Space debris flux on LAPAN satellites during Solar Cycle 25

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Abstract. Solar activity has been known to have impacts on the altitude of low Earth orbit satellites and space debris as well. Consequently, this will affect the flux of debris population around a satellite’s orbit. LAPAN currently has three satellites in low Earth orbit which will still be in operation during Solar Cycle 25 which began in December 2019 and is expected to reach the peak in 2025. It is widely known that even a very small debris can give detrimental effects to those satellites due to their hypervelocity speed. In the present study we report the space debris flux on LAPAN-TUBSAT, LAPAN A2, and LAPAN A3 satellites during the solar cycle. The flux is generated using ORDEM 3.1 released by NASA.

1. Introduction
One of modern issues that continues to be discussed internationally is space debris. The issue is becoming more and more pronounced with the typically increasing number of satellites every year. However, in the last five years, it’s becoming more alarming due to the contribution of private sectors which are able to launch thousands of satellites into space. Mostly space debris comes from spent rockets and satellites or from fragmentations of both rockets and satellites. The fragmentation which is now considered as the biggest contributor of space debris could happen accidentally or intentionally.

Basically, space debris is all manmade objects that are non-functional. This leads to an enormous size range since it does not only include large objects of several meters in size like defunct satellites and spent upper stage but also all sort of centimeter and millimeter-sized debris created by explosions and collisions of their parent objects. Moreover, it also consists of even tiny particles like paint flakes as resulted from surface degradation of the parent objects and slag or dust that are produced from solid rocket motor firings. Since all these objects are basically coming from operating satellites or rocket bodies around the Earth, they share the same regions in near-Earth space with altitudes ranging from 300 to 40,000 km. Being orbiting in the same regions with operational spacecraft means that space debris not only contaminating the space but also has the potential to hinder and even put future space activities to an end.

What makes space debris as an international issue is not only its growing number of populations but also its incredibly high orbital velocity. Space debris comes in various sizes. If we consider only objects bigger than 10 cm than the number is believed to be around 36,000 which is already a big number. But if we consider also much smaller objects until 1 mm than the number is around 330 million which is enormous. Moreover, since the beginning of the space activity the number keeps growing. In average, the velocity of space debris is around 7 km/s or around 25,000 km/hr. With this velocity, even a very small debris possesses an extremely high orbital momentum which could ruin a satellite or its components.

Figure 1 illustrates the current population of manmade objects. It shows us the distribution of all manmade objects from low Earth orbit of less than 2000 km up until the geosynchronous orbit of around 40,000 km. From this figure, we can see the density of debris population is highest at geosynchronous orbit and decreases towards low Earth orbits.
36,000 km. Figure 2 shows the spatial density in terms of effective number of objects as a function of altitude in km in low earth orbit. There we can see that the highest number of objects is located around 800 km. We can also see the contribution of the big fragmentations which happened in 2007 and 2009 and the contribution of private sectors together with the proliferation of CubeSat satellites below around 600 km after 2010 as well.

![Figure 1](image1.png) Figure 1. A view from a vantage point above the north pole of objects in Earth orbit that are currently being tracked by the Space Surveillance Network as of January 1, 2019. Approximately 95% of these objects are space debris. Credit: NASA Orbital Debris Program Office (ODPO).

![Figure 2](image2.png) Figure 2. Effective numbers of objects per 10 km altitude bin between 200 and 2000 km altitude at three different epochs [1]. These are objects, approximately 10 cm and larger, tracked by the Space Surveillance Network.

Reference [2] summarizes the hazards posed by space debris in four points:

1. In principle, the probability that a spacecraft will be struck by debris is dependent on the spacecraft's orbital altitude and, to a lesser extent, its orbital inclination.
2. Current models indicate that a collision in orbit will result in complete breakup if the ratio of the impactor's relative kinetic energy to the mass of the object with which it collides is greater than about 40 J/g.
3. Impacting space objects not large enough to break up a spacecraft can still cause significant damage through a variety of mechanisms, including perforation, spallation, and impulsive loading.
4. Small debris impacts (even less than 1 mm in size) can degrade spacecraft surfaces and component.

Solar Cycle 25 began in the late of 2019 and is expected to last until around 2032 according to the latest NOAA prediction. The peak is expected to occur around the mid of 2025. Similar with the previous cycle, it is supposed to be, again, a less intense cycle than average in the last 100 years. The increasing solar activity towards the peak of the cycle will also increase the amount of atmospheric drag experienced by low Earth orbiters including space debris. This will lower down their altitudes together with active satellites within the same orbital region. This paper will report how the space debris flux on the three LAPAN satellites in orbit now vary during Solar Cycle 25.

2. Data and methods
The study requires the satellites’ orbital data, their weight, and size. All the initial orbital data are taken from Space-Track website (www.space-track.org) in the form of two-line elements data. The date chosen is the first date of 2016. All satellites’ weight and dimension are taken from figure 3 where gives us also a comparison table of three LAPAN satellites in orbit now which are LAPAN-TUBSAT, LAPAN-A2, and LAPAN-A3. All of them are Earth observation satellites in low Earth orbits with less than 650 km altitudes.
3. Characteristics of the three LAPAN satellites under study.

Both LAPAN-TUBSAT and LAPAN-A3 are semi-synchronous satellites with more than 95° of inclinations but LAPAN-A3 is at much lower altitudes of around 500 km. Both LAPAN-TUBSAT and LAPAN-A2 reside at around the same altitudes of around 640 km but LAPAN-A2 is at a semi-equatorial orbit at 6° inclination. Regarding their weight, all of them have mass less than 100 kg except LAPAN-A3 with 115 kg of weight. Regarding their size, LAPAN-A3 is also the biggest among them all with a volume of a bit more than 120,000 cubic cm.

For the methods, firstly, all satellites’ initial orbit is propagated from 1 January 2016 until 1 January 2033 to completely cover the Solar Cycle 25 using DAS 3.1.2 from NASA to get perigee and apogee altitudes at the beginning of each year along the simulation time. Secondly, using ORDEM 3.1 also from NASA, we calculated the cumulated space debris flux at the beginning of each year along the simulation time. For the simulation we kept the inclination value constant. Also, we chose randomized values for the argument of perigee and the right ascension of the ascending node. Lastly, from the resulting flux table, we selected the flux for 0.1 cm, 0.5 cm, 1 cm, 5 cm, 10 cm, and 50 cm debris which are considered sufficient enough to represent the wide spectrum of space debris size.

3. Results

Figure 4 shows the results of the simulation for the three satellites. The debris flux is shown in number per square meter per year as a function of simulation time which run from 2016 until 2032. Essentially, the fluxes are highest for LAPAN-TUBSAT then for LAPAN-A2, and then for LAPAN-A3. We can also see on the results that all LAPAN satellites experience a significant drop of the total cumulated space debris flux around the peak of the Solar Cycle 25. The biggest contribution comes from the 1 cm and 5 cm debris size.

The significant drop around the peak of solar cycles is as expected. This is due to the increasing solar activity which subsequently increase the level of atmospheric drag experienced by all low Earth orbiters below 2000 km altitudes. In the figure, we can see that this is also happens at the beginning and at the end of the simulation which set around other peaks of solar cycles. We also see a secular trend of space
debris flux that can only be noticed on the larger than 1 cm debris size. By taking the average of the
total flux during the simulation, we can calculate the expected number of collisions with any debris per
year. And we found that the expected number of collision with any debris is around 1 per 5 yr., 1 per
6.8 yr., and 8.6 yr. for LAPAN-TUBSAT, LAPAN-A2, and LAPAN-A3 respectively.

![Figure 4](image)

**Figure 4.** The result of the simulation in this study for LAPAN-TUBSAT (left image), LAPAN-A2
(center image), and LAPAN-A3 (right image).

4. **Conclusion**
Through the simulation of space debris flux on three LAPAN satellites in orbit now using DAS 3.1.2
and ORDEM 3.2, we found that all satellites experience a significant drop of the total cumulated space
debris flux around the peak of the Solar Cycle 25. The biggest contribution comes from the 1 cm and 5
cm debris size. We also found that the secular trend of space debris flux can only be seen on the larger
than 1 cm debris size. However, this cannot be noticed in the case of LAPAN-A3 which is supposed to
reenter before the end of Solar Cycle 25. In addition, by taking the average of the total flux during the
simulation, we found that the expected number of collision with any debris is around 1 per 5 yr., 1 per
6.8 yr., and 8.6 yr. for LAPAN-TUBSAT, LAPAN-A2, and LAPAN-A3 respectively.

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**References**
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