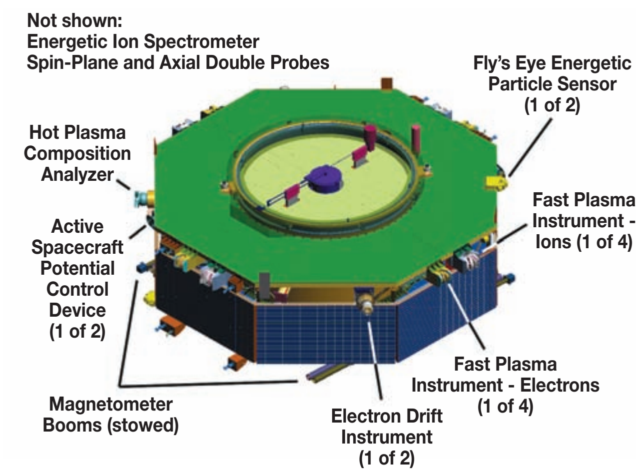


The four MMS spacecraft will carry identical suites of plasma analyzers, energetic particle detectors, magnetometers, and electric field instruments as well as a device to prevent spacecraft charging from interfering with the highly sensitive measurements required in and around the diffusion regions. The plasma and fields instruments will measure the ion and electron distributions and the electric and magnetic fields with **unprecedented high (millisecond) time resolution and accuracy.** These measurements will enable MMS to locate and identify the small (10's of km) and rapidly moving (10-100 km/s) diffusion regions, to determine their size and structure, and to discover the mechanism(s) by which the plasma and the magnetic field become decoupled and the magnetic field is reconfigured. MMS will make the first unambiguous measurements of plasma composition at reconnection sites, while energetic particle detectors will remotely sense the regions where reconnection occurs and determine how reconnection processes produce such large numbers of energetic particles.

The four satellites will be launched together on a single launch vehicle and inserted sequentially into Earth orbit. As they explore the dayside and nightside reconnection regions, the spacecraft will fly in a **tetrahedral (pyramid) formation,** allowing them to capture the three-dimensional structure of the reconnection sites they encounter. Onboard propulsion will be used to adjust the separation among the spacecraft, from hundreds of kilometers to as close as 10 kilometers, in order to achieve the optimum interspacecraft separation for probing the diffusion region.

The MMS Team

The MMS mission is a major scientific undertaking, involving a number of institutions in the United States as well as partners in Europe and Japan. The MMS Science Team (J.L. Burch, PI) is led by Southwest Research Institute, San Antonio, Texas, and consists of an Instrument Team and a Theory and Modeling Team. In addition, NASA has selected three interdisciplinary Science (IDS) teams to participate in the mission as members of the MMS Science Working Group. The four spacecraft are being built, integrated, and tested at NASA's Goddard Space Flight Center, Greenbelt, Maryland, which is also responsible for mission operations. Science operations planning and instrument command sequence development will be performed at the MMS Science Operations Center (SOC) located at the University of Colorado's Laboratory for Atmospheric and Space Physics, Boulder, Colorado.

MMS Quick Facts

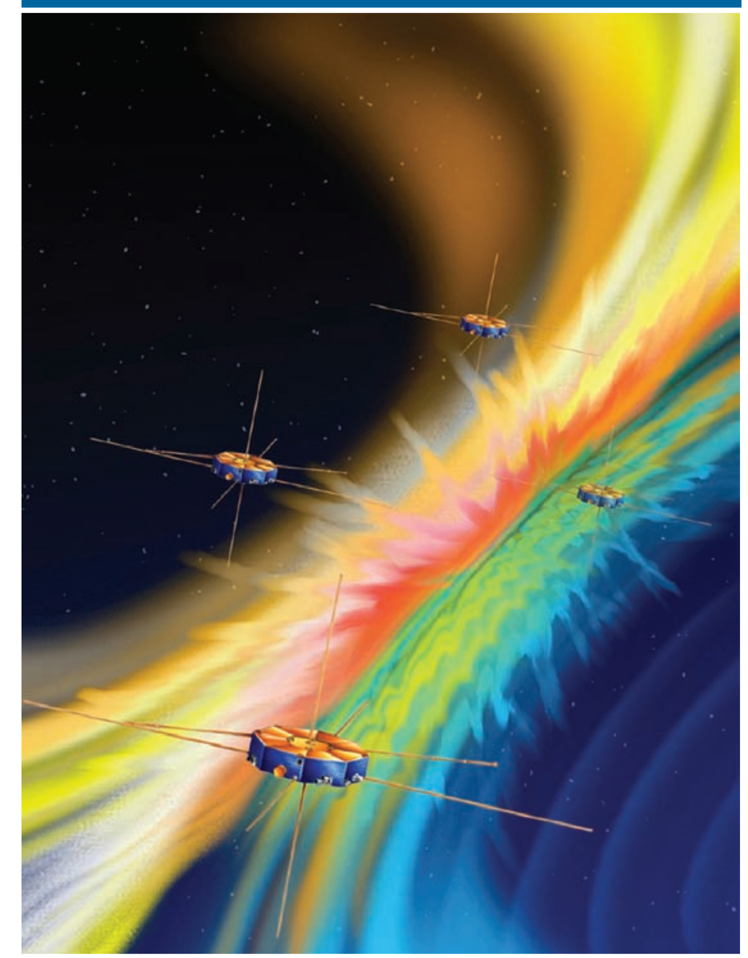
- ✓ Objective: *Discover the fundamental physics of magnetic reconnection using Earth's magnetosphere as a laboratory*
- ✓ Implementation: *4 identically instrumented spin-stabilized spacecraft launched on a single expendable launch vehicle and configured in a tetrahedral formation to probe the dayside and nightside reconnection regions*
- ✓ Launch: *October 2014*
- ✓ Orbit: *1.2 R_E by 12 R_E (dayside); 1.2 R_E by 25 R_E (nightside)*
- ✓ Instrument Suite: *Fast Plasma Instrument; Electric and Magnetic Fields; Hot Plasma Composition Analyzer; Energetic Particles; Active Spacecraft Potential Control; Central Instrument Data Processor*
- ✓ MMS Team Leads and IDS: *Southwest Research Institute (Science Team Lead, Hot Plasma Composition Analyzer, Central Instrument Data Processor); NASA Goddard Space Flight Center (Fast Plasma Instrument, Theory & Modeling, spacecraft development, mission operations, IDS); University of New Hampshire (Electric and Magnetic Fields); the Johns Hopkins University Applied Physics Laboratory (Energetic Particles); University of Colorado (MMS Science Operations Center, IDS); Austrian Academy of Sciences (Active Spacecraft Potential Control); University of California Berkeley (IDS)*
- ✓ *MMS was ranked the highest-priority moderate-sized mission in the 2003 solar and space physics decadal survey of the National Research Council*

For more information on MMS, see:http://mms.space.swri.edu/

NP-2008-12-060-GSFC

National Aeronautics and Space Administration

MMS



Magnetospheric Multiscale

A Solar-Terrestrial Probe Mission

www.nasa.gov

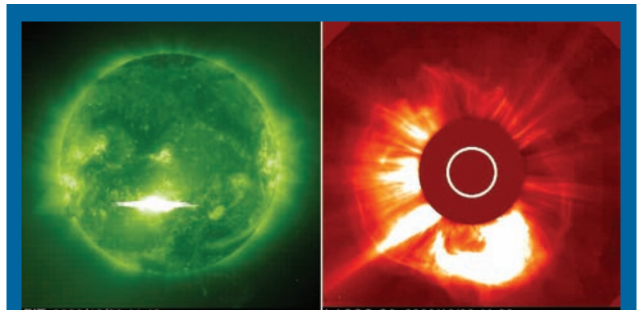
Magnetic forms produce activity and violence in the otherwise serene thermal degradation of the cosmic landscape.
– E.N. Parker

The Magnetospheric Multiscale Mission

The Magnetospheric Multiscale (MMS) mission is a Solar-Terrestrial Probe Program mission within NASA's Heliophysics Division. The MMS mission, consisting of four identically instrumented spacecraft, will use Earth's magnetosphere as a laboratory to study ***magnetic reconnection***, a fundamental plasma-physical process that taps the energy stored in a magnetic field and converts it—typically explosively—into heat and kinetic energy in the form of charged particle acceleration and large-scale flows of matter.

Magnetic reconnection occurs universally in ***plasmas***, the electrically conducting mixes of positively and negatively charged particles that account for an estimated 99% of the observable universe. It is the ultimate driver of the phenomena we know as "space weather": eruptive solar flares, coronal mass ejections (CMEs), geomagnetic storms, and magnetospheric substorms all involve the release through reconnection of energy stored in magnetic fields.

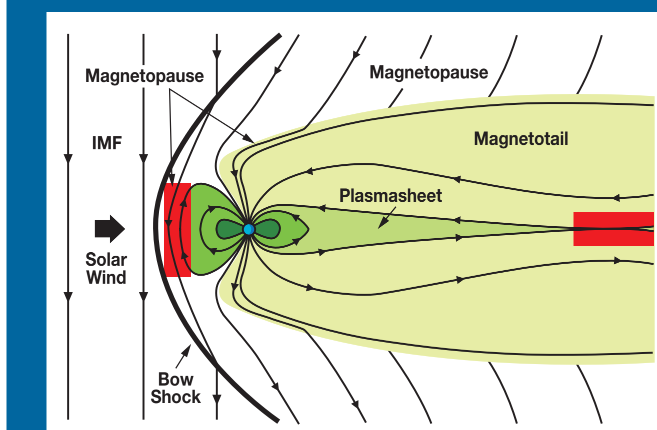
In addition to its ***central role in solar-terrestrial relations***, magnetic reconnection has been invoked in theoretical models of a variety of astrophysical phenomena including star-accretion disk interaction, pulsar wind acceleration, and the acceleration of ultra-high-energy cosmic rays in active galactic nuclei jets. Reconnection occurs in man-made as well as natural settings, in fusion machines (tokamaks, spheromaks) and in laboratory reconnection experiments.



Tremendous amounts of energy are stored in the Sun's magnetic fields. Magnetic reconnection releases some of this stored energy in the form of solar flares (left) and CMEs (right).

Earth's Magnetosphere: Nature's Plasma Physics Lab

Much of what we know about the physics of magnetic reconnection comes from theoretical studies and computer models. True understanding requires that our theories and models be placed on the secure foundation of *in situ* observation. The reconnection mechanism cannot be studied *in situ* on the Sun or in remote astrophysical systems; nor can it be effectively studied in laboratory experiments where the scale sizes on which the critical processes operate are too small to be resolved. However, Earth's magnetosphere, whose structure and dynamics are controlled by reconnection, is accessible to regular *in situ* measurement and provides the ideal ***natural laboratory*** in which to investigate magnetic reconnection as well as other plasma processes that occur throughout the cosmos.



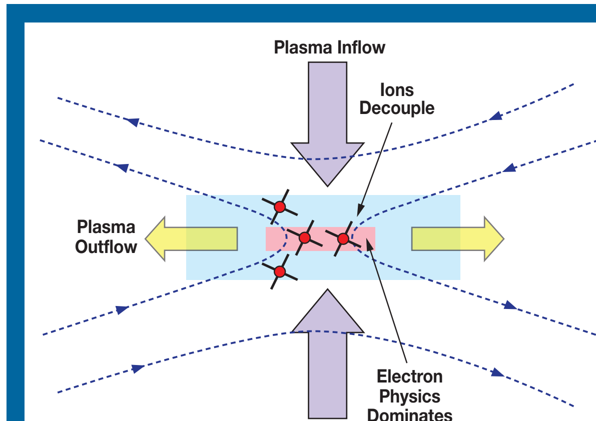
Magnetic reconnection occurs in two main regions of the magnetosphere (red boxes): (1) the dayside magnetopause and (2) the nightside magnetotail. MMS will employ ***a two-phase orbit strategy*** to explore each of these regions in turn. In ***Phase 1***, MMS will probe reconnection sites at the dayside magnetopause. Here the interplanetary magnetic field (IMF) merges with the geomagnetic field, transferring mass, momentum, and energy to the magnetosphere. The solar wind flow transports the merged IMF/geomagnetic field lines toward the nightside, causing a build up of magnetic flux in the magnetotail. In ***Phase 2***, MMS will investigate reconnection sites in the magnetotail, where reconnection releases the stored magnetic energy in explosive events known as magnetospheric substorms and allows the magnetic flux stripped away from the dayside magnetopause by the solar wind/magnetosphere interaction to return to the dayside.

Unlocking the Secrets of the Diffusion Region

Cosmic plasmas are threaded throughout with magnetic lines of force. The field lines and the plasma are tied to one another and move together in the flow of the plasma. If magnetic fields in adjacent regions have opposite or significantly different orientations, the field lines and plasma can become decoupled, with the field lines breaking and then "reconnecting" with those in the adjacent region. When this happens, the energy stored in the magnetic fields is released as kinetic energy and heat. The breaking and reconnection of the magnetic field lines takes place in a narrow boundary layer called the ***diffusion region***.

The overarching goal of the MMS mission is to measure the plasma and the electric and magnetic fields inside the diffusion regions in Earth's magnetosphere in order to answer the following fundamental questions:

- ✓ ***How do the plasma and magnetic fields become decoupled in the diffusion region? In particular, what role do the electrons play in facilitating reconnection?***
- ✓ ***What determines the rate at which reconnection occurs?***
- ✓ ***What is the structure of the diffusion region?***
- ✓ ***What conditions determine when reconnection is initiated and when it ceases?***
- ✓ ***How does reconnection accelerate particles to high energies?***
- ✓ ***What is the role of turbulence in the reconnection process?***



Inflowing plasma carries oppositely directed magnetic field lines into the diffusion region, where, separated by as little as 10 km, the four MMS spacecraft will make the measurements needed to determine the processes that drive reconnection.