Group No.8
How Small Satellites Can Comply with the Space Debris Mitigation Guidelines?

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Background

The United Nations developed 7 recommended guidelines for limiting space debris generation.

This group focused on Guideline 3 and Guideline 6.

- **Guideline 3 limits the probability of accidental collision in orbit.** Therefore, the probability of accidental collision with known objects during the system’s launch phase and orbital lifetime should be estimated and limited.

- **Guideline 6 limits the long-term presence of spacecraft and launch vehicle orbital stages in the low-Earth orbit (LEO) region after the end of their mission.** Therefore, spacecraft and launch vehicle orbital stages that have terminated their operational phases in orbits that pass through the LEO region should be removed from orbit in a controlled fashion.
Guideline 6 is known as the 25-year rule which limits orbital lifetime within 25 years.

I was surprised that 25-year rule does exist.

I would like to share fruitful knowledge that I obtained through the discussion group.
Criterion for the 25-year Rule

Image explanation:
- The graph illustrates the area-to-mass ratio (A/m) in m²/kg against altitude in km.
- The x-axis represents altitude ranging from 200 km to 2000 km.
- The y-axis shows the area-to-mass ratio ranging from 0.0001 to 100.
- The shaded area represents the area-to-mass ratio range for CubeSat at 700 km altitude, which is below 0.026 m²/kg. This indicates compliance with the criteria for the 25-year rule.
- The graph also shows that altitudes above 700 km, represented by the line, require an area-to-mass ratio above 0.026 m²/kg to comply with the 25-year rule.
We need to do some activities for long-term sustainability of outer space activities.

**Suggestion**

We supposed that making WG which share the knowledge because we need better understanding of the current space debris environment and the Guideline.
Background and Motivation

- Space Debris Mitigation Guidelines of the Inter-Agency Space Debris Coordination Committee
- Space Debris Mitigation Guidelines of the Scientific and Technical Subcommittee of the United Nations Committee on the Peaceful Uses of Outer Space
  - Guideline 3 limits the probability of accidental collision in orbit
  - Guideline 6 limits the long-term presence of spacecraft and launch vehicle orbital stages in the low-Earth orbit region after the end of their mission
- The scope of group discussion includes but is not limited to
  - A better understanding of the current space debris environment,
  - Ideas how to comply with the guidelines, and
  - Ideas how to minimize impact of small satellites insertion on the future space debris environment
Criterion for the 25-year Rule

Area-to-mass Ratio Range

< 25 years

> 25 years

0.026 m²/kg

700 km

Altitude [km]
Scope of Group Discussion

The scope of group discussion includes but is not limited to:
- A better understanding of the current space debris environment,
- Ideas how to comply with the guidelines, and
- Ideas how to minimize impact of small satellites insertion on the future space debris environment.
Options Applicable for Small Satellites @ 700 km Alt.

In order to have an area-to-mass ratio > 0.026 m²/kg

1. Limit their mass: < 14.4 kg for a cube 50 cm on a side
   (Note: satellite frame ~ 1.1 kg)

2. Enlarge their average cross-sectional area at the beginning or the end of their mission: > 1.3 m² for a mass of 50 kg
   (Note: average cross-sectional area of a cube 50 cm on a side ~ 0.4 m²)

Therefore,

- Option 1 seems to be nearly impossible
- Option 2 seems to be quite possible but may conflict with Guideline 3
Assumptions to Discuss Guideline 3 for Small Satellites

- LEODEEM, an orbital debris evolutionary model for the low-Earth orbit region, used for this study
  - Initial population includes all > 10 cm objects with perigee altitudes < 2000 km on 1 Jan. 2009
  - Orbital insertion history for the years 2001 through 2008 for > 10 cm objects with perigee altitudes < 2000 km repeated as the 8-year traffic cycle

- Sun-synchronous orbit at 700 km alt. with an inclination of 98.2 deg.

- A small satellite with a mass of 50 kg in a cube 50 cm on a side
  - Average cross-sectional area ~ 0.4 m²
  - Area-to-mass ratio ~ 0.008 m²/kg
Cumulative Probability of Accidental Collision

- Cumulative probability for $A/m = 0.008$ [m$^2$/kg]
- Cumulative probability for $A/m = 0.026$ [m$^2$/kg]

Time intervals:
- 25 years
- 82 years
Cumulative Probability of Accidental Collision

Orbital lifetime [year]

Cumulative probability of collision [%]

A/m [×10⁻³ m²/kg]
Concluding Remarks

- This paper concerns about how small satellites can comply with Guideline 6 or the 25-year rule

- This paper compares two options applicable for small satellites to limit their orbital lifetime within 25 years

- Enlargement of their average cross-sectional area may be a quite promising option

- This paper also concerns that the promising option may conflict with Guideline 3

- This paper clearly demonstrates:
  - the promising option raises the probability of accidental collision, but
  - the 25-year rule can reasonably and adequately reduce the cumulative probability of accidental collision at the re-entry