MITIGATION RULES COMPLIANCE IN LOW EARTH ORBIT

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ABSTRACT

Space debris mitigation is one of the French Space Operations Act objectives, through the removal of non-operational objects from populated regions. At the end of their mission, space objects are to be placed on orbits that will reduce collision hazards with other spacecraft or debris.
This paper presents our investigations on mitigation guidelines compliance in Low Earth Orbit (LEO) by space operators from 2000 to 2013. We are particularly interested in studying the expected decrease of the mid- and long-term collision risk in LEO, through the application of the 25 years rule or the reaching of a graveyard orbit above this region.
We have identified space objects ending their mission during the period of interest and estimated their orbital lifetime. We obtain a global compliance rate and analyze its evolution over a 14 years period.

1. INTRODUCTION

Since the very beginning of the space era, human activities have led to place into orbit more than forty thousand space items. These objects are of a great variety, going from several tons spacecraft to Cubesats. However, less than 7% of orbiting objects are still considered today as operational. This implies that the in-orbit population is mainly dominated by space debris of various sizes, rather than active spacecraft, and their growing number increases the probability of collision hazards, as illustrated by the loss in 2009 of the operational Iridium-33 satellite after the collision with the inactive Kosmos-2251. Such dramatic events create a large amount of new debris, corrupting durably the given space area, as already expressed by Kessler *et al.* in 1978 [1].
Therefore, space debris mitigation becomes a topic of primary importance for the preservation of the space environment and for the space systems operations safety, especially in Low Earth Orbit (LEO) and Geostationary Earth Orbit (GEO). Objects removal from these regions once their missions are terminated is today a common practice to mitigate the growth of the debris population.
In the last two decades, several actions have been undertaken in order to restrict the expected growth of the debris population. In France, the French Space Operations Act (FSOA) [2] came into force in 2010 with Space debris mitigations being one of its objectives. At international level, the UN Committee on the Peaceful Uses of Outer Space (COPUOS) [3] and the Inter-Agency Space Debris Coordination Committee (IADC) [4] published their mitigation guidelines respectively in 2007 and 2002. In the FSOA, two protected regions have been defined, as shown in Fig.1:

A. The LEO protected region, which is the area with the highest space debris population density, is defined by an altitude lower than 2000 km;
B. The GEO protected region is defined by an altitude within 200 km of the geostationary altitude, and an absolute value of inclination inferior to 15°.

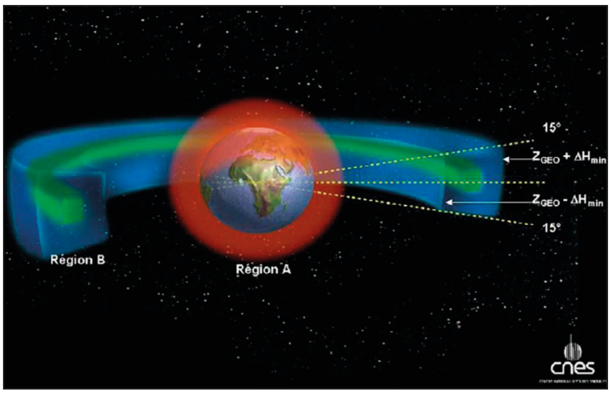

Figure 1. LEO and GEO protected regions

The French Space Operations Act states that a satellite or launcher element placed on an orbit crossing the LEO protected region shall reenter the Earth atmosphere by performing a controlled re-entry, or, if impossibility to do so is duly proven, to reenter the atmosphere no later than 25 years after its end of mission date [2].
This paper focuses on the mitigation guidelines compliance analysis in the LEO protected region, for all space operators. The LEO region is the one with the highest objects spatial density, and consequently with the highest probability of collision between objects orbiting through this region, as presented in Fig. 2.

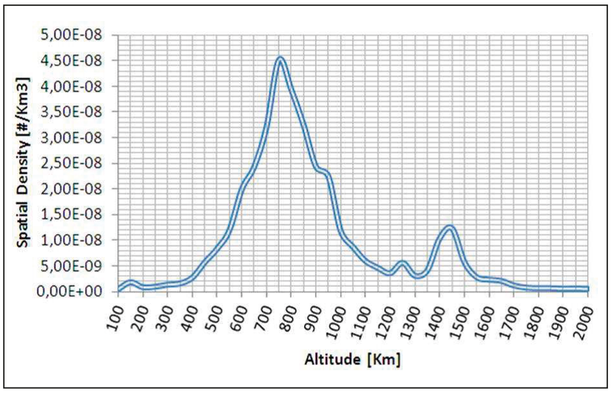

Figure 2. Spatial density as a function of altitude in protected region A

Once we have computed the mitigation guidelines compliance rate for LEO objects orbiting the Earth, we can use these statistics together with the long-term projections of the Earth's satellite population and the expected evolution of the Post-Mission Disposal (PMD) compliance rate, in order to evaluate if the efforts made to increase the global compliance with mitigation guidelines in LEO are already noticeable, and if such efforts are good enough to guarantee the long term sustainability of space activities.

1.1. Expected increase of the PMD compliance

Even if the number of objects orbiting the Earth has increased steadily since the launch of the first satellite in space, mainly due to new launches or explosions, the global dimension of the problem affecting the long term sustainability of space activities has not been understood until recent times.
Starting in the 90s, such awareness has motivated new initiatives to limit the proliferation of space debris. However, national mitigation guidelines were not published until 2002 [4]. This means that most satellites and rocket bodies orbiting presently the Earth have never been designed to be compliant with such guidelines.
Hopefully, new treaties and laws such as the FSOA, as well as other initiatives to come, will start to have a significant impact on the compliance to mitigation guidelines in the years to come.

1.2. Long term projection of the Earth's satellite population

In the last decade, space debris modeling has been used intensively to analyze the way in which the Earth's satellite population will evolve in the long term as a function of a given number of endogenous and exogenous variables, as for example the global compliance of the spacecraft and rocket bodies with the mitigation guidelines.
Such long-term simulations can be used to define the critical values of a group of variables (e.g. Post Mission Disposal compliance rate, frequency of explosions …) in order to guarantee the long term sustainability of space activities, or to analyze the sensitivity of the model to a modification in one of these variables.

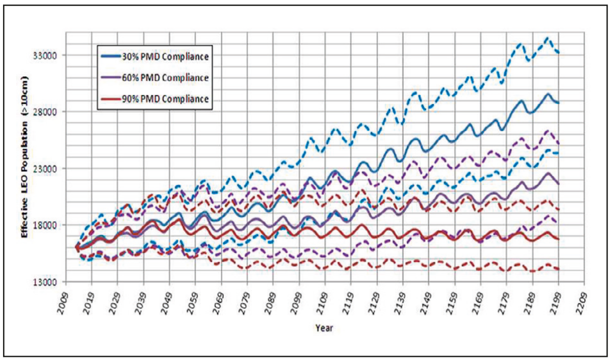

Figure 3. MEDEE simulated LEO debris population (objects 10 cm and larger) as a function of PMD compliance rate. The thick curves are the arithmetic means from 40 MC projections. The dotted curves represent the 1-σ standard deviation

Fig. 3, excerpted from [5], depicts the long-term evolution of the LEO population of objects larger than 10 cm, between 2009 and 2200, as a function of the PMD compliance rate and under the following assumptions:

- *Initial Population:* ESA's MASTER reference population ≥ 10cm residing in, or passing through, the LEO region on 1st May 2009.
- *Launch Traffic:* The observed 2001–2009 launch traffic cycle, is repeated throughout the simulation.
- *Satellite Properties:* Operational lifetime of satellites is set to 8 years. No station keeping or collision avoidance maneuvers are considered.
- *In-Orbit Explosion:* No future explosions are assumed.
- *Solar activity:* 200 years variable solar activity projection.

The PMD compliance rate presented in Fig. 3 refers to the percentage of objects in LEO, initially not compliant with the 25 years rule, performing a deorbit maneuver at the end of their operational lifetime. As we can see, the PMD compliance rate has a huge impact on the population evolution. It is therefore relevant to try to estimate its real value.