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A STUDY ON COST ADVANTAGE OF INTERORBITAL TRANSPORTATION NETWORK BY USING MULTIDISCIPLINARY SYSTEM DESIGN OPTIMIZATION APPROACH

Abstract

Recently, the market for orbital transfer vehicle (OTV), which is responsible for "transportation in space" after rocket separation, has been developing, and many private companies have already entered the OTV market for low earth orbit. In the future concept, it is expected that OTVs will be refueled and reused in an interorbital transport network that connects various orbits among the Earth, the Moon, and beyond, and future space transportation will be made dramatically more efficient. Previous research has examined the efficiency of the interorbital transportation network based on very futuristic technologies such as In-Situ Resource Utilization. However, in the transitional state leading up to that future, it is unclear how commercially viable the reusable OTV is and insufficient to evaluate its cost effectiveness. Therefore, the objective of this research is to develop a method for evaluating the business feasibility and cost advantage of interorbital transportation networks. One of the problems considering the reuse of OTVs is that the mission scenario becomes more complicated than a conventional one-shot mission because the number of rocket launches will be multiple and the target and transit orbits will also be diverse. Therefore, in this research, we focus on graph theory and hierarchize mission scenarios using directed graph elements such as "nodes", "edges", "paths", and "scenarios" to enable comprehensive mission scenario search. Subsequently, a V database for each path obtained by graph theory is generated by trajectory optimization to minimize required delta V under boundary conditions that maximize the rocket's capability. By referring to this delta V database, we formulate a multidisciplinary system design optimization (MSDO) problem covering scenario, trajectory, propulsion, structure, and cost, and establish a model to minimize the unit cost of cargo transportation. Solving MSDO problem enables to evaluate the cost performance of an interorbital transportation network that utilizes the reusable OTV, taking into account the orbital dynamics and realistic constraints of spacecraft subsystems. Finally, this study demonstrates case studies on cargo transportation to near rectilinear halo orbit (NRHO) on which is Gateway will be located and low lunar orbit. It is verified that the cost performance of reusable OTV for transportation to Gateway and low lunar orbit is much superior to the conventional one-shot transportation.