Space Fan: A Mechanical De-Orbiting Device System for Satellites

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1. Introduction

With increased launch of particularly nanosatellites to Low Earth Orbit (LEO), the orbital debris threatens all LEO spacecraft currently orbiting or to be launched. As a remedy, United Nations, most space agencies and other related organizations have agreed to deal with it particularly by integrating De-Orbiting Device Systems to new space systems that will be launched. As a contribution to these efforts, this study proposes an affordable, scalable, easy to use CubeSat De-Orbiting System (DDS) that uses aerodynamic drag force for de-orbiting. The proposed system does not require any propellant and has low complexity and mass.

2. The CubeSat

The DDS will be used to de orbit a 3U CubeSat based on the latest CubeSat standard. It is assumed to have a max mass of 4kg with dimensions 10*10*33.4 cm. The CubeSat uses the QB50 ADCS system for its normal operation prior to de-orbiting. Based on the mission power requirements the CubeSat may have body mounted (Figure 1) or deployable solar panels (Figure 2) .

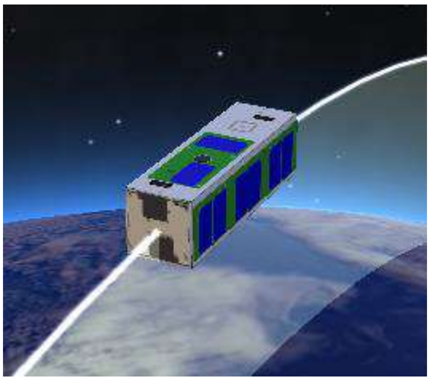


Figure 1: 3U CubeSat with body mounted solar panels Case A (taken from QB50 ADCS ICD).

Figure 2: Example 3U CubeSat with deployable solar panels, Case B (taken from [1]).

In both cases, with the help of QB50 ADCS and suitable moments of inertia and the center of mass, the satellite 1U face is normal to the orbit direction. Based on the conditions specified by the DDC the de-orbiting times for the two cases are:

Case A: more than 40 years (see Table 1)
Case B: 919 days (see Table 1)

The analysis is carried out using the STK program (AGI Satellite Tool Kit http://www.agi.com/products/stk/).

The proposed DDC is explained in the following section to reduce substantially the de-orbiting time.

3. De-orbiting Mechanism

A DDS that is easy to developed and use is sought. It is important that DDS material is affordable and easily obtainable such that every CubeSat developer can have it. Therefore the Kapton is chosen as the surface material. Multi layers of Kapton can be employed as needed.

The de orbiting time is very much affected by the solar activity period as well as the initial altitude prior to starting de-orbiting. Aerodynamic drag increase is proportional to an increase in area for a fixed satellite mass.

A fan like modular de-orbiting mechanism is proposed. Eventually, the fan is placed in parts to cover the frontal 1U area, Figure 3:

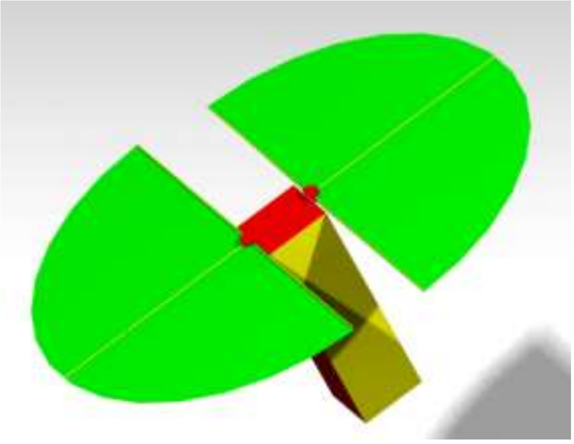


Figure 3a: Deorbit Mode of the Satellite with body mounted solar panel

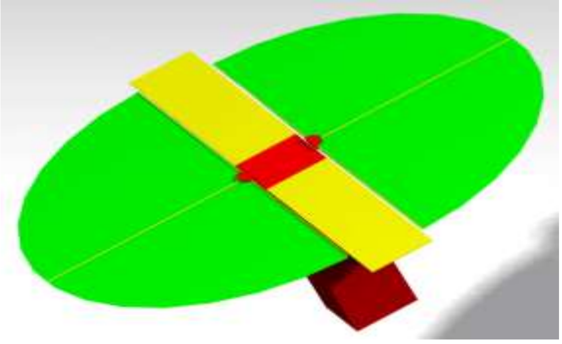


Figure 3b: Deorbit Mode of the Satellite with Deployable Solar Panel

Figure 3a/b shows the de-orbit device when deployed. A coil spring that is activated by the OBC is used for deployment. First the folded fan deployed and then the fan itself is deployed, providing an area increase compared to the 1U face.

The proposed system is preferred for its simplicity, low cost and positive effects on satellite de-orbiting time at the end of its mission life. To design an effective DoD system, we need to consider if it operates properly in the space environment. It shall have an acceptable atmospheric re-entry time at the end of its mission life. To decrease atmospheric re-entry time of the satellite, the aerodynamic drag force concept is used. This requires reducing the ballistic coefficient of the satellite. The ballistic coefficient (BC) is used to characterize spacecraft orbital decay, incorporating spacecraft mass, m, its line-of-flight cross sectional area, A, and associated drag coefficient, C_D, where:

$$BC = \frac{m}{C_d A}$$

For objects in Low-Earth Orbit, atmospheric drag represents a significant perturbing force. The drag force that a spacecraft experiences is given by;

$$F_{aero} = -\frac{1}{2} q C_D S \parallel V_{rel} \parallel V_{rel}$$

q is the local atmospheric density, C_D is a dimensionless drag coefficient, S is the spacecraft area projected along the direction of motion, and V_{rel} is the relative velocity of the spacecraft with respect to the atmosphere.

We need to increase that perturbing force to reduce satellite atmospheric re-entry time by decreasing the ballistic coefficient (BC) which is inversely proportional to C_DA.Therefore ,$C_D$or satellite projected area along the direction of motion(A) must be increased. We make DoD design upon satellite to increase projected area by using its solar panels with the fan (Figure 4.1b) or only by the fan (Figure 4.1a).

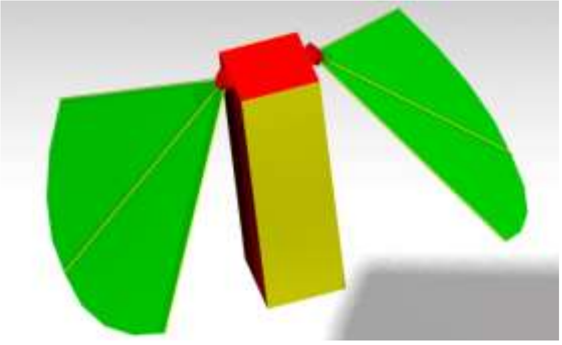


Figure 4.1a: Deorbit Mode of The Satellite with body mounted solar panel

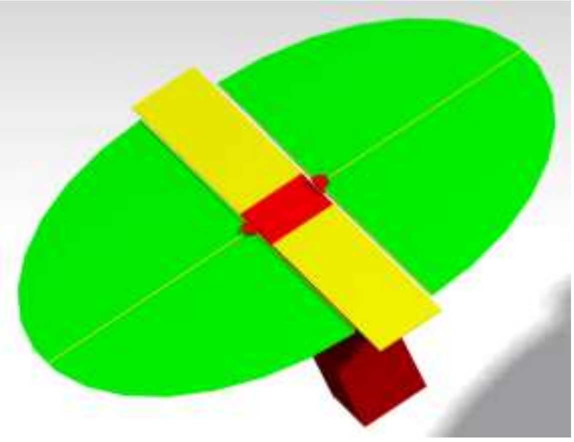


Figure 4.1b: Deorbit Mode of the Satellite with Deployable Solar Panel

Figure 4.1 a shows the de-orbit device in deployed form .We use the coil spring that is activated by the OBC command. When the de-orbiting device mode is activated, satellite has the possible largest area.

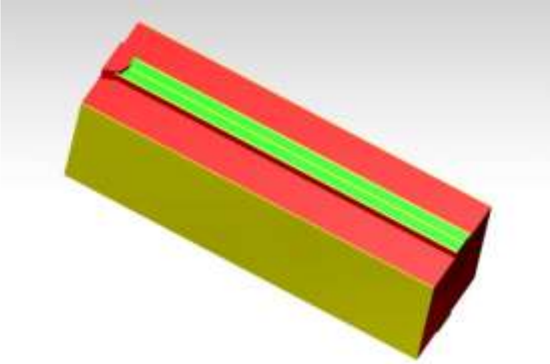
For Deorbit Mode of The Satellite with body mounted solar panel the Area is:

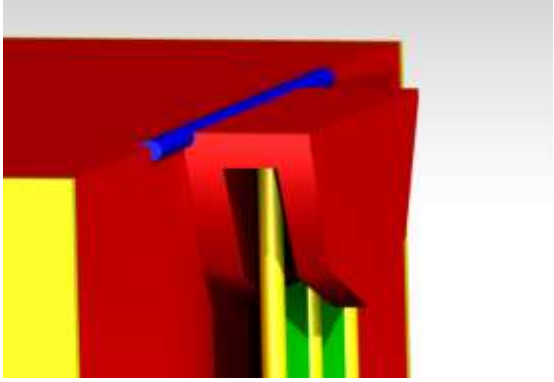
$A=3.14 x 0.334 x 0.334\ m^2 + 0.1 x 0.1 m^2 = 0.3603 m^2$

For Deorbit Mode of The Satellite with Deployable Solar Panel the Area is:

$A=3.14 x 0.334 x 0.334\ m^2 + 0.1 x 0.1 m^2 + 2 x 0.1 x 0.34 = 0.4271 m^2$

The Fan mechanism is explained below:





At the end of the satellite's life coil spring that is activated by the OBC command and the fishing wire is melted with the resistance. Then, de-orbiting device is deployed.

De-orbit times are given in Table 1:

Table 1:

	Case A	Case B	Case A DDS	Case B DDS	Case A 2 DDS
CubeSat Mass	4	4	4	4	4
Drag Area	0,01	0,0768	0,3603	0,4271	1,4
Altitude	552	552	552	552	552
Start time for DDS	21 October 2018	21 October 2018	21 October 2018	21 October 2018	21 October 2018
Attitude Control	3 axis	3 axis	none	none	none
Düşüş Tarihi		27 April 2021	27 April 2020	9 April 2020	3 January 2020
Yörünge Süresi	+39 Years	919 Days	555 Days	537 Days	440 Days

4. Conclusion

An affordable easy to make and use DDS is proposed. The de orbiting time is reduced from 40 years to only 555 days to de orbit the satellite. The system is scalable to larger satellites. The complete details will be given in the full paper.

Reference

[1] https://nasa.asu.edu/sun-devil-satellite-laboratory?destination=node%2F166