Navigation Concepts for the Magnetospheric Multi-Scale (MMS) Mission

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The Magnetospheric Multiscale (MMS) mission consists of four identical spacecraft flying in formation in highly elliptical orbits about the Earth. The primary objective of the mission is to study the phenomenon known as magnetic reconnection, a process that converts magnetic energy into heat and kinetic energy of charged particles. The Earth's magnetosphere charges passing solar wind particles via the process, and the Earth's magnetosphere is the only location where this process can be practically studied *in situ*. The three primary phases of the mission are Phase 1 for day-side science objectives when the spacecraft is in an elliptical orbit and has a perigee radius of 1.2 Earth radii (Re) and apogee radius of 12 Re, Phase 2a when the apogee is raised from 12 Re to 25 Re, and Phase 2b for night-side science objectives following the apogee raising.

The baseline navigation concept for MMS is autonomous, independent estimation of each spacecraft state using an Extended Kalman Filter (EKF) that incorporates both Global Positioning System (GPS) pseudorange measurements referenced to an Ultra Stable Oscillator (USO) and acceleration measurements during maneuvers from an Attitude Control System accelerometer. MMS is NASA's first spinning spacecraft mission that employs onboard acceleration measurements for on-orbit navigation. State estimation for MMS is performed autonomously by the Goddard Enhanced Onboard Navigation System (GEONS), which is embedded in *Navigator*, a weak-signal tracking GPS receiver developed by the Goddard Space Flight Center. The estimated state from GEONS consists of the position, velocity, clock bias, clock-bias rate, and clock-bias acceleration. The clock bias estimated by GEONS is used onboard for critical timing processes, and the position and velocity states are used by analyst teams on the ground to generate the definitive ephemeris for science data analysis as well as the basis for maneuver planning. Therefore, a consistent and reliable performance by GEONS is critical for mission success. The onboard navigation process for MMS is highlighted in Figure 1.

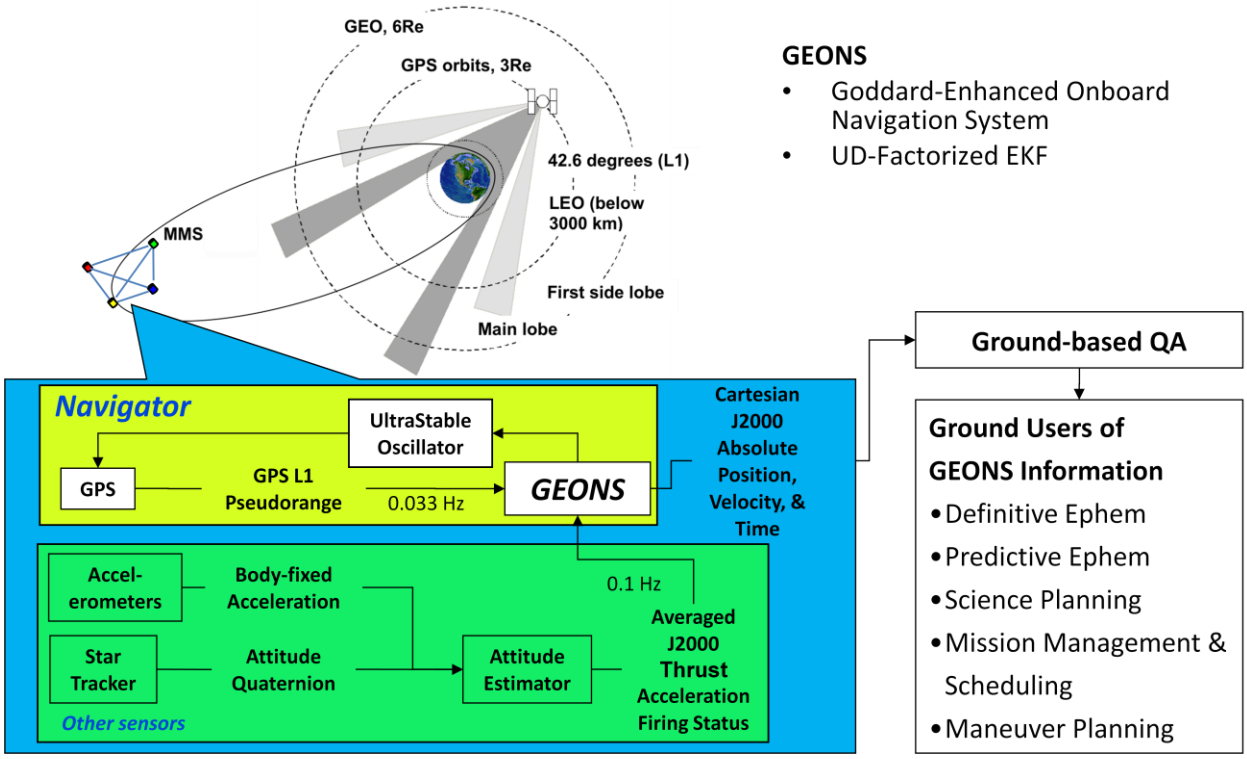

Figure 1: MMS Navigation Concept Diagram