DYNAMICAL EVOLUTION OF A CLOUD OF FRAGMENTS AFTER A DESTRUCTION EVENT IN GEO

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ABSTRACT

The analysis of destruction events in near-Earth orbits and in GEO is presented. The analysis shows that in many cases the destruction was low energy and the velocity of fragments is limited in few meters per second. Long term evolution of fragments cloud formed as a result of destruction of the geostationary satellites was studied. The initial cloud of fragments was set within the model of low power explosion. Dimensions of considered fragments lay in the range 0.07 - 0.9 m with the initial velocities in the range 3 - 60 m/s. The movement of each fragment was simulated on a time interval of 11 years with the numerical model of a movement of the artificial satellites of the Earth, developed in Tomsk University (Russia). This model includes Earth's gravitational field up to 20th order, Sun, Moon, Earth's tides and light pressure. A number of explosions of low power were considered. The initial elements of orbits of destructed objects were accepted as: semimajor axis 42165 km, zero eccentricity, inclination 0° or 10°. Satellite longitudes were chosen near stable (75°E, 105°W) and unstable (165°E, 15°W) libration points and two intermediate (30°E, 120°E). The expansion of the cloud along the orbit and closing it to the torus is a result of the fragments moving in circular modes only. The inner structure of the cloud will stay heterogeneous on a long-term interval. During evolution in a cloud of fragments two areas with small cross section will arise. These areas correspond to the line of nodes of destructed object. Peculiarities of the evolution of longitudes of fragments orbits node allow to separate regions where the particle flow is maximal. These regions are most suitable for search explosion fragments; on the other hand this regions are present highest emergency for active geostationary objects.

1. INTRODUCTION

Geostationary orbit and its vicinity are very populated regions of near-Earth space. Withdraw of satellites after their active period into burial orbits allow to adjust number of objects in GEO. Observations show that in geostationary area the increase of number of objects occurs. By observant means it is possible to determine only separate largest fragments. The increase may be due to fragmentation of satellites and rocket bodies. From results of modeling follows, that the number of particles of the small size is increased greater, then large fragments. They can represent serious threat for space vehicles. One of the reasons of destruction of a space object is its explosion. To the present time few explosions of objects in GEO are registrated, but one can suppose, than real number of destruction events in GEO is much greater. [Rykhlova et al, 2001, Bagrov et al, 2000, Verskov et al, 2001].

We study the dynamic evolution of a cloud of fragments of particles formed as a result of explosion of geostationary object, with the purpose of an estimation of a degree of danger of these particles for objects of geostationary area. The analysis long term evolution has allowed to reveal areas, where density of a flow of fragments is higher, what area of space will appear most dangerous and where it is necessary to search for fragments of explosion.

2. SIMULATION OF EXPLOSIONS

On the basis of low energy explosion model [Kuzetsov, 2003, Bordovitsina, Druzhinina, 1998, Pardini et al, 1998] two types of explosions were considered. As a result of the first type explosion one fragment of large mass (about 0.2-0.3m_0, m_0 – initial mass) and small amount of fragments (from 9 up to 26) of low mass are formed. The explosions of the second type give the greater number of fragments (from 230 up to 310), and weight of the largest fragment does not exceed 0.02 m_0. Mass distribution supposed to be power with slope s=1.83. In Tab. 1 the basic parameters of fragments formed as a result of explosions of both types are given. The maximal speed correspond to particles with the minimal mass.

Table 1. Parameters of fragments of explosion.

	1 type explosion	2 type explosion
Min Mass (kg)	0.1-0.7	0.1-0.11
Diametr (m)	0.07-9	0.007-3
S/m (m^2/kg)	0.13-0.33	0.17-0.33
Velocity (m/s)	3-60	4-69

The dynamical evolution of orbits of fragments was studied with the help “Numerical model of a satellite movement” developed by [Bordovitsina, 1986]. Initial orbital elements were chosen as:

Semimajor axis 42130 km ≤ a ≤ 42210 km; inclination 0° ≤ i ≤ 20°, eccentricity 0 ≤ e ≤ 0.01. The model of

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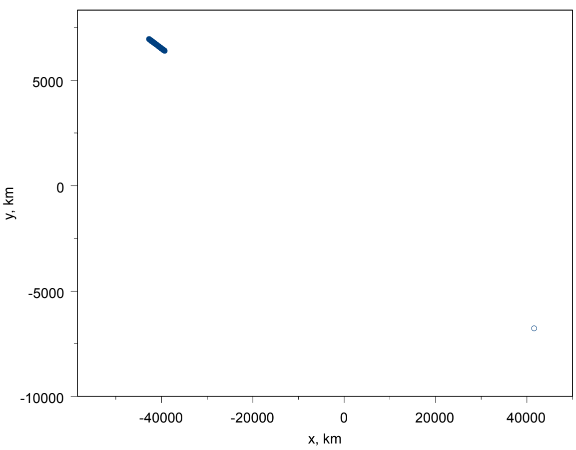
orbital evolution includes Earth potential up to the 20-th order, Earth tides, Sun, Moon and direct light pressure. For short time evolution (100 days) 84 explosions were examined, and for long time evolution (11 years) – 24 explosions.

The analysis of results of simulation has shown, that more than 95% of particles formed as a result of an explosion of the geostationary satellite, appears in the field of rotational (concerning a surface of the Earth) movement. If at the moment of explosion the satellite was near to a steady libration point 75°E or 105°W, no fragments achieve another libration point. If at the moment of explosion the satellite was in a vicinity of a unstable point 15°W, the majority of fragments on libration orbits move in a mode including two stable libration points. In contrast, the explosions in the vicinity of unstable point 165°E produce very few fragments on libration orbits.

Even for fragments on non-libration orbits resonance 1:1 with the Earth rotation results that the internal structure of a cloud does not become homogeneous even on long intervals of time.

3. EVOLUTION OF A CLOUD OF FRAGMENTS

During evolution in a cloud of fragments two areas with small cross section are formed. These areas correspond to nodes of orbits of fragments on an orbital plane of the blown up object. Directly after explosion the nodes of orbits of particles are concentrated in a point of explosion and opposite to that point (Fig. 1a). For relatively short time (from 0.2 to 0.7 years) the nodes of orbits are distributed along an orbit of parental object (Fig. 1b). During the further evolution distances between nodes of orbits decrease (Fig. 1c, d).



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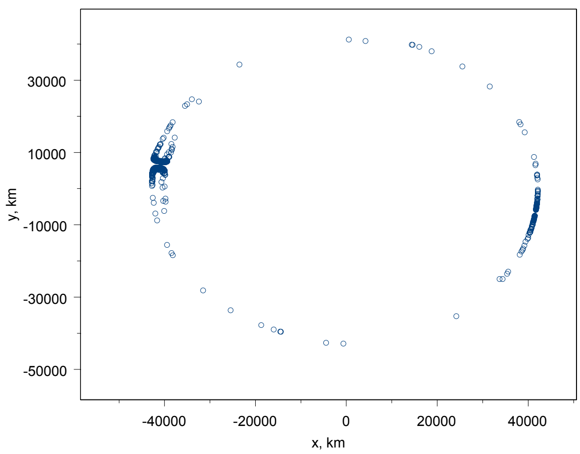

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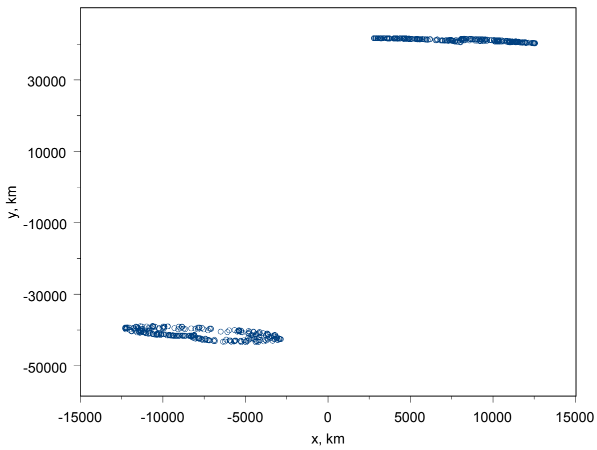

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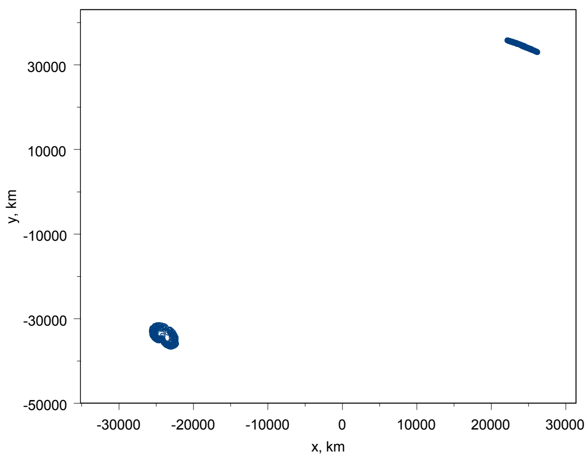

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Figure 1. Evolution of longitudes of nodes of orbits of fragments for explosion in a vicinity of a steady libration point 105°W: a) the moment of explosion, b) 4 day after explosion, c) 5,5 years after explosion, d) 11 years after explosion.

As a criterion of proximity of nodes of orbits average distance between them was used. In the initial moment average distance between nodes of orbits was from 300 up to 800 km, then it increase up to 23000-32000 km, and at the end of a considered 11-year's interval it was reduced to 1000-2600 km. For explosions occurred in a vicinity of a unstable libration point 15°E, minimal distance between nodes was achieved in 4-8 years and was kept within 2-7 years, then a slow increase began.

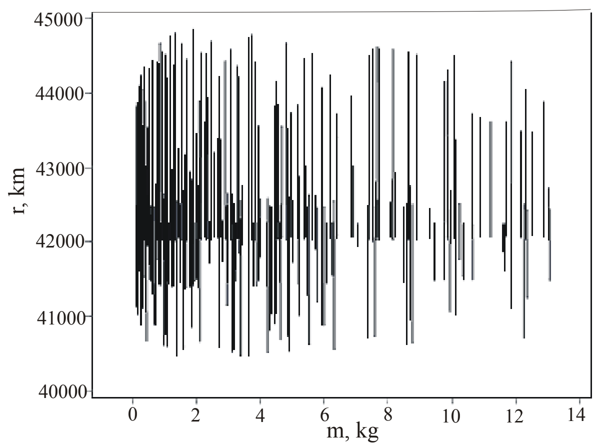
Our simulations show that in some years after explosion in a vicinity of nodes of orbits of fragments density of particles is maximal and, hence, the search of fragments of explosion should be carried out in a vicinity of nodes of their orbits.

4. STRUCTURE OF A CLOUD OF FRAGMENTS

The cloud of fragments has a non-uniform structure. It is determined by the several factors: by initial distributions of masses and velocities of objects, and also whether destruction took place in the vicinity of libration points. In used model of low energy explosion in the initial moment all fragments have identical coordinates, but different masses and velocities. The initial orbits of massive fragments appear closer to an orbit of the blown up object, than orbit of low massive fragments.

Due to a number of fragments and their mass distribution the structure of a cloud of fragments can differ. In a Fig. 2 the dependences of a geocentric distance change (r) of a fragment from its mass (m) for three mass distributions of fragments are given.
In case of formation of a large number of fragments with masses distributed in a narrow range (Fig. 2a, 279 fragments with weights from 0.1 up to 13 kg), the intervals of r change appear to be close for the majority of fragments. With growth of fragments mass the change of r on the average decreases due to reduction eccentricities of orbits of particles and affinity of large semi major axes of their orbits to an orbit of the blown up body.

With reduction of a number of particles formed as a result of explosion, mass of individual fragments grows (Fig. 2b, 228 fragments with masses from 0.1 up to 35 kg). The reduction of a change of r with growth of fragments masses is expressed precisely.
In Fig. 2c the case of formation of a small number of fragments with different masse is presented (14 fragments with masses from 0.2 to 500 kg). The most massive fragments are moving on an orbit close to an orbit of the blown up body.



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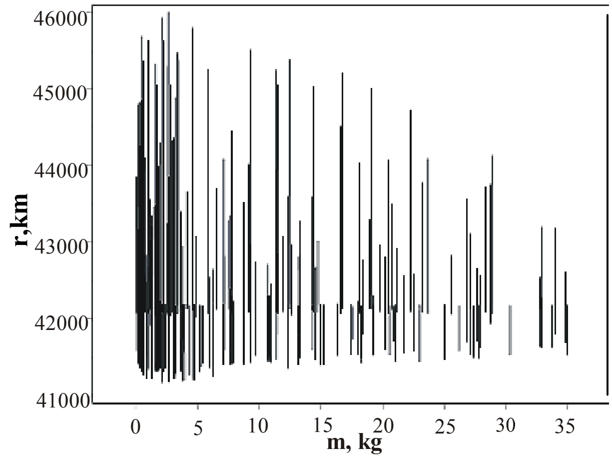

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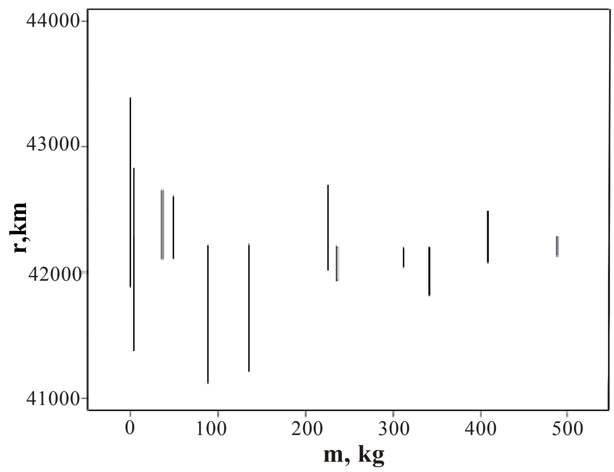

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Figure 2. Ranges of change of distance r for fragments with mass m.

5. CONCLUSIONS

On the basis of the carried out simulations of dynamic evolution of a cloud of particles formed as a result of explosion on GEO we obtain the following results.

More than 95 % of particles formed as a result of explosion on GEO, appears in the field of rotational (concerning a surface of the Earth) movement. Only few fragments appear in area of a libration movement.

The features of evolution of nodes of fragments orbits allow to allocate areas, in which the flow of particles is maximal. These areas are most convenient for search of fragments of explosion in them, on the other hand, these areas are of the increased danger for active satellites on GEO.

Structure of a cloud of fragments is non-uniform. The more massive objects concentrate to center of a cloud and have smaller amplitude of change of geocentric distance. The internal area of a cloud remains non-uniform due to librstion resonance 1:1.

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