Forecasting scenarios of collision catastrophes produced by celestial body falls

V. Shor[1], O. Kochetova[1], Y. Chernetenko[1], N. Zheleznov[1], V. Deryugin[2], and A. Zaitsev[3]

[1]Institute of applied astronomy of RAS
[2]Lavochkin Research and Production Association, Moscow region
[3]Center of Planetary Defense, Moscow

The subject under discussion arose in the course of developing a computer program, which gives the possibility for numerical and graphical modeling of the scenarios of catastrophes caused by collisions of cosmic bodies with the Earth. It is expected that this program can be used for computer-assisted training of the personnel of units of the Ministry for Emergency Situations in the case of a situation caused by the fall of a celestial body on the Earth. Also, it is anticipated that the program can be used in real situations when a dangerous body is discovered on an orbit leading to an imminent collision with the Earth. From the scientific point of view, both variants of use require solving of analogous tasks. In what follows, we discuss both variants.

1. The computation of the circumstances for a fall on the Earth (or approach within short distance) of a real body begins with the determination of its orbit from the observations available using the least-squares method. The mean square error of the representation of the observations on the base of the initial values of the coordinates and the velocities is computed, as well as their covariance matrix. Then, the trajectory of the body's motion is followed by numerical integration starting from the osculating epoch to the collision with the Earth or to its flyby. The computer program takes into account the various cases: at the initial moment, the body can move away from or approach the Earth, it can be outside the sphere of action or inside it. At the moment, when the body enters the sphere of action, the coordinates of the center of the dispersion ellipse on the target plane are computed as well as the dimensions of its axes. Using these data, the probability of collision with the Earth is calculated. Then, the point of penetration of the body into the Earth's atmosphere at a given height above the level of the Earth geoid is determined. In case the body is passing by the Earth, the minimum distance of the body from the Earth center is calculated. If the body penetrates into the atmosphere, the dispersion of such parameters as the longitude and the latitude, the geocentric velocity, azimuth and inclination of the trajectory to the horizontal plane are determined at entry. The energy of the body which is delivered to the Earth is also estimated. Then, the calculation of the body's motion in the atmosphere is fulfilled by taking into account its resistance. Possible dispersion of trajectories is considered, too. The computer program gives the possibility to draw a chart of the area, where the body fell or where the airburst took place, to estimate the destruction level within different distances from the epicenter, and to solve a number of other problems, important for providing help in the calamity area.

2. The training of students for actions in emergency conditions can be best solved through computer modeling of the real situation that could happen in the specified area and in the given time as a result of a fall of a cosmic body having prescribed characteristics. The student is proposed to introduce into the computer program at will the geographical coordinates of a place and to fix the time of the fall of the cosmic body, then select for it such characteristics of its trajectory as the geocentric velocity (within possible limits), azimuth, and inclination with respect to the horizon. It is necessary to introduce the size of the body or its energy and also the lead time (the amount of time that remains before the collision). On the basis of these data, the program determines the heliocentric orbit of the body. After that, numerical integration of the equations of motion is carried out in the time-reversed direction on the time interval equal to the lead time. In the end point, the elements of the new heliocentric orbit are calculated. In order to make subsequent calculations identical to those which are fulfilled in the case of a real body, we generate artificial observations of that body, whose orbit was found by reverse integration, on the time interval equal to the lead time. The moments of observations are selected by chance under the condition that they are distributed uniformly, whereas the observation errors are distributed according to normal distribution. Fictitious observations are used to create the conditional equations and then to form the normal system of equations. Their solution gives close to zero corrections to the parameters that were found by the reverse integration. In reality, these corrections are not used: instead, the covariance matrix found is used as a replacement for the covariance matrix of the parameters obtained by reverse integration. Subsequent actions repeat those which are fulfilled in the case of a real body. As a result, the picture of the body's fall with parameters similar to those which were prescribed by the student is reproduced.