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Navigation Operations for the Magnetospheric MultiScale Mission

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Abstract

The Magnetospheric Multiscale (MMS) mission consists of four identical spinning spacecraft flying in tetrahedral formation in highly elliptical Earth orbits. The primary science objective of the mission is to study the phenomenon known as magnetic reconnection, which is a process that converts magnetic energy into heat and kinetic energy of charged particles. The Earth's magnetosphere is the only location in which this process can be practically studied in situ at this time. The regions of prime science interest are the electron diffusion regions of the Earth's dayside magnetopause and night-side neutral sheet in the magneto-tail. The mission design involves a two-phase apogee approach, where the apogee region of the orbit provides long durations in the regions of prime science interest.

The science requirement for definitive relative orbit knowledge of 1% of the separation of the spacecraft in the regions of science interest is the primary driver for the design of the MMS onboard navigation system and the associated ground system. Additional drivers for the design of the associated ground system components are the need to automate navigation support for the four spacecraft and to provide accurate spacecraft state and covariance solutions in near real-time to support maneuver planning and conjunction assessment among the spacecraft. This paper discusses the MMS navigation operational concepts and the MMS ground system components build to support navigation-related operations during the commissioning and routine mission phases.

The baseline navigation concept for MMS is independent estimation of each spacecraft state using Global Positioning System (GPS) pseudo-range measurements referenced to an Ultra Stable Oscillator (USO). High precision, high-resolution acceleration measurements from an onboard accelerometer within the Attitude Control System are included to model the frequent formation resize and formation maintenance maneuvers. Each MMS spacecraft houses an onboard navigation system consisting of a weak signal Global Positioning System (GPS) receiver, two sets of four 120-degree field of view (FOV) GPS antennas (one set of prime, one set of redundant) distributed around the spacecraft deck apexes, and onboard navigation software to estimate spacecraft position, velocity, clock bias, clock bias rate, and clock bias acceleration. The GPS receiver, *Navigator*, and the onboard navigation software, *Goddard Enhanced Onboard Navigation System* (GEONS), are both products of in-house NASA Goddard development tailored to MMS needs.

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The MMS Flight Dynamics Operations Area (FDOA) at GSFC supports MMS navigation operations, as well as maneuver planning, conjunction assessment and attitude ground operations. The GEONS Ground Support System (GGSS) component of the FDOA provides the tools needed to support MMS navigation operations. To significantly reduce routine operations staffing requirements, the FDOA System Manager component is used to automate the GGSS tools that perform daily routine GEONS telemetry monitoring, quality assurance (QA) of the onboard GEONS solutions, and definitive navigation product generation for all four spacecraft. In addition, the GGSS includes an extensive set of tools that are used to perform checkout and calibration of the onboard navigation system during an extensive commissioning phase and later as needed for performance trending and anomaly investigation and to prepare GEONS commands required to maintain the required level of performance. The GGSS tools are accessible via a single Graphical User Interface that employs "wizards" to reduce manual input from the user. Figure 1 provides a high-level view of key components that support MMS navigation operations. The paper will discuss each of these components in more detail.

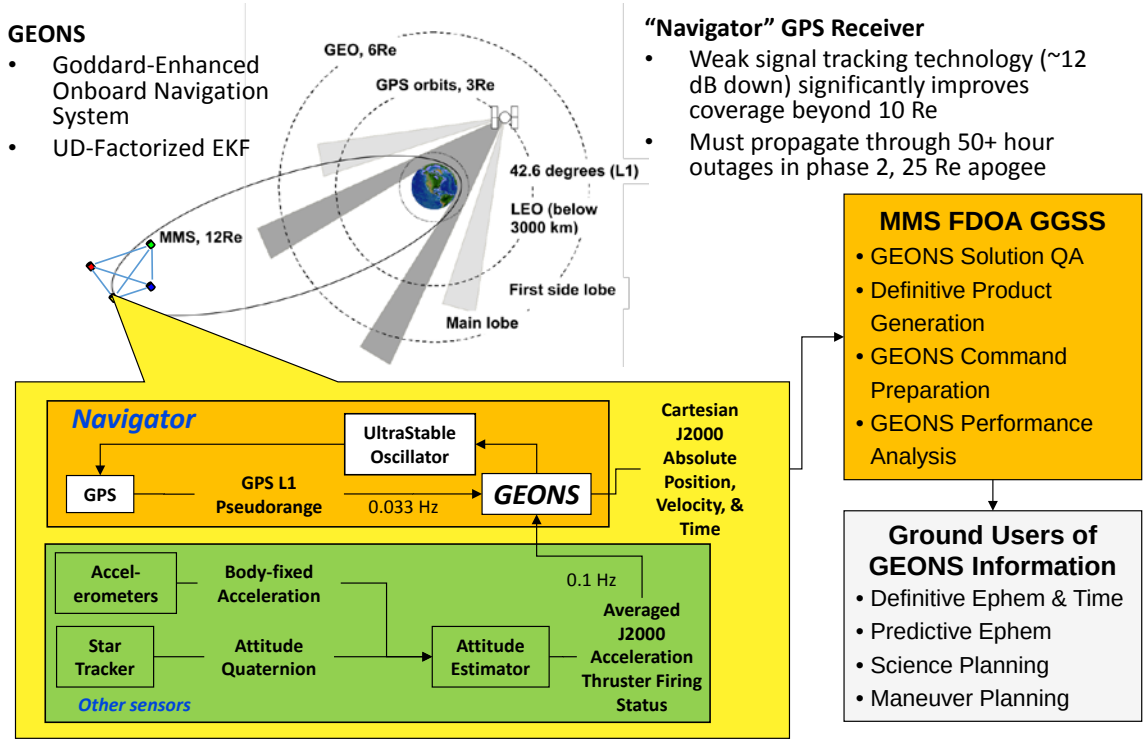

Figure 1. Overview of MMS Navigation Operations