

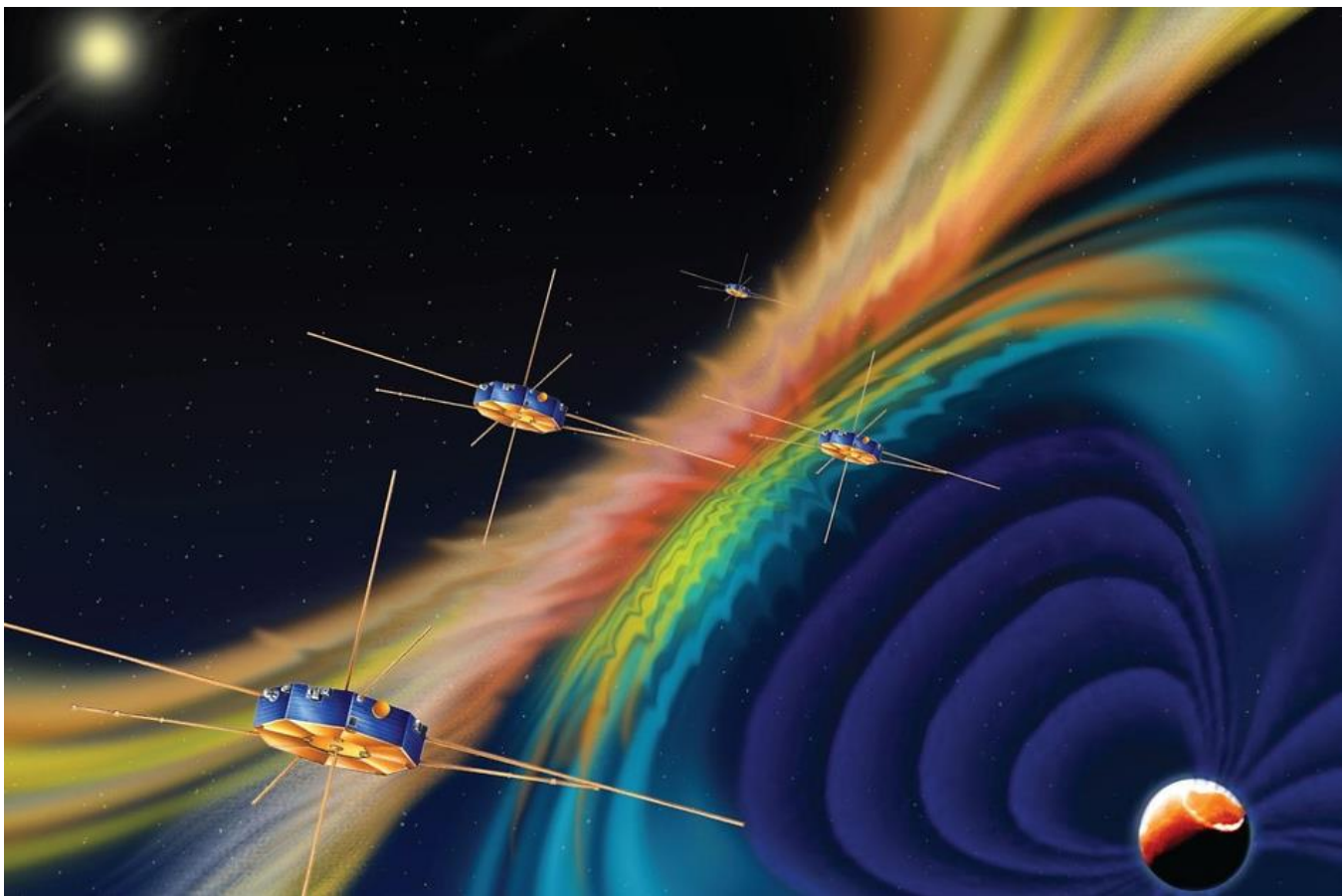
National Aeronautics and Space Administration



PRESS KIT/March 2015

## **MAGNETOSPHERIC MULTISCALE:**

Using Earth's magnetosphere as a laboratory to study the microphysics of magnetic reconnection



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## **Media Services Information**

### **NASA Television Transmission**

For digital downlink information for each NASA TV channel, access to all three channels online and a schedule of programming for Magnetospheric Multiscale activities, visit: <http://www.nasa.gov/ntv>

#### **Audio**

Audio of the pre-launch news conferences on L-2 and L-1 and launch coverage will be available on “V-circuits” that can be reached by dialing 321-867-1220, -1240, 1260, or 7135.

#### **Launch Media Credentials**

News media interested in attending the launch must be accredited through the NASA News Center at Kennedy Space Center. To apply for credentials, visit: <https://media.ksc.nasa.gov>

Journalists may contact the KSC news media accreditation office at 321-867-6598 or 321-867-2468 for more information.

#### **Briefings**

Two pre-launch press briefings will be held at the KSC press site. A pre-launch mission briefing will be held March 10 at 1 pm EDT. A pre-launch science briefing is scheduled for March 11 at 1 pm EDT. Both of these press briefings will be carried live on NASA TV.

#### **NASA Television Coverage**

NASA TV coverage on launch day will begin at 8 p.m. EDT. For information about NASA Television coverage of the launch, visit: <http://www.nasa.gov/ntv>

#### **KSC News Center/Status Reports**

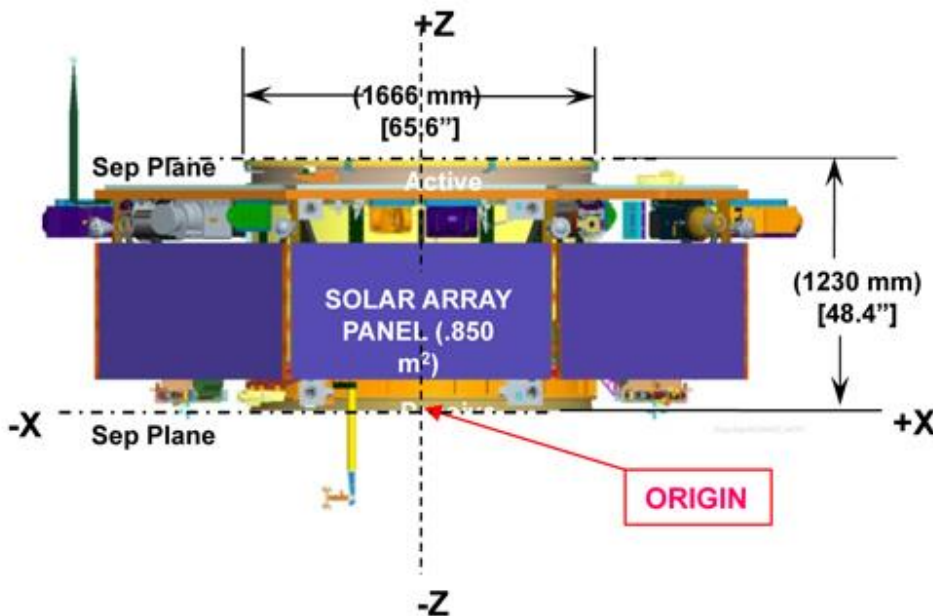
The NASA News Center at KSC will be staffed for the Magnetospheric Multiscale mission beginning four days before launch and can be reached at: 321-867-2468. Launch status reports will be recorded on the KSC news media Codaphone beginning Monday, March 9, 2015 by dialing 321-867-2525.

#### **NASA Web Prelaunch and Launch Coverage**

NASA’s homepage will provide extensive prelaunch and launch day coverage of the MMS mission at: [www.nasa.gov](http://www.nasa.gov)

## QUICK FACTS

**Spacecraft:** Each of the four MMS observatories are octagonal in shape, approximately 11 feet across by 4 feet high. When stacked together inside the launch vehicle, the observatories are more than 16 feet tall.



**On Orbit Spacecraft Dimensions:** Each observatory, with axial booms and wire booms extended, grows to about 94 feet tall by 369 feet wide.

**Fueled Mass:** Each observatory weighs about 2,998 pounds (1360 kg).

**Primary Power:** Provided by eight solar array panels on each observatory, with secondary battery energy storage for use during eclipses.

**Propulsion System:** Consists of 12 thrusters and four hydrazine propellant tanks located within the central thrust tube on each observatory.

**Spin Rate:** Each observatory is spin-stabilized, with a spin rate of three revolutions per minute.

**Attitude Information:** Provided by four star cameras, two three-axis accelerometers and two sun sensors. Thrusters are used for attitude and orbit adjustment maneuvers.

**Position Information:** Each observatory is equipped with a new navigator based on extremely sensitive GPS equipment to provide absolute position information. This is necessary because the

observatories fly in an orbit higher than that of the GPS satellites, so they must rely on the weaker signals from GPS satellites on the far side of Earth.

**Launch Vehicle:** Atlas V 421 provided by United Launch Alliance. The vehicle consists of an Atlas first-stage engine and a Centaur second-stage engine, with two additional strap-on solid rocket boosters.

**Launch:** March 12, 2015 at 10:44 pm ET, at the beginning of a 30-minute launch window, from Launch Complex 41 located at Cape Canaveral Air Force Station, Florida.

**Deployment:** The first of four MMS observatories will be deployed into orbit beginning about one hour, 32 minutes after launch and continue to deploy at five-minute intervals.

**Commissioning phase:** (time between deployment and commencement of primary science mission) is 5.5 months.

**Primary mission:** Two years in addition to the commissioning phase.

**Orbit:**

MMS will travel in two 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 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.

**NASA Investment:**

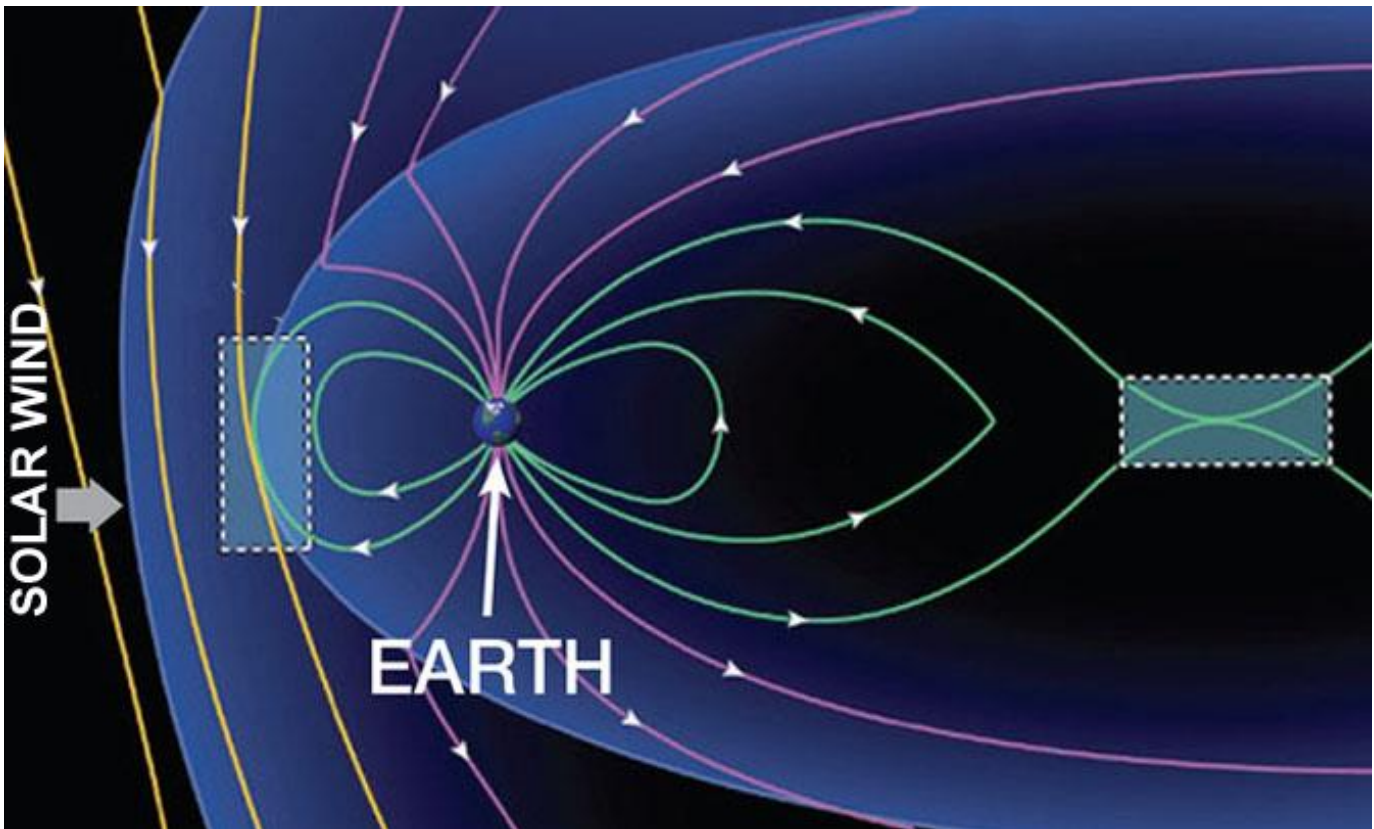
\$1.1 billion (design, development, launch and operations)

**Historical Context:** Several spacecraft, such as NASA's Time History of Events and Macroscale Interactions during Substorms, or THEMIS, Explorer mission and the European Space Agency (ESA) and NASA's Cluster, have previously gathered some data when they happened to fly through a magnetic reconnection event in Earth's magnetosphere. However, *MMS is the first mission dedicated to the study of this phenomenon and will collect data at rates more than 100 times faster than any previous mission.*

## Science Objectives

Much of what scientists know about the small-scale physics of magnetic reconnection is derived from theoretical studies, computer models and observations of reconnection events seen on the sun. A better understanding, however, can only be obtained by measuring reconnection directly. MMS will access a natural laboratory by traveling through the magnetic, plasma-filled environment around Earth, called the magnetosphere.

MMS will fly directly through areas near Earth thought 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 is believed to help trigger aurora, also known as the Northern or Southern lights.



*Caption: MMS will use a two-phase orbit strategy to explore different regions where magnetic reconnection often occurs, one on the day-side and the other on the night-side of Earth. Credit: NASA*

By studying how reconnection occurs near Earth, MMS will vastly improve our understanding of how this fundamental process works elsewhere in the universe. Magnetic reconnection also occurs on the sun and is the driver for solar flares and massive eruptions of solar material called coronal mass ejections.

Scientists also theorize that magnetic reconnection may be involved with a variety of astrophysical phenomena including how ultra-high-energy cosmic rays are accelerated so fast. Understanding reconnection better could even provide clues to developing a new source of efficient, clean, sustainable energy here on Earth, as magnetic reconnection can interfere with the success of fusion energy reactors.

## **What Questions Will MMS Answer?**

MMS will vastly improve our understanding of magnetic reconnection by addressing these fundamental questions:

- What conditions determine when reconnection is initiated and when it ceases?
- What determines the rate at which reconnection occurs?
- What is the structure of the reconnection region?
- How does the plasma become demagnetized in the reconnection region?
- What is the role of turbulence in the reconnection process?
- How does reconnection accelerate particles to high energies?



## Science and Instrument Payload

Each MMS observatory carries 11 scientific instruments made up of 25 separate sensors. The numerous instruments are divided into three investigations, or groups:

- [Hot Plasma Suite](#): to observe the nature of the charged gas, or plasma, present during reconnection
- [Energetic Particles Detector Suite](#): to observe the fast-moving, energetic particles
- [Fields Suite](#): 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 have 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.

The Johns Hopkins University Applied Physics Laboratory in Laurel, Maryland led the EIS

development.

### **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 University of California in Los Angeles provided the AFB sensors. 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 electric 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 resulted from a collaboration between the University of New Hampshire, the Royal Institute of Technology in Sweden, and the University of Colorado in Boulder. The University of Colorado provided the ADP.

### **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 MMS payload includes:**

**Active Spacecraft Potential Control Devices (ASPOC):**

The two 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.

For the location of each instrument as well as a more thorough description, visit:

[http://www.nasa.gov/mission\\_pages/mms/spacecraft/mms-instruments.html](http://www.nasa.gov/mission_pages/mms/spacecraft/mms-instruments.html)

## NASA's Launch Services Program

NASA turns to the engineers and analysts in its Launch Services Program, or LSP, to send robotic spacecraft on their way for some of the most exciting and notable missions in the agency's history.

The LSP is based at NASA's Kennedy Space Center in Florida and boasts a roster of engineers and technicians who specialize in all aspects of rocketry and spacecraft integration. LSP selects the appropriate launcher for a mission's spacecraft; in this case the United Launch Alliance Atlas V. Often, this selection process takes place years before the first launch opportunity. The program then provides oversight as the designs of the rocket and mission are integrated with each other. As liftoff nears, teams oversee the launch vehicle's engineering and manufacture and its integration with the spacecraft.

LSP also conducts the countdowns for NASA's scientific missions and provides additional quality assurance along with other controls to ensure a successful mission.

Working with commercial rocket builders, planners have a number of rocket models to choose from, ranging from the small, air-launched Orbital Sciences Pegasus to the workhorse Delta II rocket from the United Launch Alliance, or ULA, to the powerhouse Atlas V, also from ULA. The catalog is growing, too, with the addition of the SpaceX Falcon 9 and Orbital Sciences Antares rockets.

LSP moved its operations to Kennedy in 1998, becoming the first program based at the nation's premiere launch site. Since that time we have seen orbiters, landers and rovers to Mars, huge observation spacecraft to Jupiter and the New Horizons mission launched to Pluto and the Kuiper Belt, two astronomical locations that have never been seen up-close before.

Because some spacecraft need to fly in a different kind of orbit, LSP operates several launch centers around the world. Cape Canaveral Air Force Station in Florida is adjacent to Kennedy Space Center and hosts launches to place spacecraft in orbits that remain close to the equator. The LSP launch team goes to Vandenberg AFB in California to run launches that require spacecraft to fly around the world in a north-to-south orbit, known as a polar orbit. LSP also conducts launches from Kwajalein in the Marshall Islands, Kodiak Island, Alaska, and NASA's Wallops Flight Facility on Virginia's eastern Shore.

For Launch Services Program Updates and information, visit:

<http://www.nasa.gov/centers/kennedy/launchingrockets/index.html>

## Program/Project Management

The Magnetospheric Multiscale mission is a major scientific undertaking, involving institutions in the United States as well as several partners in Europe and Japan.

MMS is the fourth NASA Solar Terrestrial Probes, or STP, 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.

The STP Program, which is part of NASA's Science Mission Directorate Heliophysics Division, 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.

Key STP program objectives are as follows:

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.