

# A brief scenario about the "space pollution" around the Earth

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**Abstract:** In this work is presented a brief review about the main events generating of space debris around the Earth, occurred up to the present day. How the clouds of debris "polluted" the neighborhood of orbits in which the bodies were initially allocated is here analyzed. The implications of the growth of space debris existing on space missions as well as safety rules to control sources of debris are discussed.

**Keywords:** Space debris, historical scenario, main events generating debris

## Introduction

In the second half of the twentieth century, more specifically at the post-Cold War, U.S. and the former USSR vied for supremacy between their forms of government by the called Space Race. This milestone effectively began with the launch by the Soviets of the artificial satellite called Sputnik 1 in October 1957. Since then, thousands of missions were carried out not only by the two superpowers, but also by several countries. After the Sputnik 1 approximately 28,000 objects were placed in orbit around the Earth, of which approximately 9,000 are still objects in orbit and of these only 6% still in operation [1]. At the end of its useful life, the vast majority of satellite remains in orbit around the planet. Added to inactive satellites there are still missions for which the final stages of the rocket launcher, adapters, and lens caps that remain in orbit beyond debris caused by explosions of satellites, or collisions between them, or even with other debris. All these objects should be characterized as space junk. Removal of some of these objects is made naturally by gravitational and non-gravitational perturbations. It is estimated that the natural removal of objects smaller than 10 cm can last several days if these objects are below 200 km altitude, several years if their orbits are between about 200 and 600 km, hundreds of years for orbits between about 600 and 800 km, and permanently if the altitude is greater than about 36,000 km [1].

## 2 - Generating new debris

Explosions of some objects in orbit were detected and may be related to residual fuel remaining in tanks of stage of rocket launchers discarded around the Earth. Over time, the space environment may deteriorate the mechanical integrity of external and internal parts, leading to leaks or the mixture of fuel components, which can lead to auto ignition. The resulting explosion can destroy the source object and its mass is spread through numerous fragments with a wide range of masses and velocities transmitted [2]. Considering the events of collisions and



explosions there are numerous records and so some of these may be described as major sources of generation of space debris. The first verified case of collision between two objects in space is assigned to the collision between the cataloged space debris coming from the rocket Ariane 1 with Cerise, a French military reconnaissance satellite. The crash occurred on July 24, 1996 and caused a cut of 4.3 meters in the system of stabilization by gravity in the Cerise, leaving the satellite severely damaged [3].

### 3 - The main events generating debris

Below will be mentioned some of the most significant events that have already occurred in low-altitude earth orbits - LEO, given in order of increasing of generation of cataloged objects.

#### *Fengyun 1*

In January 2007, the Fengyun 1C weather satellite that was out of operation was blown up by a Chinese ASAT (anti-satellite missile) as part of a widely criticized test of anti-satellites missiles. For a period of one month after the explosion, it is estimated that the number of fragments with sizes larger than 5 cm is above 2000 and up to 1 cm that number is about 35,000, [4]. After this incident it is estimated that the volume of debris in orbit of the planet has increased by 25%, from 9,949 cataloged objects in December 2006 to 16,094 in July 2011. The debris cloud generated after the collision is dispersed in orbits between 125 km altitude up to 3,800 km, affecting a significant portion of the LEO satellites [5].

The Chinese test conducted in January 2007 with anti-satellite missiles, which culminated in the explosion of the satellite Fengyun 1, represents the largest single event generator of space debris ever recorded, with approximately 3,037 objects with sizes equal to or greater than 10 cm, the Fengyun debris corresponds at 22% of the total volume of debris in orbit in the LEO region. The cloud of debris coming from the Fengyun 1C has an apogee range of about 400 km and 3600 km, and range for the perigee of about 350 km at 900 km altitude, with the region of highest density of this cloud corresponding to an altitude interval between 500 km and 1500 km. The debris from the Fengyun 1C cause risk not only to the International Space Station - ISS but also to the various satellites in LEO orbits. Studies done by NASA simulated the debris cloud evolution of the Fengyun 1C for the next 100 years since its fragmentation and the results is that, even for this long period, it is estimated that 79% of the Fengyun C debris still remain in orbit [6].

***Iridium 33 e Cosmos 2251*** - The collision between the U. S. Iridium-33 satellite, owned by the private company Iridium, and the Russian military satellite Cosmos is the second largest generator of waste already evident, and produced approximately 1,685 cataloged debris. This collision occurred on February 10/ 2009 about 800 km altitude, but their debris generated an immense cloud covering almost all orbits corresponding to the interval between 180 km and 1700 km altitude, which is a very dense region of active satellites orbiting between 600 km and 1000 km [7]. This event "polluted" almost every region LEO offering risk for any and every object that meets these orbits.

***Breze-M*** - On 16 October 2012 the third stage of a Proton-M rocket exploded in orbit creating a cloud containing about 80 cataloged debris. This is not the third largest event causing debris, but has attracted more attention because the debris cloud generated covers orbits between 100 and 5500 km altitude, which endangers all satellites in LEO orbits and in particular shall ISS where the intersection of the two orbits are the debris which is the same altitude ISS [8].

There were also other major events generating debris in LEO orbits, like the explosion of the upper stage of the STEP II, Pegasus Propulsion System Assist the Hydrazine - HAPS, in 1996, where they were catalogued 702 debris that formed a cloud between approximately 350 km and 3000 km altitude endangering missions in low Earth orbit and will even International Space Station - ISS. And the fragmentation of Third Stage of launch vehicle Long March 4B occurred on March 11, 2000, generating a cloud of debris catalogued 345.

Figure 1 illustrates the evolution of the number of debris tracked by the Space Surveillance Network of the U.S. with emphasis on the rapid increase of the debris after the collision mentioned above. Looking at the chart it can be observed that the amount of debris orbiting the

Earth has more than doubled after the destruction of the Chinese satellite Fengyun and the collision between the satellites Iridium and Cosmos [9].

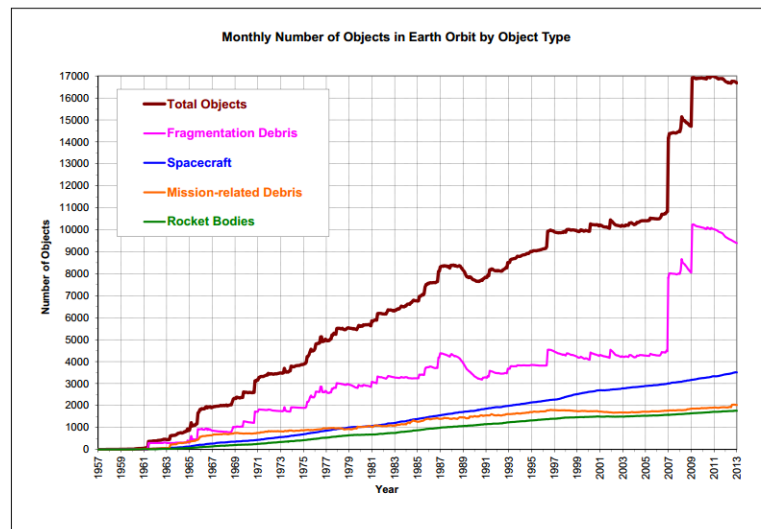


Figure 1 - Evolution of debris tracked by the Space Surveillance Network. (Extracted from [ 9]).

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### 3.1 Secondary events

Although not yet confirmed, there is strong evidence that two fragmentations resulted from collisions with debris from the Fengyun 1C.

By February 19, 2007 one of the injection stage of the Briz-M exploded on Western Australia. The cause of his outburst, though not yet demonstrated, is associated with debris from the collision with Fengyun 1C because it occurred about 37 minutes after its passage through the ring of debris generated by the event [10]. On February 14, 2007 the auxiliary engine of the SL-12 rocket exploded in orbit. This event occurred one month after the fragmentation of the Fengyun 1C. This event deserves greater attention and being technically examined, because it may have originated by a collision with debris from the Fengyun 1C [11].

All the cited events occurred in LEO orbits, but there are also events in other regions, geostationary-altitude earth orbits (GEO) and mean-altitude earth orbits (MEO). Table 1 shows the apogee and perigee of the three main events in MEO and GEO regions.

MEO Events				GEO Events			
Object	Apogee	Perigee	Number of Debris	Object	Apogee	Perigee	Number of Debris
COSMOS 2022-2024	18.410	655	105	INTELSAT 515 R/B	35.720	510	37
COSMOS 1970-1972	18.515	720	76	COSMOS 1285	40.100	720	18
COSMOS 1883-1885	19.120	335	39	CAT R/B	33.140	180	18

Table 1 - Apogee, Perigee and number of debris to the main events in MEO and GEO regions.

## 4. Safety rules to control sources of debris

Nowadays it is estimated that there are about billions of space debris orbiting our planet with a diameter of less than 1 cm. There are about 100,000 debris orbiting around the Earth with diameter between 1cm and 10 cm and about 17,000 debris with a diameter greater than 10 centimeters [1]. The existence of debris orbiting Earth can endangers the safety of space

missions and satellites. In order to limit the generation of orbital debris and considering the importance of this "pollution space" for technological advancement, NASA created the Safety Standard 1740.14 [12].

Among the conditions to be met by space missions, should also be performed:

- depleting energy sources on board after the completion of the mission to prevent the disintegration caused by bursts of residual fuel in the tanks and transmission lines;

- limit the life of the mission in orbit after 25 years performing maneuvers to a disposal orbit. These regions are most common for objects in GEO and MEO orbits and considering that the re-entry of objects at these altitudes is very unlikely; therefore, objects are allocated in storage orbits which serve as a kind of "graveyard" for satellites at the end of its useful life. The storage orbits are located down and up about 500 km with respect the orbits MEO and GEO, so this measure does not reduce the amount of "space junk" around the planet, only keeps the debris more far from the used orbits. For LEO orbits, due to its greater proximity from the Earth, the most interesting task to do at the end of the useful life of a satellite is providing its reentry "controlled" in the atmosphere, where due to the high-speed reentry friction with atmospheric air would cause fragmentation of the object. The most recent missions include in your planning an extra fuel to this maneuver. For altitudes up to 200 km reentry occurs naturally after a certain period, because in this region there is still a rarefied atmosphere which causes friction with the object. This atmospheric reentry "controlled" is made so that debris will fall into the ocean at least 46 km away from the mainland;

- limit the generation of debris associated with the normal spatial operations such as the introduction of extra fuel for the last stage rocket re-enter into the atmosphere;

- limit the risk of system components spatial to survive atmospheric reentry and thus prevent bodies from falling on populated areas endangering the planet's population.

## 5. Cloud of debris

Fragmentations and collisions of space objects give rise to a phenomenon known as "the clouds of debris" "polluted" the neighborhood of orbits in which the bodies were initially allocated. This phenomenon may preclude executing future missions in orbits affected and endangers some specific missions. Currently there are no effective means capable of removing large amounts of space debris, and the growth in the number of debris in orbit of the planet has become a big problem. Thus, the following items will treat the evolution of debris clouds in different regions. LEO orbits correspond to altitudes ranging from 200 to 2,000 km above the earth's surface. In these orbits satellites travel at a speed of about 27,400 km / h, this represents a revolution about 90 minutes. In this region the greatest concentration of debris space is found, the number of conjunctions which is proportional to the risk of collisions is about five kilometers to objects in LEO orbits in a period of 24 hours. After incidents involving the ASAT with the satellite Fengyun 1C in 2007 and the collision between the two satellites (Iridium and Cosmos) in 2009 greatly increased the number of debris and consequently the number of collisions in LEO orbits where are still found approximately 503 active satellites [13]. The Figure 2 shows the distribution of the population of debris in this region as a function of density, with emphasis on waste generated by the fragmentation of the satellite Fengyun 1C and by the collision between the satellites Iridium 33 and Cosmos 2251 [9].

Through time, various gravitational and non- gravitational forces will spread the particles beyond the original plane of the orbit. To illustrate, Figure 3 shows the behavior of the scattering of debris as function of the time. Note that, in just 80 days, the cloud of particles make up a ring around the Earth [9]. Figure 4 shows the four largest clouds of debris in LEO.

## 6. The estimated growth of space debris

A projection, for the growth of space debris for the next 200 years, taking into account the worst case, alert us to comply with the mitigation standards, without which, the space environment will become so polluted that will preclude future missions [15]. For such a projection is possible to notice that the LEO orbits require greater attention, because for these orbits is forecast exponential growth and this factor is known as the "Kessler Syndrome". This is what motivated the creation of the current mitigation measures, for example, a maximum of 25 years for a

satellite to remain in orbit. After this period the satellite is relocated into a disposal orbit. For MEO and GEO orbits the scenario is a little more exciting because predicts moderate growth in waste generation for these orbits.

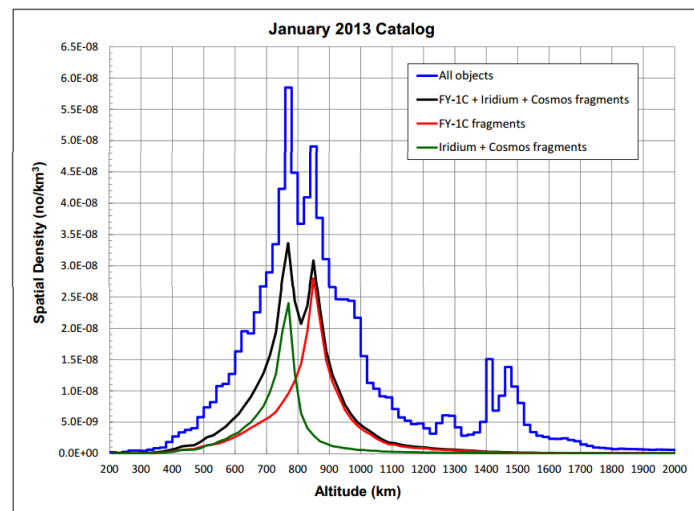


Figure 2 - Distribution of cataloged debris population in low Earth orbits before and after main events of explosion (Extracted from [9]).

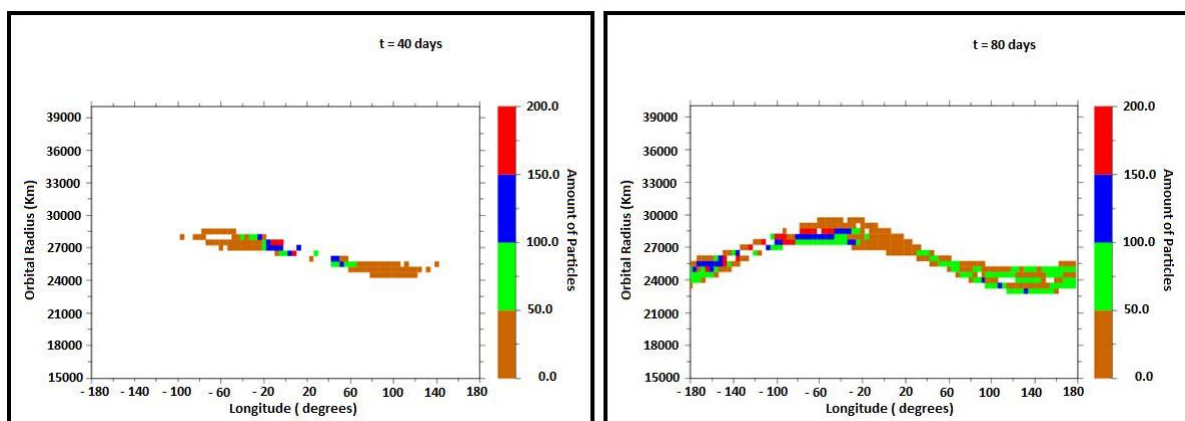


Figure 3 - Evolution of a cloud of debris microns in size after fragmentation in the region of a GPS satellite. [14]

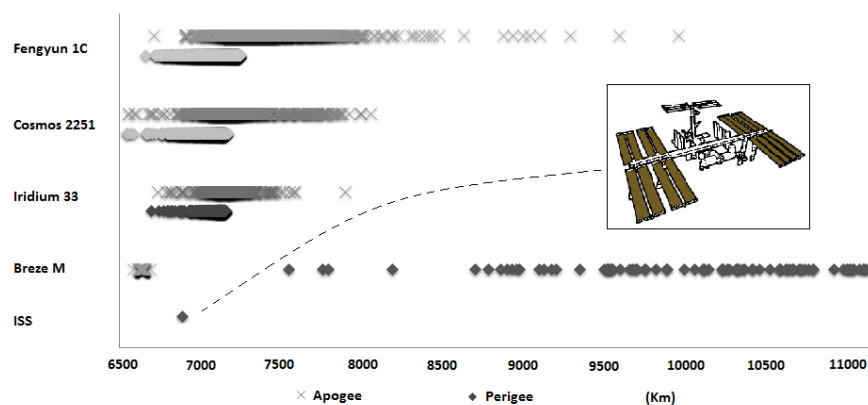


Figure 4: The four largest clouds of debris in LEO. The location of the ISS is shown.

## Conclusion

In this paper we presented a historical scenario of the environment around the Earth in terms of space debris. The main events considered sources of waste generation were cataloged and presented to estimate this future environment. These findings emphasize the importance of means of "cleansing" of regions around the Earth so that are not hindered future spatial missions and thus technological advances. Safety standards for the generation of space debris can ease the situation but not solve it fully. It would require a more effective surveillance so that these patterns could actually be met. Further research in parallel must be undertaken for more immediate and effective result. By this brief history it was observed that the formed cloud of space debris with less than 10cm may also offer lower risks but important since they are not cataloged. It is believed that this brief historical backdrop of space debris around Earth might contribute to future projects on this topic in Brazil.

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