FORECASTING OF SPACE VEHICLES APPROACHES TO SPACE DEBRIS IN GEOSTATIONARY ORBITS AREA

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ABSTRACT

The features of uncontrolled space objects motion in geostationary area are studied. The analytical dependencies for average daily drift calculation and values of longitudes of subsatellite object points moving in the libration mode. The values of libration periods, of minimum and maximum longitudes for subsatellite points of geostationary space objects and forecasting dates of maximum approaches for space vehicle "Electro-L" to space objects and minimum distances between them are presented.It Is shown that the value of dangerous approaches for geostationary space vehicles to space debris fragments doesn't exceed 2-3 times per month.

1 INTRODUCTION

It is known that the population of space debris in the geostationary orbit (GEO) area is about 1500 objects and this poses a threat of collision with manned space vehicles [1].

At present there is a weather satellite constellation in the GEO formed by the space vehicles of different countries, such as: GOES (USA), Meteosat (Europe), GMS (Japan), Insat, Metsat (India), FY-2 (China). The Russian geostationary satellite "Electro-L" has been operating since January 2011. This satellite was put into the stand point of 76° east longitude over the Indian Ocean which provides the constant monitoring of the Russian Federation territory.

The space vehicle is supposed to operate for 10 years providing Russian and foreign consumers with the data for analysis and weather forecasting, environmental assessment of sea and ocean water areas, appraisal of aviation flight capabilities, analysis of helio-geophysical environment in the near-Earth space, state of ionosphere and the Earth's magnetic field. The satellite will be also used for climate and global changes monitoring, control of emergency situations and ecological monitoring of the environment.

The data relay satellites "Luch-5A" and "Luch-5B" were put into geostationary orbits in December 2011 and November 2012.

The tasks of these satellites are as follows: information exchange with the orbit constellation, payload data relay, telemetry data from the launch vehicles and upper stages, correcting signals from GLONASS satellites.

Monitoring, forecast and detection of spacecraft dangerous approaches to space debris fragments is realized by the automated hazard alarm system in the near-Earth space (ASPOS OKP) with the leading role of the Mission Control Centre of the Central Research Institute of Machine Building.

2 DYNAMICS OF OBJECTS PASSIVE MOTION IN GEO AREA

The analysis of evolution of space objects' motion in the GEO area allows identifying the following features of orbital parameters changes with respect to time. As the geostationary plane doesn't coincide with the Earth and Moon orbit planes, the gravitational forces of these bodies have such an effect that moves the space objects from their equatorial orbits, gradually increasing the orbital inclination of the objects. Besides, because of a non-circular shape of the terrestrial equator, the part of uncontrolled space objects is slowly moving to one of the two points of the stable equilibrium along the equator. As a result, the east-west libration of the space object is carried out (drift forward and backwards) relative to these points and there is the danger of their collision with the other geostationary satellites.

A part of other uncontrolled space objects drift only in one direction: west-to-east, when their Earth orbit time is less than sidereal day or east-to-west in the other case. The value of the average daily drift D of geostationary space objects longitude can be determined using the approximate formula [1]:

$$D = 360\,(1440/P_s - 1{,}00273791)(°/day), \quad (1)$$

where P_s – sidereal period of geostationary space vehicle orbital time around the Earth measuring in minutes of solar time.

Taking into account the influence of longitudinal components decomposing the Earth potential into exponential series it is establish that there are two stable equilibrium positions – libration points: 75° and 255°

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east longitude and two unstable positions which are placed from stable points out ~ 90°.

In the frame of the simplified symmetrical triaxial Earth model changing of passive geostationary space object can be described by a pendulum equation with sufficient grade of accuracy [1]:

$$d^2f/dt^2 + D_k^2/2sin\ (2f) = 0, \qquad (2)$$

where f = λ-λ_L – east longitude of space object, λ_L – longitude for one of libration points, D_k = 0,437°/day – external parameter acting a role of critical drift for longitude.

3 FORECASTING OF DANGEROUS APPROACHES BETWEEN SPACE VEHICLE "ELECTRO-L" AND GEOSTATIONARY SPACE OBJECTS

The major parameters of libration motion for different geostationary space objects, which have risks of approaches with space vehicle "Electro-L", were determined using the presented functions (1, 2).

As examples the values of libration periods, of minimum and maximum longitudes for subsatellite points of geostationary space objects and forecast dates of space vehicles and objects maximum approaches and minimum distances between them are presented in the table. This data is presented for the different space objects performing libration motion relative to the libration point with 75° east longitude.

Table 1

N	Space object title	Libration period, days	λmin, deg /time	λmax, deg/ time	Approach date/ distance to space vehicle, km
1	STTW-1 (China)	834	46.414 23.10.13	103.775 02.09.12	28.03.13 24
2	EKRAN 9 (Russia)	836	44.583 27.10.13	105.870 04.09.12	25.03.13 38
3	GALS 1	894	34.334 12.11.13	116.109 22.08.12	25.03.13 44
4	RADUGA 1-7 (Russia)	1056	15.974 20.06.12	130.624 30.11.13	27.03.13 74
5	INDOSTAR 1 (Indonesia)	904	30.633 20.11.13	118.104 25.08.12	28.03.13 52
6	RADUGA 27 (Russia)	1066	17.180 10.01.14	130.090 25.07.12	03.04.13 50

It is shown, that the libration period values of these space objects can be from ~ 2 - 2,5 years (space objects STTW-1, EKRAN 9, GALS 1, INDOSTAR 1) up ~ 3 years (space objects RADUGA 1-7, RADUGA 27). For space objects with longer periods the values of λmin are ~ 16-17° east longitude, and for space objects with shorter periods λmin are 44-46° east longitude. The applicable values λmax are over the range from ~ 103° up ~ 130° east longitude.

After determination of these major motion parameters for geostationary objects it is possible to forecast the parameters of dangerous approaches for these space objects with space vehicle "Electro-L". Thus, space object STTW-1 will approach to the space vehicle at the distance of 24 km on 28th of March, 2013. Besides, the next approach with space object, considering its libration period, will occur not earlier than in 1 year. The dangerous approaches for space vehicle and space objects EKRAN 9, GALS 1, RADUGA 1-7, INDOSTAR 1, RADUGA 27 on the distances 38, 44, 74, 52, 50 km respectively are forecasted in March-April, 2013.

Basing on an area catalogue for geostationary satellites data [2, 3], ~ 10% of the total number of space objects move in libration mode relatively to a stable point of 75° longitude and ~ 4% of space objects relatively the point with longitude 255°. Besides about 1% of objects can change their libration points during the motion process.

Space objects quantity with negative drift account for ~ 27%, among them ~ 22% of objects drift with the speed less than -2,5° per day. About 20% of space objects have the positive drift when ~ 10% of objects have drift speed no more than 2,5° per day. The volume of operated geostationary space vehicles which are placed in vicinity of observation points is ~ 38%.

Taking into account the found specialties for dynamics of space vehicles motion in the area of geostationary orbits it is possible to develop a long-term forecast for approach of space object with manned space vehicle. Besides it is enough to conduct the clarification of space objects parameters during the final phases of their approaches with space vehicle.

High elliptical objects with altitudes of apogee higher than and altitudes of perigee lower than geostationary satellites altitude form one more category, which consist of space objects having the theoretical opportunity of approach with manned space vehicle.

In common the results of geostationary space objects motion show that at the average no more than 2-3 space objects approaches at the distance to 15 km with space vehicle "Electro-L", "Luch-5A", "Luch-5B" are registered monthly. At that, the approaches can be forecasted in advance.

4 CONCLUSION

The revealed characteristics of motion dynamics for space objects in the GEO area allow making the following major conclusions:

- for uncontrolled space objects, drifting in the GEO area, the approximate analytical dependencies are given for average daily drift calculation and longitude values of subsatellite object points;
- in spite of rather a big number of space objects having the theoretical possibility of collision with the geostationary space vehicles, taking into account the forecast of their motion it is possible to determine the approximate dates of dangerous approaches. Besides, the occurrence of these approaches with a particular object is rather high and may amount to 2-3 years;
- the conducted research on the detection of dangerous approaches of space debris fragments with “Electro-L”, “Luch-5A” and “Luch-5B” satellites showed that on average 2-3 dangerous approaches of these space vehicles with space debris fragments are detected.

5 REFERENCES

1. Didenko A.V., Demchenko B.I., Usoltseva L.A., Afonin A.N. and others. Zone catalogue of geostationary satellites. Issue 2, 2000, Almaty, Gylym, 108 p.
2. PPM Star Cataloque. The Astronomischess Reechen-Institut.: Heidelberg, Germany, 1991 - 1993, v.v. I - IV.
3. Landolt A.U. UBVR photometric standard stars around the celestial equator// Astron. J. 1983.V. 88, № 3. P. 439-460.