Preface

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The NASA Magnetospheric Multiscale (MMS) Mission is the fourth Solar-Terrestrial Probe (STP) after TIMED, Solar-B, and STEREO. The chief objective of the STP line of missions is to understand the fundamental physical processes of the space environment from the Sun to Earth, to other planets, and beyond to the interstellar medium. As an important part of this program, the primary objective of MMS is to understand magnetic reconnection in the boundary layers of the Earth's magnetosphere, which are formed by its interaction with the solar wind. Magnetic reconnection is an important energy conversion process in the solar atmosphere (solar flares and coronal mass ejections), in the interaction between the solar wind and planetary magnetospheres, in astrophysical phenomena including magnetar flares and neutron star and black hole accretion disks, and in the laboratory where it produces sawtooth crashes in magnetic confinement fusion devices. It is well recognized that the Earth's magnetosphere is the only place in space where a definitive experiment on magnetic reconnection can be conducted because of its accessibility to spacecraft. Because of the importance of magnetic reconnection and of the associated processes of particle acceleration and plasma turbulence, MMS was selected as the highest priority medium-scale mission in the National Research Council's 2003 Solar and Space Physics Decadal Survey. NASA proceeded to implement MMS within that same year.

MMS is a NASA Heliophysics strategic mission, which means that it obtains data of interest to, and for use by, the entire heliophysics science community. Under this approach, mission management and spacecraft development were assigned to the NASA Goddard Space Flight Center while the scientific measurements and associated payload development were assigned to an Instrument Suite Science Team (ISST) led by a single Principal Investigator. The ISST is named SMART for "Solving Magnetospheric Acceleration, Reconnection, and Turbulence." The SMART Team was organized around four major instruments: Fields, Energetic Particles (EPD), Fast Plasma (FPI), and Hot Plasma Composition (HPCA),

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along with an Active Spacecraft Potential Control instrument (ASPOC), a Theory and Modeling team, and an Education and Public Outreach team. NASA selected three independent Interdisciplinary Science (IDS) teams to support the mission with theory, modeling and data-analysis expertise. These teams have become an integral part of the ISST, with the IDS PIs serving on the Mission Science Working Group.

The measurements and orbital strategy were developed in response to the major MMS science objectives:

1. Determine the role played by electron inertial effects and turbulent dissipation in driving magnetic reconnection in the electron diffusion region;
2. Determine the rate of magnetic reconnection and the parameters that control it;
3. Determine the role played by ion inertial effects in the physics of magnetic reconnection.

Accomplishment of these objectives placed several requirements on the instruments and spacecraft that were unprecedented and in some cases quite difficult to meet. Previous missions such as Polar, Geotail, and especially Cluster have confirmed and refined the predictions regarding the phenomena associated with magnetic reconnection at the MHD and ion scales. In particular the role of Hall MHD in controlling the reconnection rate and the ion flow through the diffusion region was explored in detail by these missions. The most difficult requirement for MMS is to extend this understanding to the electron scale at which magnetic fields break and reconnect and as yet undefined dissipation processes convert magnetic energy to heat and particle kinetic energy.

In order to test reconnection theory at the electron scale it is necessary for MMS to obtain three-dimensional maps of particle distribution functions, electric and magnetic fields, and plasma waves within the electron diffusion region, which on the dayside, where plasma densities are high, has spatial dimensions of 10 km or less (the electron skin depth). On the nightside, in the magnetic tail, densities are lower so that the electron diffusion region is about ten times larger. Increasing the experimental difficulty is the fact that the reconnection layers are typically in motion at speeds of 10–100 km/s. In order to probe this small and moving region with multi-point measurements it was determined that spacecraft separations as small as 10 km; three-dimensional plasma electron and ion distribution functions at time resolutions of 30 ms and 150 ms, respectively; vector electric and magnetic fields every 1 ms; and plasma waves up to 100 kHz would be required. In addition, heavy ions in the keV range had to be separated from the high proton fluxes that exist near the dayside magnetopause for the first time. As with Cluster, the positive spacecraft potential that often occurs in the outer magnetosphere has to be controlled to less than a few volts.

As described in the papers contained in this special issue, all of these requirements have been met and validated for MMS. The launch on an Atlas V Centaur on March 12, 2015 at 10:44 EDT placed the spacecraft in the planned Phase-1 orbit with apogee of $12R_E$ and perigee of $1.2R_E$ at a local time of 02 hours. Commissioning of the four payloads will be complete in September 2015, at which time the orbit will commence its first scan of the dayside magnetopause (Phase 1a). During this scan the separation distance will be adjusted between 10 km and 160 km in a process to identify an optimum separation. The orbit will then scan through the night side where opportunistic science will be pursued but without close control of spacecraft separation (Phase 1x). After Phase 1x the orbit will make its second scan of the dayside magnetopause in Phase 1b with spacecraft separation fixed at the optimum value determined in Phase 1a. After the second magnetopause scan is completed, the apogee will be raised to $25R_E$, providing measurements at increasing distances along the dawnside flank of the magnetopause and then perform a scan through the magnetotail (Phase 2) during which the spacecraft separations will be varied between 10 and 400 km,

again searching for an optimum value. The primary science mission will be complete after the magnetotail scan.

Based on the early commissioning results, it is anticipated that MMS will meet all of the requirements placed on it so that it will have a unique capability for solving the mysteries of magnetic reconnection in the boundary regions of the Earth's magnetosphere as well as investigate new phenomena with its unprecedented time resolution. No doubt these new discoveries will raise new questions, but MMS should provide the important advance that is needed to move the science of magnetic reconnection forward.

Great thanks are due to the many men and women who have contributed to the successful design, development and flight of Magnetospheric Multiscale. Most of the team members are affiliated with the following major MMS institutions: NASA-GSFC for mission design and management, spacecraft development and observatory operations, lead of the FPI, lead of the Theory and Modeling team, and lead of an IDS team; Southwest Research Institute for Science and Payload management and development including the Central Instrument Data Processor and HPCA; University of New Hampshire for management and development of the Fields instrument suite; Johns Hopkins University Applied Physics Laboratory for development of the EPD instruments; Institute of Space Physics of the Austrian Academy of Sciences at Graz for development of ASPOC, lead of the digital fluxgate magnetometer, and lead of the electron gun for the Electron Drift Instrument; University of Iowa for design and development of the Electron Drift Optics; UCLA for leadership of the magnetic field investigation; Royal Institute of Technology (Sweden) and Swedish Institute of Space Physics, Uppsala, for deployer design and electronics development for the Spin-Plane Double Probes; University of Oulu (Finland), for development of Double Probe sensors; University of Braunschweig (Germany) for magnetometer calibration facilities; Institute of Space and Astronautical Sciences (Japan) for lead of the Dual Ion Spectrometers of FPI; Aerospace Corporation for development of the Fly's Eye Energetic Particle Spectrometers of EPD; University of Colorado LASP for development of the axial double probes, operation of the Science Operations Center, and leadership of an IDS team; NASA Marshall Space Flight Center for calibration of the Dual Ion Spectrometers; and UC Berkeley for leadership of an IDS team.

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