A KALMAN FILTER FOR MASS PROPERTY AND THRUST IDENTIFICATION OF THE SPIN-STABILIZED MAGNETOSPHERIC MULTISCALE FORMATION

Steven Z. Queen[1] **and Suyog S. Benegalrao**[2]

[1]*NASA Goddard Space Flight Center, Code 591, Greenbelt, MD, 301-286-0988, steven.z.queen@nasa.gov*

[2]*NASA Goddard Space Flight Center, Code 591, Greenbelt, MD, 301-286-4269, suyog.s.benegalrao@nasa.gov*

Abstract: *The Magnetospheric Multiscale (MMS) mission is the fourth mission of the Solar Terrestrial Probe (STP) program of the National Aeronautics and Space Administration (NASA) which launched on March 13, 2015. The MMS mission consists of four identically instrumented spin-stabilized observatories that function as a constellation to provide the first definitive study of magnetic reconnection in space. The need to maintain sufficiently accurate spatial and temporal formation resolution of the observatories drives the need for highly accurate orbit adjustments. The design details of the closed-loop, 6-DOF, maneuvering controller is discussed in a companion paper also submitted to the conference. The present text concerns itself with the filtering of telemetered star-camera and high-rate (1 KHz) accelerometer data during a series of calibration maneuvers to form estimates of important system properties critical to the success of the on-board maneuvering control system.*

A Multiplicative Extended Kalman Filter (MEKF) is developed that uses the star-camera measurements to estimate the spacecraft attitude and rate in a manner identical to the on-board system. This ground-based calibration filter is then augmented to also process the on-board high-rate accelerometer measurements (used for close-loop maneuvering feedback) in order to construct estimates of some additional quasi-static system parameters—specifically the spacecraft's center-of-mass, moments and products of inertia, and accelerometer intrinsic biases. Although mass properties were carefully measured pre-launch, the formation's precise maneuvering requirements and the uncertainties in the settled shape of the fuel-mass inside the diaphragm of each observatory's tanks drive the need for on-orbit verification capability. The presence on-board of an accelerometer with micro-gravity precision, and the capability to transmit high-rate data to ground made this endeavour possible.

During a carefully crafted open-loop maneuver sequence, the spacecraft thrusters are all individually actuated in order to both refine the mass property state-estimates, and determine each thruster's steady-state output. A heuristic, two-node, thermal model completes the filter-dynamics in order to account for the transient effects of warm-up in the thrust-chamber.

In total, the estimator consists of eighteen core-body states (12 constants), plus three additional states for each of MMS's twelve thrusters (four axial and eight radial). The filter itself, along with some original derivations of the partial-derivatives required for analytical linearization, are all given in a compact matrix notation that makes the presentation surprisingly tractable. Initial concerns regarding information dilution over many unknown states were over-come, and statistics on both estimation accuracy and regions of solution-convergence are reported from an extensive campaign of Monte Carlo simulations. Finally, estimates using flight-data for the four observatories are presented and evaluated against the mission design requirements.

Keywords: *Kalman filtering, system identification, dynamics and control.*