ABSTRACT

A novel method to evaluate the trajectory dynamics of low-thrust spacecraft is developed. Using a two-body Newtonian model, the thrust vector components are represented as Fourier series in eccentric anomaly, and Gauss's variational equations are averaged over one orbit to define a set of secular equations. These secular equations are a function of only 14 of the thrust Fourier coefficients, regardless of the order of the original Fourier series, and are sufficient to accurately determine a low-thrust spiral trajectory with significantly reduced computational requirements as compared with integration of the full Newtonian problem.

This method is applied to orbital targeting problems. The targeting problems are defined as two-point boundary value problems with fixed endpoint constraints. Average low-thrust controls that solve these problems are found using the averaged variational equations and a general cost function represented also as a Fourier series. The resulting fuel costs and dynamic fidelity of the targeting solutions are evaluated.

Low-thrust controls with equivalent average trajectory dynamics but different thrust profiles are also studied. Higher-order control coefficients that do not affect the average dynamics are used to reduce fuel costs and transform variable-magnitude controls into controls with constant thrust arcs, which can be implemented more easily by low-thrust propulsion systems.

These methods have applications to low-thrust mission design and space situational awareness. Example problems based on past missions and potential future scenarios demonstrate the validity and efficiency of these methods.