Optimal Reconfiguration of Tetrahedral Formations

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The problem of minimum-fuel formation reconfiguration for the Magnetospheric Multi-Scale (MMS) mission is studied. This reconfiguration trajectory optimization problem can be posed as a nonlinear optimal control problem. In this research, this optimal control problem is solved using a spectral collocation method called the *Gauss pseudospectral method* [1]. The objective of this research is to provide highly accurate minimum-fuel solutions to the MMS formation reconfiguration problem and to gain insight into the underlying structure of fuel-optimal trajectories.

Results

The preliminary results show the optimal maneuver strategy necessary to bring the formation from a deformed state to the desired tetrahedron. For this preliminary trial, only two spacecraft were perturbed from their nominal tetrahedral position. Spacecraft 1 was moved 5km downrange (ahead) of its nominal position, and Spacecraft 2 was moved -5km downrange (behind) its nominal tetrahedral position. Figures 1 depict the total fuel spent per spacecraft the duration and placement of the maneuvers for each spacecraft, respectively. It is intuitive that spacecraft 1&2 spend the most fuel, because these spacecraft were initialized with a deformation from nominal. But it is also interesting to note that even though spacecraft 3 and 4 were not deformed, they still executed small maneuvers. This shows that the fuel optimal solution is not to return to the nominal solution, but instead allow all four spacecraft to maneuver to achieve an equivalent formation that can be created in less fuel. Figure 2

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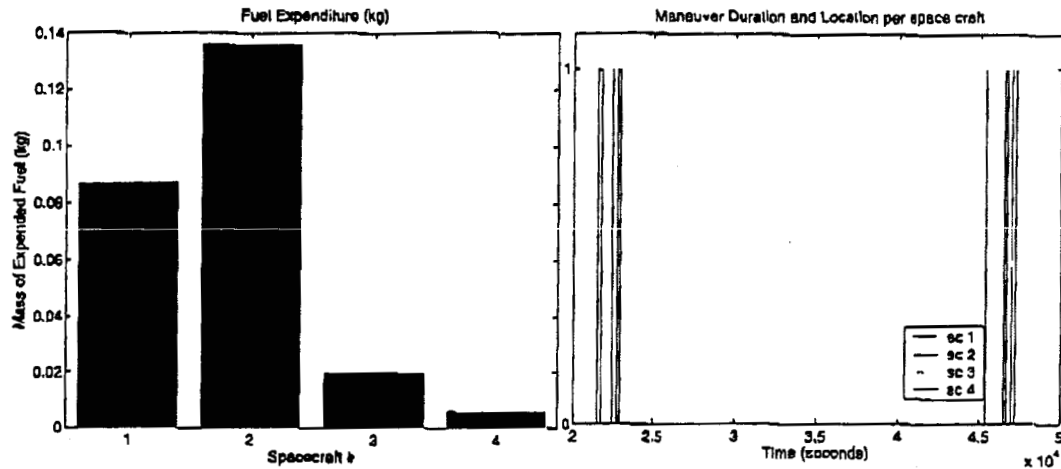‡Aerospace Engineer, Flight Dynamics Branch, steven.p.hughes@nasa.gov

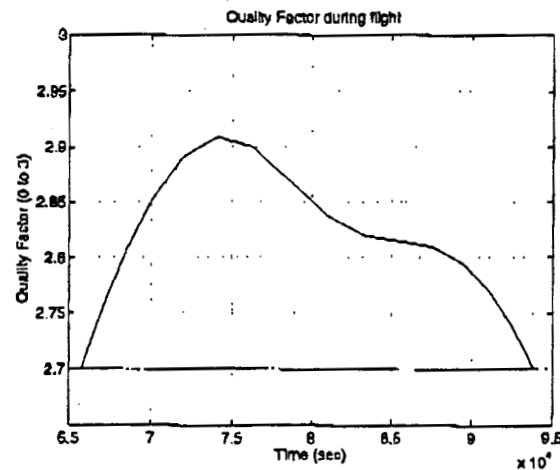Figure 1: Fuel expenditure per spacecraft and maneuver locations.

Figure 2: Quality Factor within ROI

shows that the tetrahedron quality factor is indeed above the minimum inside the region of interest, and the new tetrahedron satisfies our scientific requirement.

Acknowledgment

References

[1] Benson, D., *A Gauss Pseudospectral Transcription for Optimal Control*, to appear in IEEE Transactions on Automatic Control.