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PREDICTION OF THE DEBRIS DISTRIBUTION IN LEO BASED ON A LONG-TERM EVOLUTION MODEL OF THE SPACE ENVIRONMENT

Abstract

In recent years, with the deployment of mega constellations in LEO, the space would experience a dramatic increase in debris population. To measure the influence of these space debris, one way is to establish the long-term evolution model of the space debris environment. In this situation, the modelling method of tracking the state of the space objects individually requires significant computing resources which is not efficient. Another way utilizing macroscopic variable such as the spatial density as the state variable would only require about 1/10000 computational load, which therefore is taken as the main method in this paper.

Although the macroscopic approaches require fewer computation, the overall evolutionary accuracy of the model is limited due to the ideal approximation assumptions, such as all debris orbiting in circular orbits, debris from collisions with targets at the same height remaining at the current height and so on. In addition, the previous studies have only analyzed the impacts from the space environment, like atmospheric drag and solar radiation pressure. Human factors such as using drag augmentation device to perform active debris removal have not been considered yet. Therefore, the space debris environment evolution model using macroscopic approaches needs to be further improved with the consideration of constellations and active debris removal. The main contents of this paper are summarized below.

1. A space debris environment evolution model taking the spatial density is developed based on the continuum equation of fluid mechanics and the NASA's standard breakup model. This model considers non-zero eccentricity of the debris orbit, and utilizes the stay probability as the spatial density to improve the model accuracy. Mean equivalent effects of the air drag and mutual collisions among objects are included in the model.

2. Based on the evolution model, the long-term impact of mega constellations on the debris environment is discussed, and a drag augmentation de-orbit scheme is implemented. The results show that if no de-orbit disposal is adopted, the mega constellations will significantly change the evolutionary trend of the debris environment.

The research in the work offers an effective way to reveal the long-term evolution of space debris environment, and the obtained results could be reference for future safe operation as well as sustainable exploration in space.