thermosphere, Ionosphere, Mesosphere Energetics and Dynamics

A comprehensive list can also be found here: http://mms.gsfc.nasa.gov/acronyms.html

Solar Terrestrial Probes

The Solar Terrestrial Probes, or STP, Program is part of NASA's Science Mission Directorate Heliophysics Division. The Program addresses fundamental science questions about the physics of space plasmas and the flow of mass and energy through the solar system. **The goal is to understand the processes that determine the mass, momentum, and energy flow in the solar system from the sun to planetary bodies, including Earth, to the interstellar boundary.**

STP program objectives are to:

1. To describe the system behavior of the magnetic variable star, our sun, and its interaction with the entire solar system;
2. To understand the critical physics that link the sun, Earth, heliosphere, and the interstellar medium;
3. To understand the processes and dynamics of the magnetosphere-ionosphere-upper atmosphere system, the near space electromagnetic plasma environment surrounding the Earth: and,
4. To develop and mature instrumentation and mission technologies with the potential of advancing STP science.

These objectives support the Agency's strategic goal to understand the sun and its effects on Earth and the solar system, including space weather. STP missions study the fundamental processes leading to evolutionary and future changes. Successive missions will focus on critical science targets that systematically advance understanding of the coupled solar-heliosphere-terrestrial system. The missions use a creative blend of *in situ* and remote sensing observations, often from multiple platforms, to understand these fundamental physical processes, such as magnetic reconnection

In addition to MMS, current STP missions include:

TIMED: The Thermosphere, Ionosphere, Mesosphere Energetics and Dynamics, or TIMED, mission launched on Dec. 7, 2001, to study how Earth's Mesosphere and Lower Thermosphere are affected by solar-terrestrial events.

Hinode: A Japanese Aerospace Exploration and NASA mission, Hinode (previously known as Solar-B) is a highly sophisticated sun-observing satellite equipped with three advanced solar telescopes. It was launched on September 22, 2006.

STEREO: Launched on October 25, 2006, the Solar Terrestrial Relations Observatory, or STEREO, mission consists of two nearly identical observatories -- one ahead of Earth in its orbit, the other trailing behind -- providing views of the sun we cannot get from Earth. STEREO traces the flow of energy and matter from the sun to Earth, helps reveal the three-dimensional structure of coronal mass ejections, and helps us understand why they happen.

Magnetospheric Multiscale (MMS) Key Messages:

MMS solves the mystery of how magnetic fields around Earth connect and disconnect, explosively releasing energy via a process known as magnetic reconnection. MMS consists of four identical spacecraft that will provide the first three-dimensional views of this fundamental process that occurs throughout our universe.

Like stretched rubber bands, magnetic fields store energy that is released explosively when the field lines are broken during reconnection. Unlike rubber bands, reconnection can drive particles to nearly the speed of light.
MMS uses Earth’s protective magnetic space environment, the magnetosphere, as a natural laboratory to directly observe how it interacts with the sun’s extended magnetic field, which can result in reconnection.

The four MMS spacecraft fly in varying formations through reconnection regions in well under a second, so key sensors on each MMS spacecraft have been designed to take certain measurements of the space environment 100 times faster than any previous mission.

MMS Sub-Messages:

Reconnection is a common process in our universe; occurring in space near Earth, in the atmosphere of the sun and other stars, in the vicinity of black holes and neutron stars, and at virtually any boundary between space plasmas, including the boundary between our solar system's heliosphere and interstellar space.

MMS spacecraft will fly in an adjustable pyramid formation, to determine the size and structure of reconnection regions.

MMS will travel through areas near Earth where conditions for magnetic reconnection are known to exist, studying the unique reconnection characteristics of both the dayside and nightside of Earth.

Magnetic reconnection is one of the most important drivers of space weather events. Eruptive solar flares, coronal mass ejections, and geomagnetic storms all involve the release, through reconnection, of energy stored in magnetic fields. Space weather events can affect modern technological systems such as communications networks, GPS navigation, and electrical power grids.

Reconnection can be observed and studied in the laboratory where it can also interfere with sustainable energy generation in fusion devices.

MMS is the fourth mission in NASA's Solar Terrestrial Probes or STP Program. The goal of the STP Program is to understand the fundamental physical processes of the space environment from the sun to Earth, other planets, and the extremes of the solar system boundary.