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SPECIFIC WORK GUIDE ON "SPACE DEBRIS"

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Introduction

Space debris is a big problem. Some of that waste is very big, like the burnt stages of rockets, satellites rendered useless and some tools which are lost in space walks. However, most of it is much smaller.

Collisions with large pieces of debris can render spaceships useless or even destroy them, which is what happened with the French satellite Cerise in 1996. The smallest waste can also cause great damage or threaten astronauts on their space walks.

When the solar panels of the Hubble space telescope were moved back to Earth in 2002, they were riddled with impacts up to 8 mm wide.

Over 500,000 pieces of space debris orbit around the Earth. They normally don't suppose any threat, but in space the waste travels at great speed. Even dust particles act as tiny projectiles. The increase in space debris poses a risk for all space vehicles, and is especially alarming in the case of vehicles with human beings on board such as the International Space Station, space shuttles and other manned spaceships.

What is space debris?

In a very general way, the name space debris could include both natural objects and artificial particles, made by man. However, since meteorites generally orbit around the Sun, we usually use the term space debris for the artificial objects which orbit around the Earth.

Therefore, any artificial object without any use which orbits around the Earth is called space debris or space junk. It consists of such varied things as large debris from old rockets and satellites, remains from explosions, or remnants of rocket components such as dust and small particles.

There are over 20,000 pieces of debris larger than a foam ball orbiting around the Earth and some 500,000 pieces of debris the size of a small stone. It is also known that there are millions of pieces which are so small that they are not detected from Earth.

For us to get an idea of the impact of these small particles orbiting around the Earth, the windows of NASA's space shuttles had to be repaired several times after being hit by a material which, after analyzing the impacts, turned out to be specks of paint.

We now better understand the words of NASA's chief scientist for orbital debris when he says that “the greatest risk to space missions comes from non-trackable debris”.

Space debris has become a greater and greater concern in the past few years, since collisions at orbital speeds can be highly damaging to the operation of satellites and they can also produce even more space debris in a process called the Kessler Syndrome. With so much space debris, in fact, it is surprising that there are so few disastrous collisions in space.

Problems caused by Space Debris

Space debris is not just a theoretical probability of a collision occurring; it is a real risk and there have been different missions affected. Here is a list of the most significant historical facts related to Space Debris:

- The first official maneuver to avoid a collision was made in September 1991. The space shuttle mission STS-48 turned on its control system for 7 seconds in order to avoid a possible clash with the remains of the Cosmos-955 satellite.
- One of the first space collisions occurred in 1996, when the French satellite Cerise was damaged by the debris of a French rocket which had been used a decade earlier.
- The most important space collision took place at 4:56 p.m. on 10th February 2009 at 776 km over the Taymyr Peninsula (Siberia) when a damaged Russian satellite (Cosmos 2251) collided with and destroyed a commercial U.S. satellite of the Iridium network; the Iridium 33. The collision, besides the obvious damage for the constellation, generated over 2000 pieces of debris trackable from Earth.
- In 2007 China carried out an anti-satellite test which consisted of launching a missile to destroy an old weather satellite. This test added 3000 pieces to the problem of space debris.
- Space debris has even endangered the crew members of the International Space Station. Although the waste passed by 250 meters away, the six astronauts remaining on board were forced to carry out an emergency evacuation and take refuge in the two Soyuz capsules docked at the station.

Space debris and orbital mechanics

The principle by which objects orbit in space is the same as that of the spinning motion of a stone tied to a string, only that in the case of orbital objects, the string is the Earth's gravity.

Another particularity in the case of space is that the nearly total absence of atmosphere largely eliminates the forces of friction. For this reason, once we situate an object in orbit at a certain height and speed, the object would ideally remain orbiting permanently.

Obviously this is a simplification, because there are disturbances which affect the ideal orbit such as when the Earth's gravitational field isn't really spherical, the attraction of the Sun and the Moon, the existence of small atmospheric friction, the solar wind... However, their effect is seen over long periods of time, so we are not going to take them into account.

Therefore, we already know that once an object has reached its orbit in space, it will stay in it without needing to use engines or to maneuver, just because of the gravitation. This fact is an advantage for space missions; in fact, there are lots of low-cost satellites which have no engines and which stay in orbit for a great many years.

And at this point we should ask ourselves, why do space vehicles use engines? Well then, they use them to carry out maneuvers which correct the effects of small disturbances and to carry out maneuvers to avoid collisions with other objects. If we consider that these same rules apply to every object in space, we will identify the first problem of space debris; once a piece of debris is released in space, it will remain in orbit for long periods of time.

Now let's suppose the case of a collision in space; the thousands of fragments created are once again space debris which will continue orbiting for long periods and generating more collisions.

The Kessler Syndrome

Every day it is easier and cheaper to put an object in orbit. This is very good for science and communications, but if we are not careful enough with the way we handle these contraptions once they have finished their mission, we could turn the low Earth orbit into a truly useless space cemetery. This problem has been analyzed in depth by NASA consultant Donald J. Kessler.

According to Kessler, sometime in the near future, the volume of space junk in low Earth orbit will be so large that there will be a high probability that the objects in orbit are hit by the debris. This process will create even more debris, which in turn will increase the risk of other satellites being struck, creating a detrimental vicious circle. As the number of satellites in orbit increases and they grow old, the probability of suffering the Kessler Syndrome becomes greater, since most of the “retired” satellites do not have fuel which enables them to “dash away” in case they find themselves threatened by some piece of debris.

What makes the Kessler Syndrome so dangerous is the “domino effect”, since the impacts occurring between two objects with large mass will create a lot of additional debris as a result of the collision. Each piece of shrapnel has the potential to cause damage to other objects which are found in orbit, which in turn creates more space debris. If a large enough collision occurred - between the space station and a satellite, for example - the amount of debris generated could be large enough to render the low Earth orbit useless.

Space debris travels at speeds which are too high to attempt to collect it. Moreover, the great number and small size of the pieces make it impossible to design specific missions to remove it from orbit. Of course, all of these objects at some moment will succumb to the air resistance in the extremely dim upper atmosphere and they will burn up upon re-entry, but it is a very slow process which will require hundreds (or thousands) of years. Some scraps of ferrous metal which can interact with the Earth's magnetic field will fall first, within a few decades.

The space agencies know this problem well, and they design the missions bearing in mind everything necessary so that the objects which are sent out into space do not end up damaging other vehicles. For example, satellites can be disposed of safely at the end of their useful life, whether it is by means of a controlled re-entry in the atmosphere (in the case of low orbits) or sending them to a “graveyard orbit” in the case of them being of the “geostationary” sort. We know that the atmosphere's friction keeps the lower orbits clean. Everything that revolves at a height of under 500 kilometers and doesn't have fuel to make corrections will be swept away in a few months. But the higher orbits, in which the communications satellites can be found, don't have this natural “cleaning assistant”. All of this should be really taken into account in the upcoming years, when companies such as Interorbital Systems start to launch their satellites into space. In principle, for reasons of cost and availability of the necessary technologies, these companies will send their objects to low orbits, but in 5 or 10 years they will undoubtedly be able to send their contraptions much higher, putting the Kessler Syndrome on the cover of every daily newspaper.

Tracking Space Debris

There is a Space Surveillance Network which tracks all objects in space. The network is able to detect objects 5 centimeters in diameter in the case of orbits near the Earth (700 km) and 1 meter in diameter for geosynchronous orbits (36,000 km). Currently, of the over 21,000 objects which have been catalogued since this network began, 15,000 are still in orbit.
In order to carry out this tracking, the space surveillance network has numerous earth sensors distributed in different parts of the world.

The information from these sensors (radars and telescopes), together with the inspections which are done on the pieces that return from space, is the basis for the space debris inventory.

The risk of collision between space objects is categorized according to the size of the object which collides, so for objects that can be tracked from the Earth due to their size, the best way to avoid risk is by means of avoidance maneuvers. For non-detectable objects, the situation is more complex since a protective shield is useful to protect the space vehicle from impact only for objects less than 1 centimeter in diameter.

Planning and reaction against Space Debris

The international organizations have a set of standards and guides which are used to evaluate if a particle is going to pass by close enough to warrant making an avoidance maneuver or taking some other safety measure in the case of manned missions.

Graphically, we can say that the basis of these evaluations is to imagine a box which is 1.5 km deep and 50 kilometers long (called the pizza box) around the space vehicle. When a prediction indicates that the space debris will pass by close to this box and the quality of the tracking data of the particle is good enough, work is done to develop a plan of action.

Sometimes these encounters are known about well enough in advance and there is time to move the vehicle a little and thus manage for the debris to always be outside of the box; this is what is known as a “space debris avoidance maneuver”.
Other times, in contrast, the tracking data isn't precise enough to assure that this maneuver can be made or the risk of collision is discovered at short notice and there isn't enough time to prepare the maneuver. In these cases, the actions to take in order to minimize the effects of the possible collision are agreed upon. For example, these measures in the case of the International Space Station could be to move the crew to the Soyuz, which is the probe that transports the astronauts to the station, or take additional precautions.

Maneuvering a Satellite to Avoid a Collision

The maneuver to avoid a collision is planned when the probability of the collision is greater than 1 in 100,000. If the probability is greater than 1 in 10,000, the execution of a maneuver is totally necessary. These maneuvers are normally small and occur a minimum of 1 hour before the expected time of collision.

JSpOC is the center of the U.S. Defense Department which is responsible for analyzing the risk of collisions between every object in space. JSpOC issues collision warnings to every mission.

The affected missions can take the risk or decide to make a maneuver. In the case of making a maneuver, it must be sent once again to JSpOC to assure that the maneuver to be made is correct and that it doesn't pose a risk of collision with another space object.

Reduction of space debris

The first measure to reduce space debris is to eliminate from space a satellite which is no longer operative.

The first focus to withdraw a satellite is to wait. The Earth's atmosphere doesn't end abruptly at a well-defined altitude: it gradually fades away, until it becomes so scattered that it is insignificant.

Solar activity expands and contracts the atmosphere; consequently, the atmospheric density in the upper layers of the atmosphere changes over time. The result is that the objects orbiting around the Earth continue to be subjected to a certain amount of atmospheric resistance, whose intensity depends on the altitude and the geometrical characteristics of the body. This drag slowly erodes the satellite's orbit until it is low enough to be captured by the atmosphere.

When a satellite re-enters the atmosphere, it breaks up with the upper layers of the atmosphere at a high enough speed to be broken up and burnt.

For satellites flying below 600 km, natural decline may take up to two decades. From 600 km to 2000 km, decline can take up to a couple of centuries, and for satellites flying at about 35,000 km in the so-called geostationary orbit (GEO), natural decline can take thousands of years.

For spaceships flying in a low Earth orbit (2,000 km or less), we can significantly reduce this time by making a perigee reduction maneuver, which would be the second focus of debris reduction.

In simple terms, applying a certain amount of thrust in the opposite direction to the velocity vector can change the orbit from circular to elliptical, lowering one side of the orbit to an altitude featuring greater atmospheric resistance. This maneuver reduces the orbital disintegration to a time of 25 years or less, as demanded by the regulations on space waste.

The main reason why regulations establish a limit of 25 years instead of direct re-entry is because the propulsion systems on board most spacecrafts are only designed to execute low-thrust maneuvers in order to keep a spacecraft within its orbital path throughout the mission. A dismantling maneuver with this type of propulsion takes a long time and uses up a lot of propellant, thus reducing the life of a spacecraft by several months.

In the case of geostationary missions (36,000 km), these methods aren't applicable and the tendency is to make maneuvers which take them out of their orbit, launching them to higher altitudes. In this case, the big problem is that there are a great many missions in the geostationary belt and once a mission stops operating, it must yield its position to another satellite.

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