Paper ID: 4306
student

ASTRODYNAMICS SYMPOSIUM (C1)
Orbital Dynamics (2) (10)

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GLOBAL OPTIMIZATION OF TRANSFER ORBITS FOR FRACTIONATED SPACECRAFT

Abstract

To make a spacecraft robust to technical or environmental risk, the current approach which adds parallel redundant component strands in mission-critical areas increases system complexity and results in cost increment. In addition, fragility is the tendency of complex systems, i.e., failure modes usually lead to catastrophic sequence of events, looking to the Apollo 13, Challenger, or Columbia accidents for examples. It has been proposed by some scholars that the traditional monolithic spacecraft should progress to a cluster of wirelessly interconnected spacecraft modules. This Fractionated Space Systems has been exemplified by DARPA's System F6 (Future, Fast, Flexible, Fractionated, Free-Flying Spacecraft United by Information Exchange). The primary technique to bring this new spacecraft into application is orbital dynamics, which is presented in this paper. This thesis focuses on the modules' transfer orbits, and proposes an idea that all the modules transfer from the parking orbit successively, and arrive at the corresponding positions simultaneously.

It is assumed that the modules of fractionated spacecraft are launched to a preliminary orbit, and then all the modules transfer to the required positions. In order to start all the modules synchronously, the best way is that all of them reach the corresponding positions at the same time. Firstly, the preliminary orbit of the fractionated spacecraft is determined based on the design constraints and the capability of the launch vehicle. Then, the optimal control problem is established taking all the modules into account. Performance index is selected as the minimum sum of all the long-distance orbital transfer time and phase errors eliminating time, except the repetitious count with limited fuel. The transfer occasion and transfer orbits are determined by dint of optimization method. The simultaneity of all the modules reaching is the essential constraint. The dynamic optimal control problem is transformed into static parameter optimization problem via the steady state parameters. Finally, the parameter optimization problem is solved by optimization algorithm based on Quasi-Newton Method in virtue of Matlab optimization tools. The optimization algorithm can converge promptly with high precision on condition of a favorable initial estimate. On the other hand, the initial guess value can be obtained according to the orbital dynamics, with impulse assumption.

The simulation demonstrates the availability of the orbit design and the effectiveness of the presented algorithm. It is concluded that the strategy can be used for fractionated spacecraft transfer orbit.

Key words: fractionated spacecraft, multi-module, global optimization, orbital transfer