Potential hazards analysis of the space debris over 10 cm in size based on their orbital parameters

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Abstract. The increasing population of artificial space objects every year triggers a polemic about the safety of launching satellites into orbit as well as the safety of satellites operating in space. The artificial space object also provides a potential danger when it re-entry and then falls to Earth. Indonesia as a country that has the 2nd longest coastline in the world and has a span of 1/8 of the world's circumference (± 5000 km) is very vulnerable to experiencing atmospheric re-entry of which these space objects might fall to the Earth. Space objects that have the potential to experience re-entry and then fall to the Earth originate from space objects with a size of more than 10 cm. Until 2020, there are 6560 space objects with size 0.1<RCS<1 m² and 9526 space objects with size RCS>1 m². There are 5678 pieces of space debris with 4435 pieces with size 0.1<RCS<1 m² and 1236 pieces over 1 m². Of all space debris, only those with an altitude below 200 km potentially fall to the Earth which is around 1517 pieces. In addition, the most dangerous debris over the Indonesia region commonly has a low inclination with the passage around 12 to 16 times a day. However, there are only 15 objects which satisfy this category with a small number. Hence, the need of space debris surveillance should be done for mitigation purposes.

1. Introduction

Space debris is an unavoidable condition resulting from the launch of satellites into space. Over the past decade, the amount of space debris has grown rapidly. To date, around 24000 pieces of space debris have been recorded with around 19000 pieces of space debris having been cataloged by Space-track. In addition to the known amount of space debris, there are still unrecorded space debris that are smaller in size, which is thought to be in the hundreds of millions. Figure 1 shows the population and distribution of space objects in space based on the size. This space debris with various sizes is a threat to the safety of satellites that are still operating in space. Several Space Agencies in the world, members of the IADC (Inter-Agency Space Debris Coordination Committee) are trying to reduce the amount of space debris and mitigate the effects of this space debris on satellites that are still operating by using various methods [1]. They have made models of the evolution of space debris in order to study the long-term stability of the space environment in the future [2-8]. The research results, however, show that with this method the space environment will only be stable for only about 50 years and still high in the next future that can be seen in figure 2.
Figure 1. Population and distribution of space Objects that orbit the earths. (a) Space objects with size >1m, (b) space objects with size >10cm, (c) space objects with size >1 cm and (d) space objects with size >1mm (credit to ESA).

Figure 2. LEGEND simulation results. Population of space objects until 2210 with using Post Mission Disposal (PMD). The space objects will still increase significantly in the next 200 years although using 90% of PMD (https://orbitaldebris.jsc.nasa.gov/modeling/legend.html).

The increasing population of man-made space objects every year triggers a polemic about the safety of launching satellites into orbit in the future in addition to the potential danger of these objects falling to earth. Indonesia as a country that has the second longest coastline in the world
and has a span of 1/8 of the world's circumference (~ 5000 km) is very vulnerable to the fall of these space objects. One of the studies related to this issue was of the Tiangong 1 space station, which crashed in the Pacific Ocean [9]. Although there are several tools that can be used to predict the trajectory and survivability of re-entry objects such as NASA re-entry analysis tools DAS (Debris Assessment Software) and ORSAT (Object Re-entry Survival Analysis Tool), the ESA tools SCARAB (Spacecraft Atmospheric Re-entry and Aero-thermal Breakup) and DRAMA (Debris Risk Assessment and Mitigation Analysis) / SESAM (Spacecraft Entry Survival Analysis Module) and CNES re-entry engineering tools named DEBRISK, the mitigation of the falling space object by monitoring and predicting the possible location of falling objects still need to be done due to difficulties to predict the exact location of space object that fall to earth [10-17]. Objects that have the potential to experience re-entry and then fall to earth originate from space objects measuring more than 10 cm. Therefore, a special study of the distribution of these sized objects is very fundamental in building or developing a predictive model of the time and location of objects falling to the earth's surface. This research activity aims to diagnose the distribution of objects measuring above 10 cm by taking the type of debris, not the type of satellite/payload, both active and passive. This diagnosis will make it easier to select the trajectory of objects that have the potential to fall which will later be displayed in the tracking system for falling objects, Track-it.

2. Data and methodology

2.1. Data
The orbital space objects which size larger than 10 cm that recorded by space-track from 1960 to 2019 is used in this analysis. This data can be obtained from www.space-track.org.

2.2. Methodology.
In order to find the Potential hazards of the space debris over 10 cm in size based on their orbital parameters, space objects that orbit in the space that categorized as space debris is selected. The debris inclination is group into three categories, i<30 degrees, 30<i<60 degrees and i>60 degrees. The debris altitude also is grouped into two group, h<200 km and h>200 km. Although according to https://orbitaldebris.jsc.nasa.gov/reentry/, the break up altitude for space debris when re-enter the atmosphere is 72-95 km, the grouping at an altitude of 200 km is done considering that at 200 km the satellite altitude decreases very quickly which is caused by the atmospheric drag that occurs on the space debris. For the potency of debris fall to Indonesia area, the debris with size <200 km will be grouped into three categories based on their inclination, i<30 degrees, 30<i<60 degrees and i>60 degrees.

3. Result
The total of space objects that recorded by space-track from 1957 to 2019 are 16085 objects, consist of debris, payload, rocket body and To be announced (TBA). 6560 space objects have radar cross section (RCS) between 0.1 to 1 m² and 9526 space objects with RCS larger than 1 m². From all of these space objects, there are only 5670 space debris with 4435 debris have RCS between 0.1 to 1 m² and 1236 debris with size larger than 1 m² as can be seen in figure 3 and figure 4.
Figure 3. The type of space objects that recorded by www.space-track.org from 1960 to 2019.

Figure 4. Space Debris size.

The selected space debris is then grouped according to its inclination. There are 746 pieces of space debris with inclination smaller than 30 degrees, 1176 pieces of debris with inclination range from 30 to 60 degrees and 3746 pieces of debris with inclination larger than 60 degrees. Based on the inclination classification as shown in figure 5, we can see that most of space debris has high inclination.
Based on debris orbital altitude, there are 1517 pieces of debris with altitude lower than 200 km and 4153 pieces of debris with altitude higher than 200 km. From figure 6, it can be seen that most of the space debris has altitude between 100 to 300 km and altitude higher than 1000 km.

Although there are a lot of space debris that still orbit in space, only debris with altitude lower than 200 km has the highest potency to fall to the Earth. Based on the inclination, there are 15 pieces of debris with an altitude below 200 km which has an inclination below 30 degrees. As for the inclination between 30 to 60 degrees and inclination greater than 60 degrees, there are 470 and 1032 pieces of debris with an altitude below 200 km respectively. This result is shown in figure 7.
Figure 7. Classification of space debris based on inclination.

For Indonesia area, the potency of debris to fall is larger for debris categorized with small inclination. This is based on how many times the debris pass through Indonesian region during their evolution. For Low Earth Orbit (LEO), mostly debris has period range from 90 to 120 minutes to revolve around the Earth. So in a day, debris will revolve around the Earth 12 to 16 times a day. And for the equatorial debris with inclination smaller than 10 degrees, debris will pass through Indonesian area every time this debris revolves the Earth. The space debris with inclination range from 10 to 30 degrees will revolve the Earth 6 to 8 times a day. Meanwhile, the space debris with inclination larger than 30 degrees will pass through Indonesia area 3 to 5 times a day. The trajectory for each object based on the inclination can be seen in figure 8.

Figure 8. Trajectory of space objects with $i=5$ degrees (a), $i=20$ degrees (b), $i=53$ degrees (c) and $i=97$ degrees (d).
Although the debris that has the highest potential to fall Indonesian area is insignificant to the total of debris, but the debris is still monitored by Space Research Centre using Track-It [16, 17]. The development of tracking system for satellite that pass through Indonesia is still continuing. Figure 9 show the track of space objects (TDO 3 SPACECRAFT) that pass through Indonesia using Track-It.

![Track of space objects](image)

**Figure 9.** Track of space objects that pass through Indonesia area. The colour in the track show the altitude of space objects when they pass through Indonesia area.

### 4. Conclusion

The debris that has the highest potential to fall Indonesian area is insignificant, less than 1%, to the total of debris that have potential to fall to Earth. The mitigation of the effects of these objects, however, has to be anticipated by monitoring of these objects continuously.

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