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Nanosatellites Collision Avoidance System

It seems a new era in the space industry is just about to begin. Europe must be an active member of this transformation since it will report a lot of profits for their citizens. New inventions are about to be made, as well as, new services and technologies that would amaze us all. That is why is important to start thinking about it. One of the new tendencies is nanosatellites. However, as the market grows, new problems will arise as well. This proposal, try to mitigate and even solve one possible problem of operating nanosatellites. The collision between them in a possible future saturated network.

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Nanosatellites Collision Avoidance System

proposal submitted for the "Space for Sustainability Award 2018" by

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Key words **Nanosatellites, Collision avoidance manoeuvre, Space debris generation mitigation**

Background

The number of objects orbiting earth has increased since the first launch of Sputnik back in 1957. Even though the satellite eventually fell back to earth that was not the case for the majority of objects mankind has put into orbit. Many of them are still up there. At the same time, the space industry is constantly demanding more and more services so as a consequence the amount of satellites that are required is also increasing.

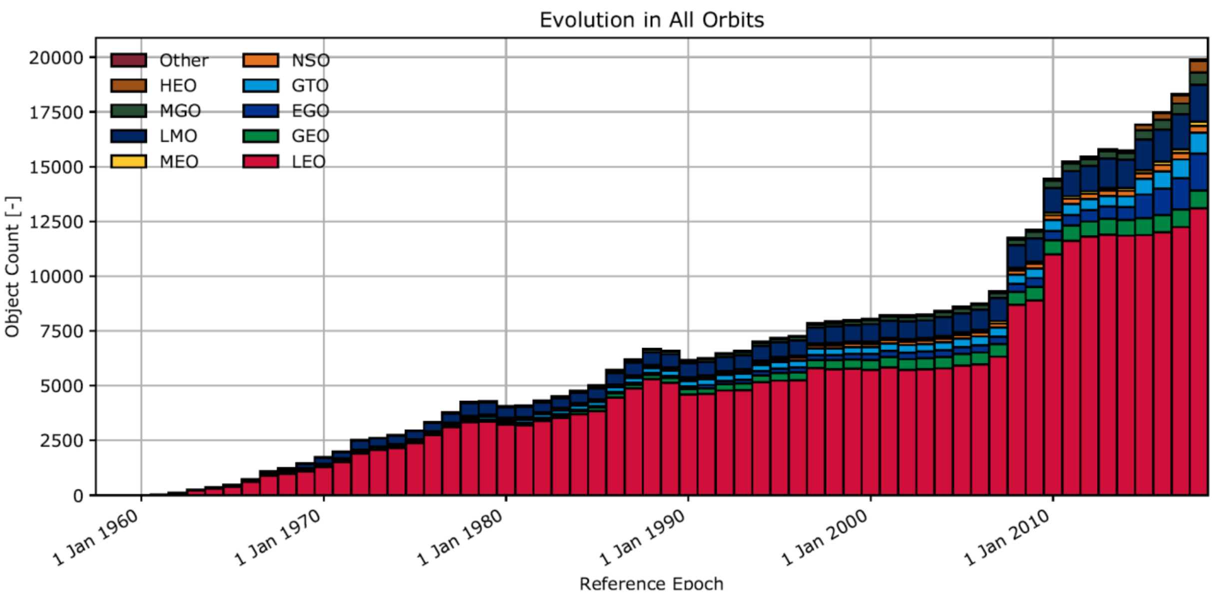

Figure 1: Nº of objects in the different orbits. [1]

Besides that, if we analyze the objects in orbit, we would realize a portion of them are not in use anymore. Therefore, a simple classification can be made, objects in use and not in use. In Figure 2, a flowchart of the interaction between these two categories is depicted.

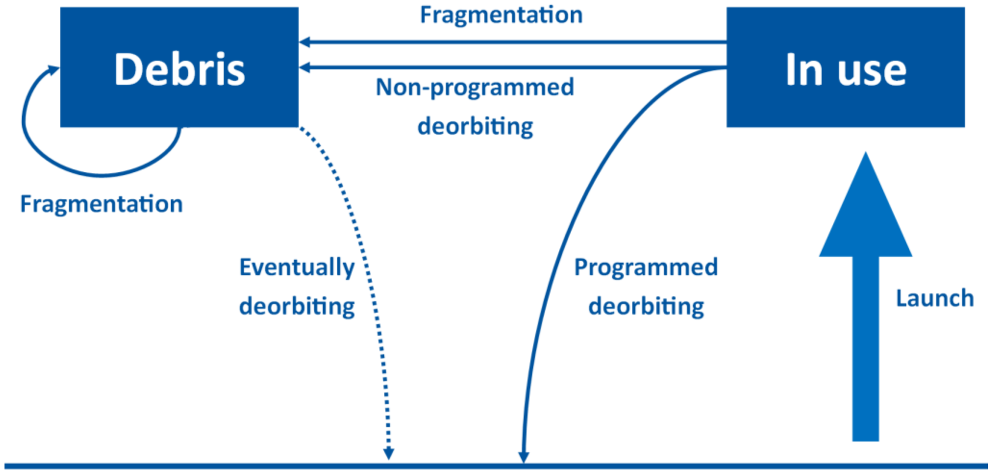

Figure 2: Scheme of orbiting objects.

It can be observed that, unless the object in use has a programmed deorbiting, the object will become space debris due to the end of its mission or by a fragmentation event. A fragmentation event is some event in which the object is divided into smaller objects. Notice that once it has become space debris the object may suffer more fragmentation events. In Figure 3, all fragmentations events recorded are depicted.

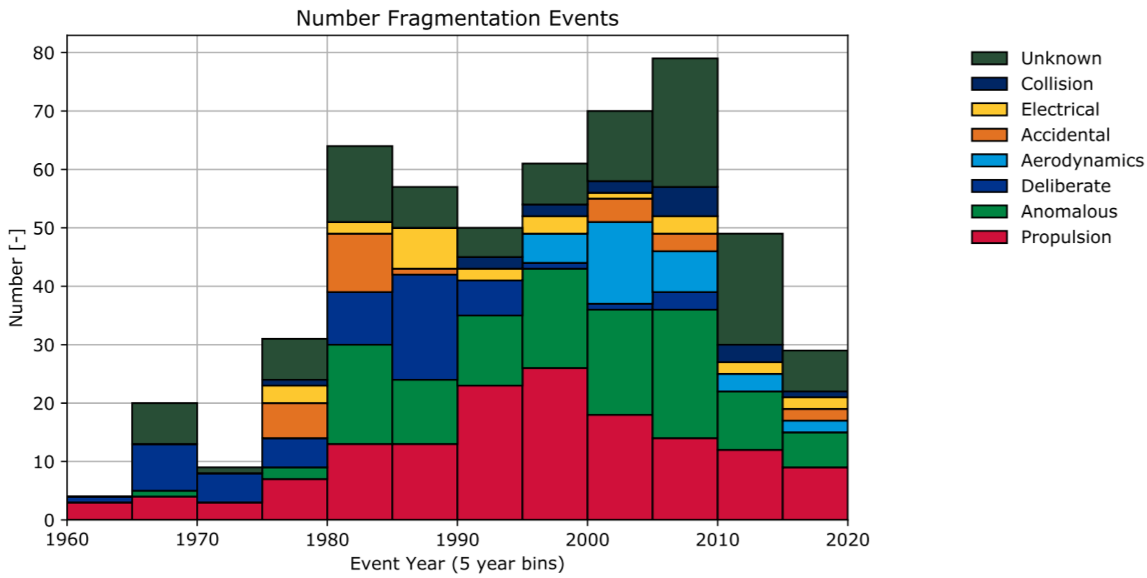

Figure 3: Fragmentations events. [2]

Even though the risk of collisions might seem low the risk is still real, especially if we consider every time there are more objects in orbit as we just saw. Besides that, their impact can be very severe since it may represent the end of an expensive mission of decades of preparation.

Traditionally, to avoid those satellites collide between them and with space debris while in active duty, space agencies and governments all over the world have dedicated vast resources to track all that space debris as well as the active satellites. This may represent a problem if we consider the increasing number of objects in orbit because it may increase the cost, risk, and complexity of space operations.

That's the reason why ESA and other space agencies are tremendously concerned about it and in fact, now there is much more awareness of the problem. ESA, in particular, has two approaches, mitigating space debris generation and removing the active space debris.

However, a new trend has arrived, nanosatellites. And they have the particularity that the previous approach is not feasible since they are mainly run by small companies or institutions that cannot afford the number of resources needed for the traditional tracking and avoidance of the collisions. Furthermore, even in the case that they could afford it, it is not effective, because nanosatellites orbits are much more difficult to track and it is more difficult to set a particular orbit for every nanosatellite.

Besides that, it is expected that this industry will put into orbit thousands and thousands of new satellites, so if Europe wants to be leading this new epoch in the satellite industry, it needs a new approach to avoid collisions between nanosatellites. Furthermore, this will result in a less generation of debris due to collisions assuring a sustainable development of the space orbit.

Description of Project Idea

The solution proposed is to decentralize the collision avoidance system by transferring it to each satellite. This has great benefits, it will create a safer, more flexible and scalar network. Let's see how it would work.

Each satellite would be transmitting and receiving in previously determined frequencies respectively, creating a spherical pattern around it using an omnidirectional antenna. As the distance from the source increases, the power of the radiation decreases. In a first approximation, neglecting the dissipation of the media, the relation between these two magnitudes can be expressed only having into account the dissipation due to the distance. Where, I, is the intensity of the wave, which is the average power transmitted per unit of area in the propagation direction of the wave [3].

$$\frac{I_1}{I_2} = \frac{r_2^2}{r_1^2} \qquad P = 4\pi r_1^2 I_1$$

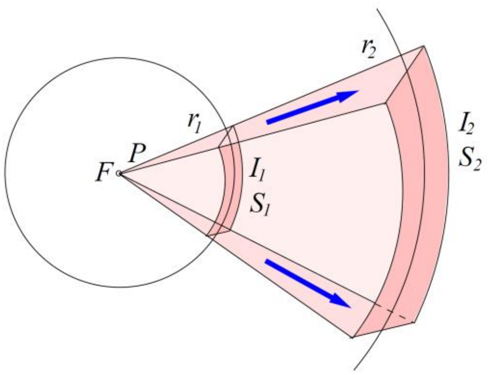

Figure 4: Sphere wave propagation. [3]

Therefore, if a certain threshold is set in the receiver, a functional sphere of influence is being obtained. Then, the emission power would be set to create a sphere of influence of a certain radius. This radius would be adjustable, but in general terms, it will be relatively small. This implies, relatively low consumption since low power is required for small spheres of influence and only those satellites close will have to execute further procedures, saving computation time that would increase the power required.

Once two satellites have entered the sphere of influence or risk of the other, they start receiving the transmission of that satellite. This transmission consists of the current position of the satellite as well as a propagation of their orbit, as a function of time, as far as a certain distance equal to an adjustable number of times the diameter of the sphere of influence. More details on how to obtain the position and the propagation are explained in the implementation section.

The position of the object may be expressed using geographic coordinates, which are a variation of spherical coordinates. Notice that this system is not static, but spins as the earth does so.

- θ: longitude: the angle between the object and Greenwich meridian.
- φ: latitude: the angle between the object and the equator.
- r: altitude: height above sea level.

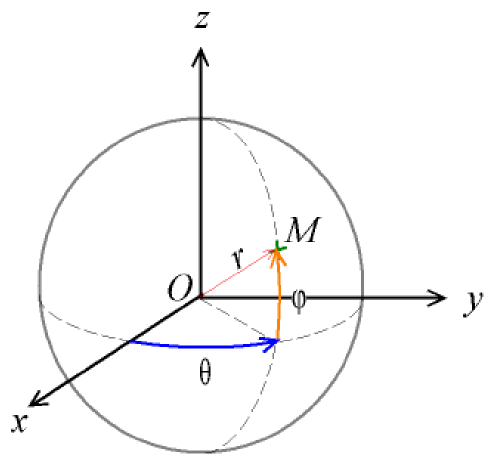

Figure 5: Geographic coordinates. [4]

With this information, it is possible to assess the risk of collision by comparing both trajectories and verifying if their position will be closer than a certain value at each given time. This operation is done in each satellite providing the system with more redundancy.

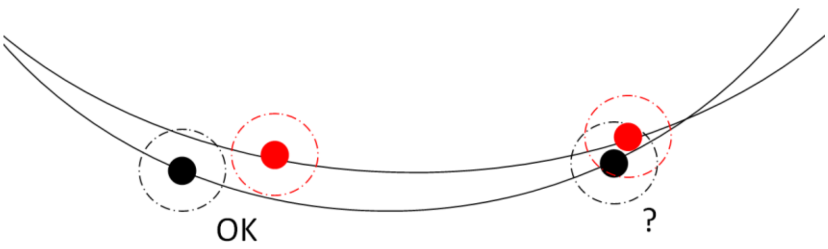

Figure 6: Dynamics of the spheres of influence.

If the risk is higher than a certain threshold, then, following some common previously set rules, is decided which satellite has to perform some orbital corrections to avoid the collision. Among these rules, it may be useful to take into account the capability of each satellite to perform orbital corrections, their controllability, the fuel available, the time left to complete the mission, if the other satellite is reacting as expected (redundancy), etc.

In the case that more than two satellites are involved, it will be more complex, but still feasible. A lot of network algorithm may be considered. For instance, one really simple approach could be, the resolution of the interaction is done in order of turn.

All those parameters that above were said to be previously set, or adjustable, …, are expected to be optimized using a genetic algorithm for instance, in order to minimize the fuel consumption and orbit deviations while guaranteeing a safe operation. However, more accurate models have to be developed and implemented in order to do so. Notice, these parameters may vary in function of the orbit, the number of objects in orbit at the time, type of object, etc.

Realistic implementation

Regarding the implementation, two parts can be studied. In one hand, the hardware or support required to implement the idea/algorithm. And in the other hand, the implementation as a project.

Regarding the hardware support, it may be implemented using two options. On one hand, it is possible to leave each satellite manufacturer to implement by their own the protocol showed before. In this case, some regulation and certification may be required to ensure the safety and quality.

On the other hand, it is possible to manufacture a small electronic device that would be attached to the nanosatellite and will perform all the protocols. This approach may be more interesting for nanosatellites since they are intended to be used by small companies and this approach will release some workload. Besides that, if some European initiative supports it, it could be possible to provide startups with this device so as a way to foster European innovation and creativity in the space industry.

This electronic device will consist of the elements needed to perform all the communications and calculations regarding the algorithm/protocol. In the following Figure, there is a conceptual scheme of all the systems and their connections.

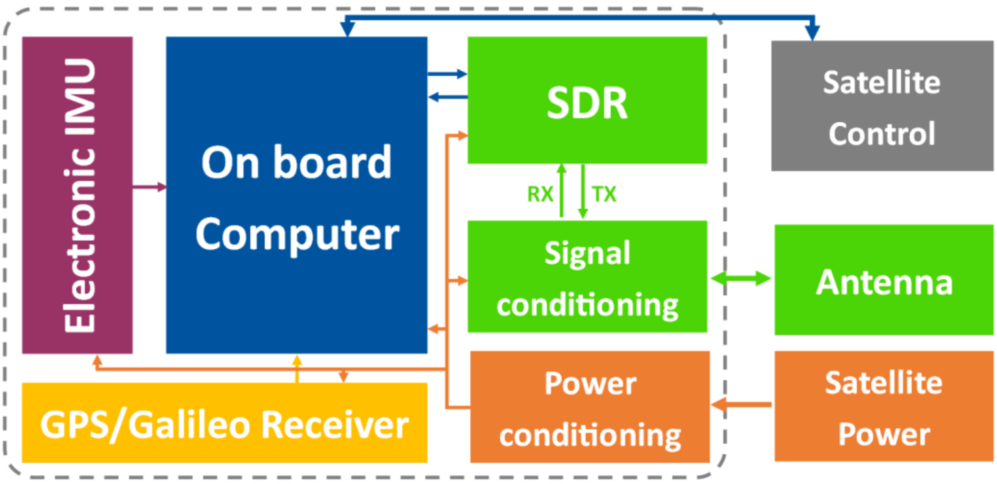

Figure 7: Device subsystems scheme.

The Inertial Measurement Unit along with the GPS or Galileo receiver will be used to obtain the position of the satellite and to obtain acceleration values so as to compute the propagation of the satellite. All those computations will be carried out in the on board computer among other routines and computations. Regarding the radio, a Software Defined Radio will be used given the flexibility and performances these devices offer these days. In the signal conditioning a controlled switch, filters and amplifiers are contained.
To kwon some of the specs about the device, a much more in deep study must be performed as well as the help of some electronic and telecommunications professionals.

Regarding the project development. Even though this implementation can be done in all orbits, due to the number of objects in LEO and the fact that most nanosatellites may be located in LEO too, the system will start its functioning at that orbit. The first steps to develop this idea proposal would be the ones depicted in the next Figure.

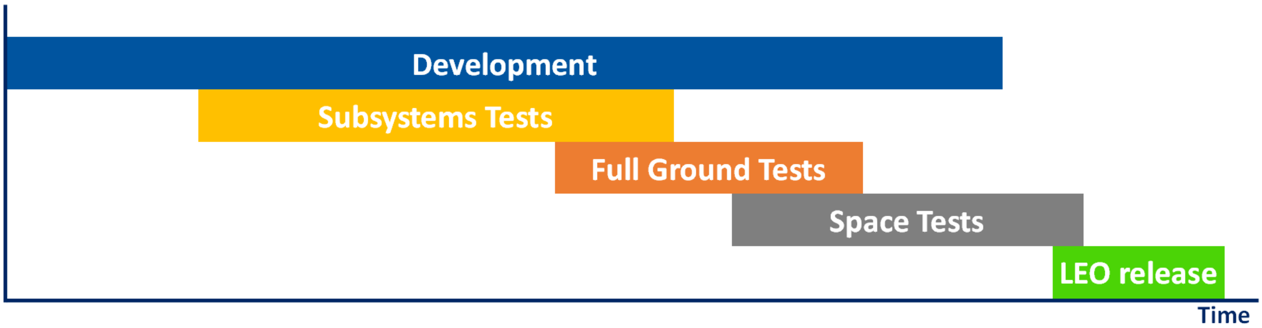

Figure 8: Project Gantt.

Subsystems Tests: each system tested to see if they operate as planned.
Full Ground Tests: all system is tested over an air cushion in a 2D test.
Space Tests: all system is tested in a 3D environment first in parabolic flights and then in on purpose collision trajectories with fast deorbiting.

Results expected

The expected results are the ones listed below.

- ✓ Avoid collisions between satellites
  - Mitigation of debris generation
  - Save on resources (money, time, potential knowledge, etc)
- ✓ Create a control network for satellites
  - Safe
  - Flexible
  - Scalar
  - Open to the public
- ✓ Democratize and open space to the public or small and brand new companies, while keeping it safe

Potential risks

In order to assess the risk associated with the project and the idea, the SWOT matrix is depicted below.

Strengths	Weaknesses

• New approach:
  • Flexible
  • Decentralized
  • Scalar
• Easy to upgrade the system by uploading the upgrade (SDR, on board computer)
	• Every satellite must adopt the technology
	• Lack of expert knowledge about all the topics

Opportunities	**Threats**
• A tendency to increase the number of satel-lites • A tendency to move to nanosatellites • Increase in the number of “makers” and space-based start-ups	• Industry resistance to adopting this approach • Unconsidered possible problems or technical limitations

Figure 9: SWOT analysis.

References

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