Man-Made Debris Problems in Geosynchronous Orbit

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Abstract

Man-made orbital debris is a collision hazard to operating spacecraft because of the high velocities in Earth orbit, leading to potentially high encounter velocities between orbiting objects. Debris sources include launch debris (upper stages, shrouds, fastener fragments, etc.), explosions (from pressurant gasses, leftover propellants, other causes), dead satellites, and collisions. Much effort has gone into the study of the orbital debris situation in low Earth orbit (LEO); not quite so much into study of the situation in geosynchronous Earth orbit (GEO) and nearby regions of space.

An important difference between LEO and GEO is that in geosynchronous orbit there is no atmosphere, thus air drag to pull objects out of orbit over time. Any objects placed in GEO will stay there until removed in some other way. Debris will accumulate, with no natural process to eliminate it.

A satellite in GEO without station keeping capability (*e.g.* runs out of propellant) experiences two types of perturbations: In the short term (periods of a few hundred days) it will undergo longitude oscillations about the nearer of two "stable longitudes" near 75° E and 105° W, due to the J2,2 term of the geopotential. In the longer term (period ~ 53 years), gravitational torques from the Sun and Moon, combined with Earth's equatorial bulge (J2 term) cause the orbit plane to precess. This leads to inclination excursions up to ~15°. Inclination excursions are more important as a collision hazard than longitude oscillations. An uncontrolled satellite at an inclination of 15° will cross the paths of active GEO satellites at a relative velocity of ~ 800 m/s, comparable to the speed of a rifle bullet an artillery shell.

The current approach to dealing with this hazard is to boost a satellite propellant up to a "graveyard" orbit 200 - 300 km above GEO the at end of its life. An alternative approach will also be presented: to place GEO satellites in a "stable plane" inclined ~ 7.3° to the equator. Plane precession in such an orbit will limit inclination excursions to ~ 1.2° from starting orbit. Careful orbit can limit relative inclinations among satellites in such an orbit to < 0.2°. A relative inclination of 1.2° reduces relative velocity to 67 m/s; 0.2° to 11 m/s.