SPACE DEBRIS EVOLUTION MODELING WITH ALLOWANCE FOR MUTUAL COLLISIONS OF OBJECTS LARGER THAN 1 CM IN SIZE

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ABSTRACT

To estimate the contribution of consequences of collision of small-size space objects (SOs) into the current near-Earth space (NES) contamination level, the situation forecasting since 1990 to 2012 was carried out. The forecasting has been fulfilled in two stages. At the first stage on the mentioned time interval the evolution of altitude distributions of various-size objects has been constructed without allowance for mutual collisions. At the second modeling stage these results were used as initial data for determining characteristics of objects larger than 1 mm in size taking into account mutual collisions of SOs larger than 1 cm in size.

During situation forecasting the fragmentation model was used, whose parameters were updated based on available experimental data. For catalogued objects the forecasted and real data agree well enough. For smaller-size objects the results occurred to be unexpected. They testify to very strong effect of mutual collisions on NES contamination by particles of size from 1 mm to 5.0 cm. As compared to the SDPA model data for 2010 (without allowance for mutual collisions), the estimates of a number of objects of mentioned size occurred to be greater an order of magnitude. The conclusion was drawn from modeling materials that the so-called cascade effect transmuted from a hypothesis to reality.

Keywords: the mutual collisions, situation forecasting, model.

1. INTRODUCTION

The estimates of the effect of catalogued objects' collisions on the near-Earth space contamination [1, 2] were presented at recent IADC sessions. These materials stated: «*Space activity continuation and space debris (SD) population growth will inevitably initiate the cascade effect in the near-Earth space. This effect (Kessler's syndrome) was predicted by Kessler and Cour-Palais more than 30 years ago. The current SD modeling in the near space (at altitudes up to 2000 km) confirmed that the NES contamination has already reached the instability level. The NES contamination mitigation measures, approved by the international space community including the Interagency Debris Committee (IADC) and the United Nations Organization (UN), may be insufficient to stop the future growth of SD. If the NES contamination instability is confirmed, it would be necessary to consider additional measures to save the NES for future generations*».

The mutual collisions effect on NES contamination was considered in reports [3, 4]. The results stated in them not fully agree with IADC publications [1, 2]. Possible reasoning of this consists, apparently, in the fact that the situation forecasting technique applied in the Russian SDPA model [5, 6, 7] essentially differs from the methodology of preparing the materials of the mentioned IADC report.

The Space Debris Prediction and Analysis (SDPA) model is a semi-analytical stochastic model for mid-term and long-term forecasting of man-made SD larger than 1 mm in size in the LEO and GEO regions, which is used for constructing spatial distributions of density and velocity characteristics, as well as for estimating the risk of collisions. The model began to be developed in ≈ 1990. It has been permanently updated and renewed for the past 23 years. The summary data on various-size SD (without their "attribution" to particular contamination sources) are considered. The current state of NES contamination is characterized by: a) SD density dependence on the altitude and latitude of a point, and b) statistical distributions of magnitude and direction of particles velocity in the inertial coordinate system. These characteristics were constructed on the basis of complex utilization of accessible measurement information and various a priori data.

Prominent features of the technique applied in the SDPA model are as follows:

- The original technique of accounting for mutual collisions of various-size SOs is developed. Its fundamentals are stated in the monograph [6].

- Collisions of non-catalogued objects (smaller than 10 - 20 cm in size) are taken into account.