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"SPACE LOGISTICS STATION"-INTELLIGENCT OPERATION SPARE SCHEME OF LEO MEGA CONSTELLATION BASED ON SUPPLY CHAIN INVENTORY MANAGEMENT

Abstract

The Low Earth Orbit (LEO) mega constellation boasts unique advantages in global satellite navigation, communications, and remote sensing. To guarantee the service level and cost-effectiveness of the mega constellation, a good operational and maintenance strategy for the constellation system is essential. Based on the supply chain inventory management method, this paper presents an intelligent operation spares scheme for the constellation system.

Firstly, a multi-echelon (R, Q) inventory management strategy is employed to address the satellite constellation spares problem. The model considers the satellite constellation spares strategy as a multi-echelon supply chain system that simultaneously considers different levels of spare satellites within the system. The ground spares are regarded as suppliers, the parking orbits serve as distributors, and the on-orbit spares act as retailers. The parking orbit is slightly lower than the constellation's nominal orbit (i.e., the working orbits), causing the parking orbit plane to continuously drift relative to the constellation's on-orbit plane. The inventory of the on-orbit spares (retailers) will be replenished from the nearest (i.e., the shortest waiting time) available distributor when it is out of stock, and the parking orbits (distributors) will be replenished from the ground (suppliers).

Secondly, the efficiency measurement of the spares strategy is derived from the analysis model, and a cost model is developed, including manufacturing, holding, launching, and maneuvering costs. The model is simulated using the Monte Carlo simulation method, and the proposed model is verified. Concurrently, based on the inventory control theory model, an optimization algorithm based on genetic algorithms and nonlinear programming functions is proposed to optimize the proposed model strategy and minimize the system maintenance cost.

Finally, the conceptual design of the supply chain autonomous mission management system and the structural design of the subsystems are presented. The intelligent algorithm is utilized to establish the framework of the supply chain autonomous mission management system to achieve the integrated and autonomous operation of the satellite health monitoring, information exchange, and inventory control of the system, making it more autonomous and reliable. The multi-echelon inventory model of the supply chain captures the interaction among inventory demand, lead time, and supply allocation at different levels. The model has multiple drift distributors (parking orbits), which can provide spares for all on-orbit planes (retailers) and possesses a certain degree of flexibility. This solution will establish a theoretical

basis for the operational spares of the LEO mega constellation.