ABSTRACT

AUTOMATING THE GENERATION OF FEASIBLE TRAJECTORIES FOR TRADE STUDIES

by

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The goal of this work is to provide methods which can be used to auto-generate feasible electric propulsion interplanetary trajectories for use with Hall and Ion thrusters. The research is aimed at automating the trajectory generation for trade studies. Automating the trajectory generation process allows non-trajectory specialists to generate a good initial guess for use in optimizers and to rapidly conduct trade studies.

Two types of trade studies are considered, high and low level trades. High level trades utilize reduced order models, which simplify the problem, while low level trades use high fidelity models of the thruster and power system. High level trades are used to capture technology trends, while low level trades are used to conduct detailed analysis. In order to automate the generation of feasible trajectories, two different methods are used, one for high level trades and another for low level trades.

Novel methods are designed to automate the entire trajectory generation process. They use information from previous iterations so the user does not have to supply an initial guess. The initial guess for the first iteration is generated using a "self starting" method, which allows for the generation of a unique initial guess for each subproblem.

For high level trades with variable efficiency constant specific impulse thrusters it is found that the optimal specific impulse is independent of the launch mass and varies with the propellant and power system. The optimal solution favors a larger power system mass vs. the propellant mass. To carry out these trade studies a homotopy method is used in a proof of concept tool which optimizes the C_3, power level, and specific impulse over a range of power systems power to mass ratios.

A two phase approach is used to generate trajectories for low level trades. The first phase uses Chebyshev polynomials to model the trajectories. The Chebyshev coefficients are optimized, which allows for the selection of a unique low cost trajectory for a large range of launch and arrival dates. The Chebyshev trajectory is then used as an initial guess to a feasible trajectory solver which integrates the trajectory and uses thruster and power system models to constrain the trajectory. The use of the Chebyshev polynomials with the fully integrated solver allows trajectories to be generated without requiring the user to supply any initial guess.

Finally, a new high order optimization algorithm is designed which maintains feasibility while optimizing. The algorithm generates a second order control update which satisfies the constraints and necessary conditions to the second order. The use of a second order update is novel because current optimization methods use linear control updates. The algorithm demonstrates better convergence properties over conventional linear control updates.