ASTRODYNAMICS SYMPOSIUM (C1)
Guidance, Navigation & Control (3) (9)

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OPTIMAL STATION KEEPING BY ELECTRIC PROPULSION IN FAILURE MODE

Abstract

The Boeing 702 spacecraft are currently in geosynchronous orbit, with four independently mounted XIPS thrusters operating daily to provide the first all-electric satellite station keeping system. The thrust components obtained in the radial, tangential, and normal directions from each of the four thrusters are used to achieve station keeping. The four firing locations are determined by desired inclination vector change since the inclination control consumes over 90% of the station keeping fuel. The thruster's firing durations are determined by the desired change in longitude drift rate, eccentricity vector, and magnitude of the inclination vector.

In the event of a single thruster failure, the opposite diagonal thruster will not be used for station keeping. Consequently, the failure mode configuration consists of two diagonal thrusters: either NW-SE or NE-SW. The original station keeping failure mode strategy of Boeing 702 consisted of the following; fire the north thruster at $\sim 90°$ RA, the south thruster at $\sim 270°$ RA. The sum of the normal ΔV components counters the secular growth of the inclination. The difference of their tangential ΔV components controls the longitude drift rate. The tangential ΔV components, either NW-SE or NE-SW, can cause secular drift in eccentricity vectors. The remaining diagonal thrusters are fired a second time, simultaneously, and with equal duration. In this case the tangential components are sized to cancel the secular drift in eccentricity vectors. The right ascensions of the third and fourth firings are close to 180° (0°) for diagonal pair NW-SE (NE-SW).

However, the firing locations for the third and fourth firings will not be acceptable since they should fall within one of the two eclipse periods. A fuel optimal station keeping method is proposed in this work with a diagonal pair of thrusters under eclipse constraints. The number of equations to control the orbit state is five: two equations for the inclination vector, two equations for the eccentricity vector, and one equation for the mean longitude drift. The number of the variables in those equations is eight: four firing locations and four firing durations. The firing locations and durations are set as free variables to be searched for fuel consumption minimization. The inequality constraints with respect to firing locations are considered to avoid the electric thrusters fired at the eclipse. Then the constrained optimization can be easily handled by the classical nonlinear optimization algorithms such as sequential quadratic programming (SQP).