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Robust Formation Design for the Magnetospheric Multiscale Mission using a Stochastic Optimization Approach

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Summary

A stochastic optimization approach is used to design a tetrahedral spacecraft formation for the NASA Magnetospheric Multiscale (MMS) mission whose performance characteristics are robust with respect to differential semimajor axis errors. The MMS mission requires a formation of four satellites which is to form a nearly regular tetrahedron near apogee of a highly eccentric orbit, and is to remain in this configuration throughout as many successive orbits as possible without maintenance maneuvers. When all design parameters are deterministic, such a formation can be designed by maximizing a "quality factor" throughout a "region of interest," either over multiple orbits or over a single orbit with an additional constraint to ensure long-term stability. However, inaccurate maneuvers and navigation systems introduce errors in the design parameters; in particular, differential semimajor axis errors greatly degrade formation lifetimes when a deterministic optimization approach is used. The stochastic optimization approach instead maximizes the expected value of the quality factor using the estimated probability distribution of the semimajor axis errors, and produces formations which are less sensitive to these errors at the cost of a reduction in performance in the nominal case.