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Prediction of the space debris spatial distribution on the basis of the evolution equations

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ABSTRACT

The numerical–analytical technique for long-term prediction of the space debris (SD) spatial distribution, based on derivation and solution of new evolution equations, is developed. These equations are represented in two forms – difference and differential. In the latter case the problem is reduced to integration of the system of two ordinary differential equations. A high efficiency of the proposed technique, as compared to the traditional approach, is demonstrated.

1. Introduction

It is assumed that two factors have effect on the evolution of the space debris time–spatial distribution during the prediction of space debris contamination in the region of low orbits (LEO) [1–8]: the increment of a quantity of new objects as a result of launches, technological operations, explosions, accidents, etc., and the atmospheric drag that results in lowering the perigee altitude of space objects (SOs) and their reentry.

Two approaches are used for solving the considered problem. The traditional (*deterministic*) approach is widely applied by specialists. For example, NASA's contemporary "EVOLVE" model simulates the after-effect of all known satellites' launching and destruction events, as well as similar events possible in the future. For each object (or a group of objects) the vector of initial conditions is formed. Prediction is performed using the traditional motion models. To estimate the danger of collision of a pair of satellites D. Kessler's methods are used. The results have been summarized for a great number of objects. The distinction in modeling over the future time interval lies in the fact that all fragmentation events are formed according to the Monte Carlo technique. In this case several prediction operations are performed. Obviously, this approach is very labor-consuming; it can be implemented on rather powerful computers only. However, even on the contemporary large computers the traditional approach does not correctly predict the distribution of small-sized space debris fragments. The labor consumption in solving the problem in question can be judged by quotation from paper [8] given below:

> "As one of the more time consuming operations of our model deals with the orbital propagation of the sixth orbital elements for each objects of the population, the code of MEDEE has been designed to take advantage of massively parallel, computer system available at CNES. This means that the orbital propagation module has been parallelized, in order to propagate the population at each time-step over all available cores.
>
> The computer system in which MEDEE is executed is formed by 360 cores summing a total RAM of 24 Go and an overall computing power of 4 Tflops/second."

In spite of its labor-consuming character, this approach does not guarantee the model's adequacy. The accuracy of destruction after-effect modeling is unknown. The model

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