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Discrete event simulation of long-duration space station operations for rapid evaluation

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A long term space station operational scenario involves a large number of on-orbit missions, however, for their successful implementation they require various logistics missions to be performed. Logistics missions are triggered by on-orbit missions and there are complex interactions between different missions. Based on the computational efficiency afforded by event-based simulation, Discrete Event Simulation (DES) is used to model diverse on-orbit and logistics missions holistically within an integrated scenario and schematize it as a discrete system. It helps to quickly evaluate the physical feasibility and performance effectiveness of complex space station operations. Moreover, operational uncertainty is introduced into the DES model, comprising launch delays of visiting vehicles and onboard emergencies hazarding the safeties of space station or astronauts. Monte Carlo simulation is adopted to help in stochastic analyses and five measurable metrics are further defined to quantify the impact of uncertainty on nominal scenarios. The proposed DES model and associated metrics are demonstrated with both nominal and contingency operations. Simulation results indicate that such an approach is effective and efficient in simulating space station operations and able to support the top-level mission design of China's future space station program.

Keywords: space station; discrete event simulation; operational scenario; logistics

1. Introduction

The United States of America and Russia have successfully built and operated several space stations such as the International Space Station (ISS) and the Mir. In a typical long-duration space station scenario, various on-orbit missions are required to be performed simultaneously, incorporating many aspects such as crew life support, experiments, utilization arrangements, maintenance of platform and payload, as well as orbital maneuvers. Meanwhile, the logistics missions, namely the visits of the cargo vehicles and the manned vehicles, are scheduled and executed on Earth to enable the resource resupply and the crew rotation. The logistics missions

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