RECOMMENDATION ITU-R S.1003*

ENVIRONMENTAL PROTECTION OF THE GEOSTATIONARY-SATELLITE ORBIT

(Question ITU-R 34/4 (1986))**

(1993)

The ITU Radiocommunication Assembly,

considering

a) that satellites are designed as fragile structures that have little survivability in case of a collision in orbit;

b) that telecommunications functions of a satellite would be lost or at least degraded by a collision in orbit;

c) that satellite breakup due to a collision or explosion would create a cloud of orbital debris that would dissipate around the orbit, increasing the collision probability within that orbit;

d) that a satellite drifting in orbit after the end of its life may block RF links of active satellites,

recommends

1. that as little debris as possible should be released into the geostationary-satellite orbit (GSO) during the placement of a satellite in orbit;

2. that every reasonable effort should be made to shorten the lifetime of debris in the transfer orbit;

3. that a geostationary satellite at the end of its life should be transferred, before complete exhaustion of its propellant, to a supersynchronous graveyard orbit that does not intersect the GSO (see Annex 1);

4. that the transfer to the graveyard orbit should be carried out with particular caution in order to avoid RF interference with active satellites;

5. that the following Note should be considered part of this Recommendation.

Note 1 – Further studies are required to define what constitutes an effective graveyard orbit.

ANNEX 1

Environmental protection of the geostationary-satellite orbit

There are in the geostationary-satellite orbit (GSO) region, effective October 1991, 322 active and derelict spacecraft and 111 rocket bodies and other objects associated with the placement of these satellites. Most of these objects are no longer subject to active control by their original operators. In addition to the population of objects in the GSO region, there are other objects that transit the region periodically. Some are geosynchronous transfer orbit stages with their perigee in low-Earth orbit but others are objects that have been displaced to storage orbits above or below the GSO (see Fig. 1).

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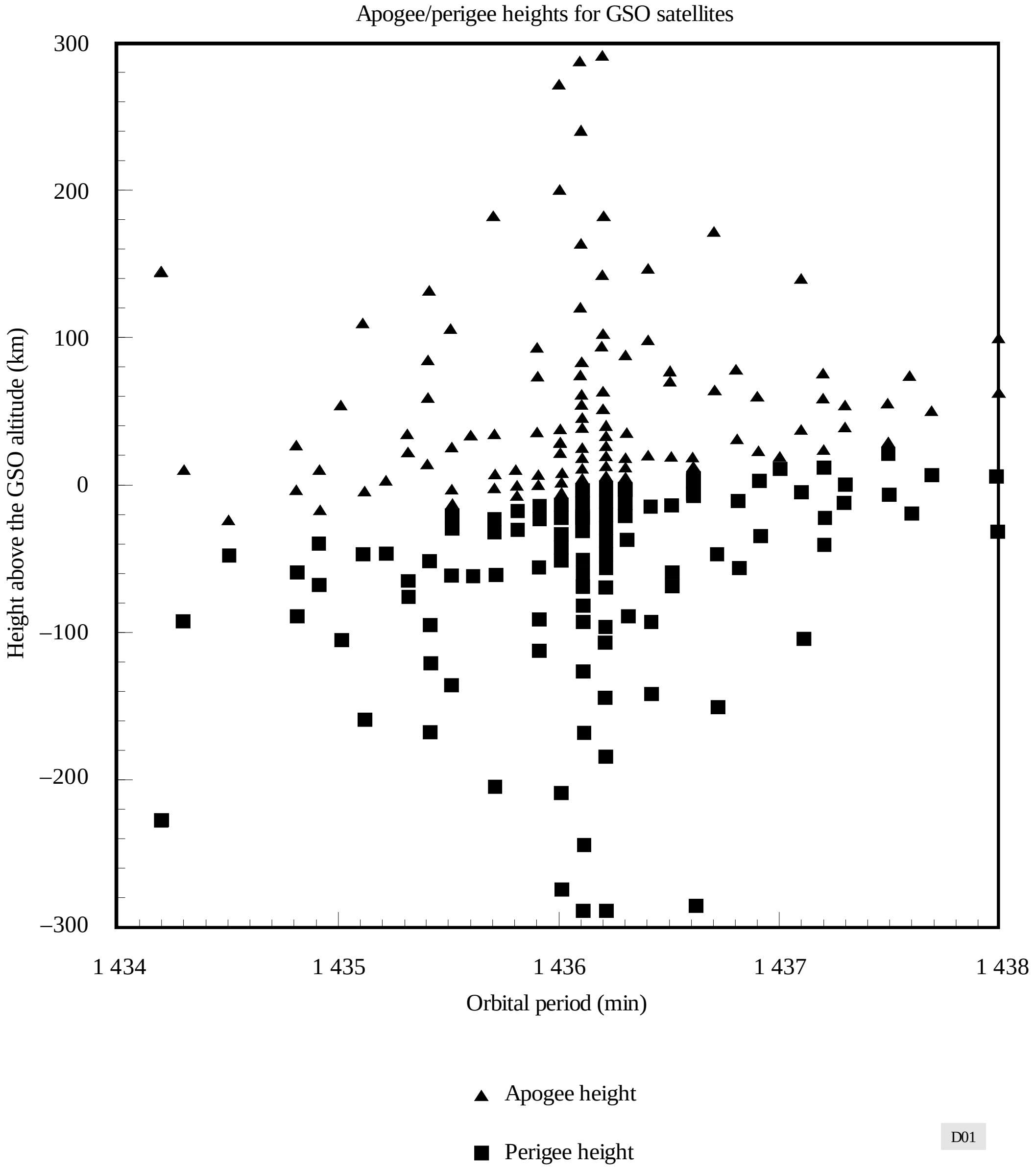
* This Recommendation should be drawn to the attention of Radiocommunication Study Groups 7, 8, 10 and 11. It is requested that Radiocommunication Study Group 7 should address the subject of the preventing of the deposit in the geostationary arc of spacecraft or transfer stage components that represent a hazard to functioning spacecraft.

** Former CCIR Question 34/4.

FIGURE 1

Objects in or near GSO



Operators of geostationary assets have used significantly differing orbital control strategies and these have changed over time. Many orbits have significant degrees of ellipticity; and a recent change in the relevant ex-IFRB (now the Radiocommunication Bureau) rule of procedure allows a significant degree of excursion in inclination. These have all been permissible strategies but the effect has been to expand the effective dimensions of the region characterized as geostationary. For purposes of considering environmental measures the GSO may be defined as the mean earth radius of 42 164 km ± 300 km and extending to 15° N/S latitude or a distance of approximately 10 000 km. The dimensions of the region are dictated by the initial conditions at loss of control of the spacecraft or of other satellites and the influence of the lunar and solar perturbations, solar pressure and the tesseral terms of the Earth’s oblate shape.

Knowledge of the geostationary environment is limited by the resolution of Earth-based observations. The smallest dimension of an object detectable and trackable (under best conditions) in the GSO at present is 1 m; by comparison, in low-Earth orbit the population of objects having dimensions above 30 cm is deterministically known and catalogued, and the population of objects having dimensions down to 5 mm is statistically characterized as to altitude and inclination. Position knowledge of spacecraft or objects not under RF control is not as good as the operators' knowledge of position of active spacecraft.

Risk to operational spacecraft derives primarily from explosion debris fragments attributable to residual propellants and gases in rocket bodies and less frequently to stored energy in batteries. Over half of the objects in the Space Surveillance Catalogue are fragmentation debris objects. There have been two to four suspect events in low-Earth orbit that may have been collisions but none have been verified. There have been two events that have been characterized as explosion events in GSO. It is quite likely that there have been other events that have escaped detection due to the limitations of observation methods.

While collisions in the geosynchronous orbit will not have the extreme consequences of those in low-Earth orbit they can be significant. The velocities are more than high enough to inflict significant damage if the coupling efficiency exceeds a few tens of per cent. At the long-term characteristic collision velocity (500 m/s) the consequences could be comparable to jet aircraft collision damage.

Because of operator practice in the past there is a significant spatial density in the GSO. However, because it migrates predominately in a single direction and the velocities are relatively low the collision hazard probability is quite modest. It is modest not because of the nature of the event – which can be quite impressive when it occurs – but because the potential intersection occasions are infrequent. As Fig. 1 indicates there is a significant concentration in the most stable region but significant numbers in the adjacent regions.

Boosting the orbit of a satellite near the end of its functional lifetime appears to some to offer the advantage of reducing the near-term collision probability by some amount. It is important to note that the same forces that cause migration of the derelict spacecraft in the GSO will perturb the spacecraft in the graveyard orbit. Figure 2 illustrates the effect of a major explosion or collision event. Each point in the figure is a fragment. Those which acquire retrograde energy have a lower perigee and an apogee at the original altitude; those that acquire posigrade energy have perigee at the original altitude and apogee at a new higher altitude. It is this effect which places debris from the graveyard orbit back into the geosynchronous arc.

The requirement for reboost is 3.64 m/s/100 km or 1.69 kg of propellant/1 000 kg of mass of the spacecraft. For each 100 km in elevation above the geostationary altitude a westward drift rate of 1.28° per day is induced.

It is important to note that there are many objects other than spacecraft in the geostationary arc; e.g. apogee kick motors that are normally separated from the spacecraft after circularization in order to reduce the mass of the spacecraft to minimize station keeping fuel. It is not clear what advantage there is to reboosting the spacecraft at end of life if such objects continue to be added to the population.

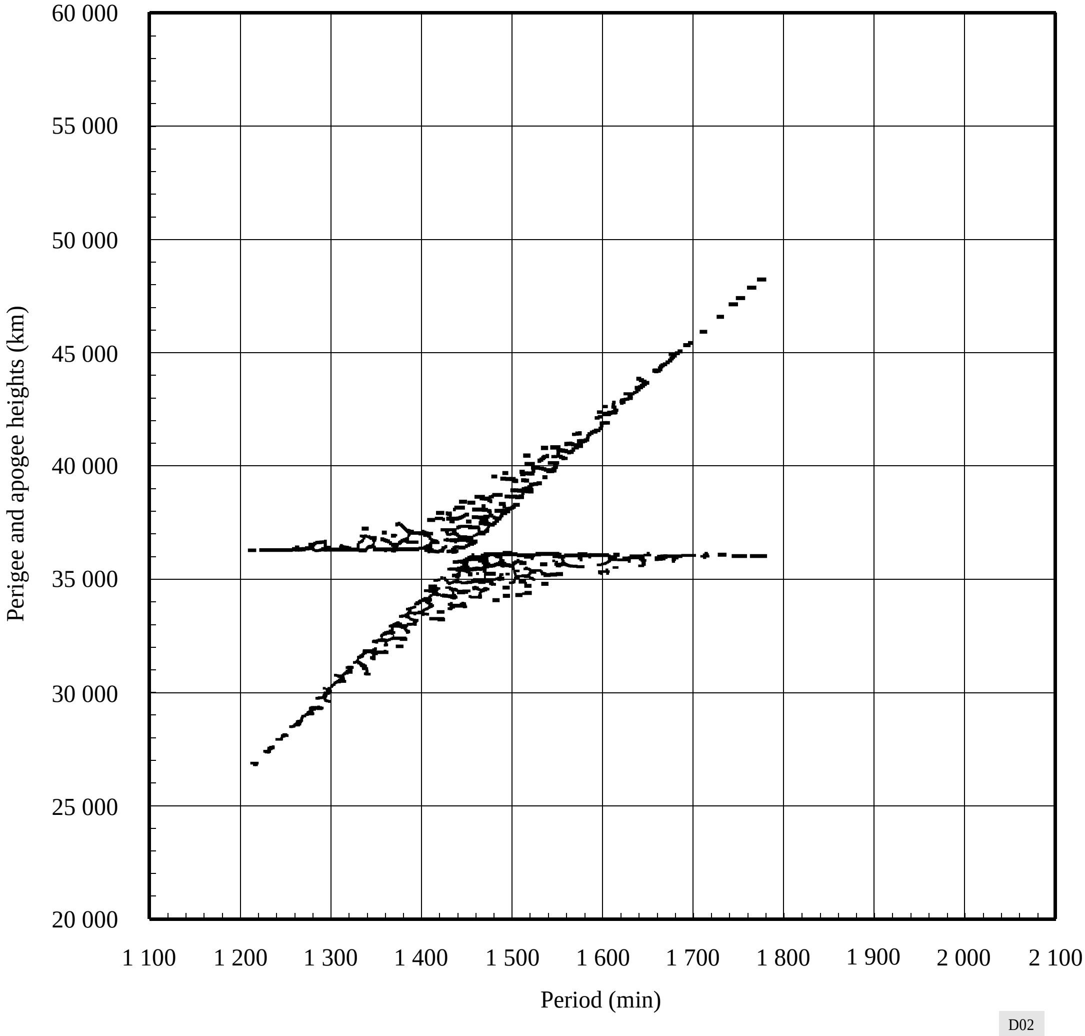
Because of the orbital characteristics of the current population in the geosynchronous arc, if a spacecraft is to be reboosted it should be to increase the perigee altitude by, for example, 300 km or more and the apogee by a comparable amount. It may be noted that of the objects reboosted to date, the mean perigee increase is in excess of 250 km. Definition of an effective minimum altitude is a topic for further study.

If spacecraft reboost manoeuvres are to have any long-term beneficial effect they must include measures to preclude explosions. Such debris mitigation procedures have been adopted for all upper stages left in low-Earth orbit; the residual propellants and pressurants are vented or consumed. Similar action should be effected for objects left in graveyard, geostationary or geosynchronous transfer orbits.

There is an orbit at 7.3° inclination with a zero angle of right ascension that is inertially stable due to the lunar and solar forces. Spacecraft in this orbit would not require N/S station keeping because these forces are in balance. Reboosting from this orbit is also stable and the risk of collision in the higher altitude is quite small and the contact velocities are very low (5 m/s).

FIGURE 2

Gabbard diagram for collisional break-up of 1 000 kg satellite in the GSO, 423 > 10 cm particles



Impact velocity = 500 m/s

Spacecraft debris and rocket stages abandoned in a transfer orbit have a low perigee and an apogee at geosynchronous altitude. These debris cross the GSO at least twice a day. The lifetime of the object in transfer orbit depends upon the initial perigee height, the initial longitude of the ascending node and the season of the year. It is possible to select these parameters so that the apogee height will decay rapidly and the transfer stage will not be a hazard to objects in the GSO. This constraint on launch window is often not compatible with other constraints.