PROTECTION OF THE GEOSTATIONARY ORBIT REGION AGAINST SPACE DEBRIS

E.A.Ashurkov, V.I.Malyshev
Scientific-Production Association of Applied Mechanics.

V.I. Lukyashenko, M.A. Mikhailov, S.V.Chekalin, M.V. Iakovlev
Central Research Institute of Machine.

A.S.Sochilina
Institute of Theoretical Astronomy.

V.P.Blagun, S.V.Kulik, U.E. Lewizki
Russian Space Agency.

Taking into account the permanently growing geostationary (GEO) debris population density, they strictly demand, that modern spacecraft (S/C) should keep their attitude relative to the earth surface with a high precision. The fact is that most of new GEO S/C, launched currently in the world are kept in their position within the error range of $\pm 0.1^0$ in latitude and longitude. What`s more, in future this range may be even reduced to $\pm 0.05^0$.

The limits of keeping S/C in longitude define the value of a maximum deviation of a real orbit radius of the spacecraft r(t), from the GEO radius, r_{GEO} = 42164 km. This value $\Delta r(t)=|r(t)-r_{GEO}|$ runs to about 40km. So, alll orbits of modern and future S/C are and willl be in the close vicinity to GEO and they form a certain stationary ring - an operational region, specified by the correlation; $|\Delta r(t)| \leq 40$km.

All in all, due to all disturbances effect the semi-major axis is subjected to minor periodical changes with the total amplitude of 3km. At the same time, there are rather significant eccentricity changes due to disturbing effects of the terrestrial, lunar and solar gravitational fields, as well as due solar radiation pressure. In the first instance spacecraft flight altitude change may constitute about 27 km. But in the second case spacecraft eccentricity and, accordingly, its flight altitude would depend on the optical properties (spacecraft reflectivity), mean mid-section area and spacecraft weight. As for the national space vehicles the Δr value due to light pressure does not, as a rule, surpass 80 km, and in some casesitit is even considerably lower(up-to 20-40 km) due to uncontrolled spacecraft orientation in its unpowered flight. However the two values are tentative and are to be specified on the basis of investigating near-GEO orbits evolution on long-time legs of spacecraft unpowered flight (for more than 54 years), that is for the known libration period of the orbit plane in relation to the Laplace plane.

During S/C operation sometimes a necessity would arise to alter S/C longitude. In that case depending on the new operational longitude S/C is transferred by its engine to a semi-major axis orbit, different from the GEO radius. As a result S/C begins to shift (drift) along its longitude in the eastern or in the western directions. GEO S/C operation experience shows, that to implement such kind of S/C maneuver it would suffice to impart the drift velocity equal to about 1.5 to 2.5 degrees per cycle. It brings about an increase or decrease of the S/C mean flight altitude by about 200km. Maneuver control strategy should be arranged so, that when a spacecraft is being transferred along its longitude it should not ``immerse in the GEO operational region.

Taking into consideration the above-stated and regarding, that:

I. flight altitudes of the great majority of spacecraft, launched earlier lie within the limits of 42164 ±200km;

2. S/C, when unexpectedly fail and further evolving, remain within the 200km GEO vicinity in radius while;

one should recommend to transfer spent S/C to outer trajectories in relation to GEO . In this case after transfer to the burial region a spacecraft while continuing its flight should not enter the 200km GEO vicinity. It means, that when transferring a spent spacecraft from GEO one should take into account the new orbit evolution and, first of all, its semi-major axis and eccentricity. Analysis of evolution of circular equatorial orbits with the semi-major axis of

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about r_{GEO} +200 km demonstrates, that for the given orbit class influence of the earth gravitational field off-centeredness is considerably weaker than for GEO due to availability of secular displacement along the Greenwich longitude in the western direction ($\lambda<0$).

So, in order to assure flight safety in GEO spent spacecraft should be removed to a burial region and at any time in future a spent spacecraft would not approach GEO closer that at the distance of 200 km. Specific values of the minimally required propulsive mass reserve should be chosen with due regard for this factor and true characteristics of a spacecraft.

But it is natural, that in a general case when removing a spacecraft it would be desirable to extend the removal procedure so as to fully spend the engine propulsive mass, thus enabling to move spacecraft orbits as far deep as possible into the burial region.

Drawing-up of a complete object catalog is one of the basic objectives for assuring GEO flight safety. Currenty there is available a catalog, made up by the Institute of Theoretical Astronomy of the Russian Academy of Sciences, which contains about 600 objects, measuring over I meter. Orbital characteristics of 50 objects are being refined. The GEO population level with objects less than one meter is not investigated to-day. There is no GEO spacecraft fragmentations catalog and data on standard element separations from spacecraft.

Placing of a tracking capability-equipped spacecraft in a high circular orbit with the altitude of about 36000 km and inclination of 180^0 would enable to track GEO objects, measuring less than Im. Such spacecraft moves towards GEO objects, approaching them at minimum distances in each 12 hours at a relative velocity of about 7 km/sec. Tracking capabilities may include an optical-electronic system, operating in the IR and optical wavelengths.

An International Program to monitor, protect and safely use the GEO region under conditions of its man-made pollution should, in our opinion, comprise the following basic areas:

- organization of joint GEO object tracking operations using on-ground and orbital capabilities;
- drawing up of a common catalog of GEO objects and their orbit elements, applying observation results of a tracking station network and space facilities;
- development of a methodological system for GEO objects identification, long-term prediction of their motion and collision risk using observation data;
- working out of coordinated recommendations on GEO region protection against space debris.