SSCD: Sailing System for Cubesat Deorbiting

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The multitude of satellites crowding Earth's orbits is ever increasing and the need for regulating and implementing the re-entry of such devices is a driving force in the current satellite engineering. In particular, reaching compactness and efficiency is essential for small satellites and in particular for the CubeSat standard.

For this purpose, many systems have been developed for a cost-effective deorbiting of small satellites and the current state of art offers three main technologies:

1. deorbiting sails[4] that exploit the atmospheric drag;
2. space tethers[2] that use the Earth's magnetic field;
3. on-board thrusters[3] used to provide the required amount of deltaV for the satellite re-entry.

In the nano-satellites field, the possible methods are restricted by mass and volume constraints and the deorbiting sails remains the most reliable, feasible and simple option.

Currently, nano-satellites are inserted into orbit by using the P-POD (Poly-Picosatellite Orbital Deployer), a standard deployment system that plays a fundamental role as the interface with the launch vehicle. The space among the P-POD walls and the nano-satellite solar panels, around 6.5 mm in the standard configuration , can be used to host a system for the CubeSat re-entry, as is shown in Figure 1. With this goal in mind, the Sailing System for Cubesat Deorbiting (SSCD) has been designed to optimize and exploit the free and unused volume.

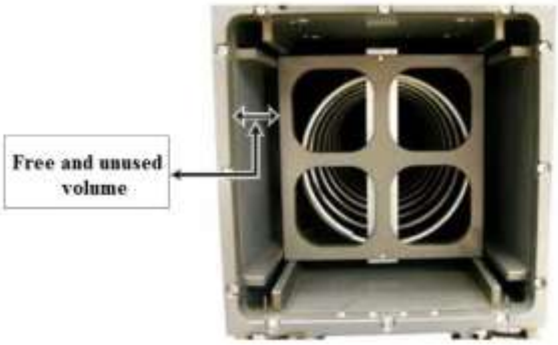

Figure 1. Standard P-POD device for CubeSat deployment in orbit.

The SSCD four sails and the related deployment system are located on the four sides of the CubeSat structure in order to increase the 3U-CubeSat cross section, reaching an exposed area of 1.45 m² after the deployment. The operational principle of such device consists in increasing the impact area of the satellite with respect to the Earth's atmosphere at the end of its lifetime. Consequently, the atmospheric resistance applied to the nano-satellite increases notably reducing the expected re-entry time.

In fact, simulations performed with DAS[1] 2.0, the NASA Debris Assessment Software, show that the re-entry time, without considering on-board the SSCD, is almost 8 years and a half, while it would take less than 2 years by using the SSCD device, as it can be seen in Figure 2. The orbit used (insertion at 21:00:00 UTC, October 21, 2018) for the simulations is characterized by the following orbital parameters:

- Semi-major axis of 6930 km;
- Inclination of 97.6 degrees;
- Eccentricity equal to 0.002;

- R.A.A.N. of 30 degrees;
- Argument of Perigee of 210 degree;
- Mean Anomaly of 190 degree at the in orbit insertion time.

Figure 2. Orbit Decay plot.

As can be seen in Figure 3. The system is composed of four “wings”, each consisting of four aluminum rods of dimension 300x5x2mm and five aluminum bars of dimension 80x5x2 mm. These bars are connected each other through torsion springs aiming at stretching the sail tissue. The deployment system was designed to reduce encumbrances while reaching a high structural resistance. The rods are located next to one other grouped on two planes to occupy only 4 mm and to avoid mechanical interferences during the system deployment.

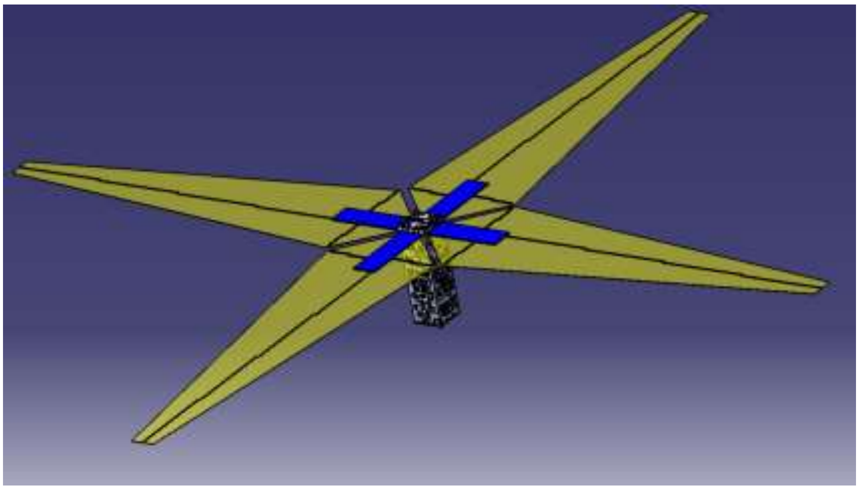

Figure 3. SSDC design.

The SSDC will be activated at the end of the operational life of the 3U-CubeSat. The mechanism is retained by a wire system connected to thermal cutters. The energy used to activate the thermal cutters is provided by the satellite batteries, which must be discharged at the end of the operational life, according to end-of-life passivation regulations. The torsion springs enable the rotation of the solar panels, located on the four sides, by 90 degrees with respect to the short sides of the 3U-CubeSat. Subsequently, the sail deployment system starts operating and deploys a sail of 0.36 m² for each panel.

A trade off between the maximum exposed area for each sail and its mechanical complexity led to choice of final configuration and shape of the SSDC drag sail. In particular, the selected design, shown in Figure 4, allows obtaining a reduced number of rods and torsion springs compared to the rectangular shape thus reducing the possible failures during deployment and the use of trapezoidal sails offers the highest structural resistance.

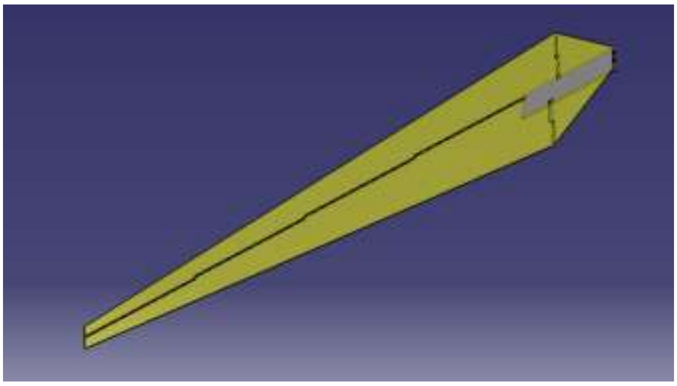

Figure 4. SSDC design.

For the connections among the rods, several possibilities have been taken into account, such as silicone joints, shape memory materials and torsion springs. The silicon joints can be easily performed and are not expensive, but they do not guarantee a high reliability during the deployment phase and do not keep the desired shape. The shape memory materials can perfectly keep the geometry during both deployment and re-entry phases, but they require a huge amount of energy, especially during deployment. The needed energy should be supplied by the 3U-CubeSat batteries, that at the end of their operational lifetime could not have enough available energy. The torsion springs are the simplest and the most reliable solution, requiring only one thermal cutter and are the best solution for the SSDC design, as shown in Figure 5.

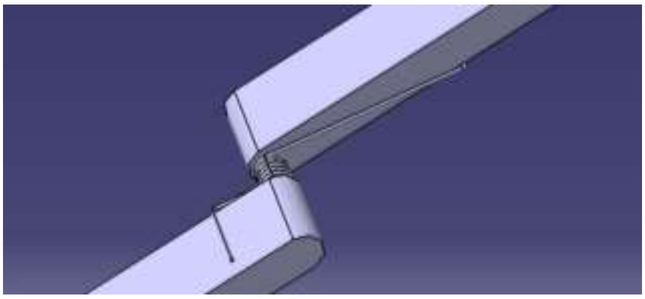

Figure 5. SSDC torsion springs.

The chosen material for the supporting rods is Aluminium due to his low density and good mechanical properties. These features allow achieving the device lightness and the structure capability to withstand the loads related to the atmospheric density at the re-entry altitude (around 200 km). Moreover, this material can be easily manufactured due to its ductility and low melting point. The rods assembly will be performed by welding them between two adjacent rods in order to avoid the drilling of so thin rods. Figure 6 shows the rods system architecture.

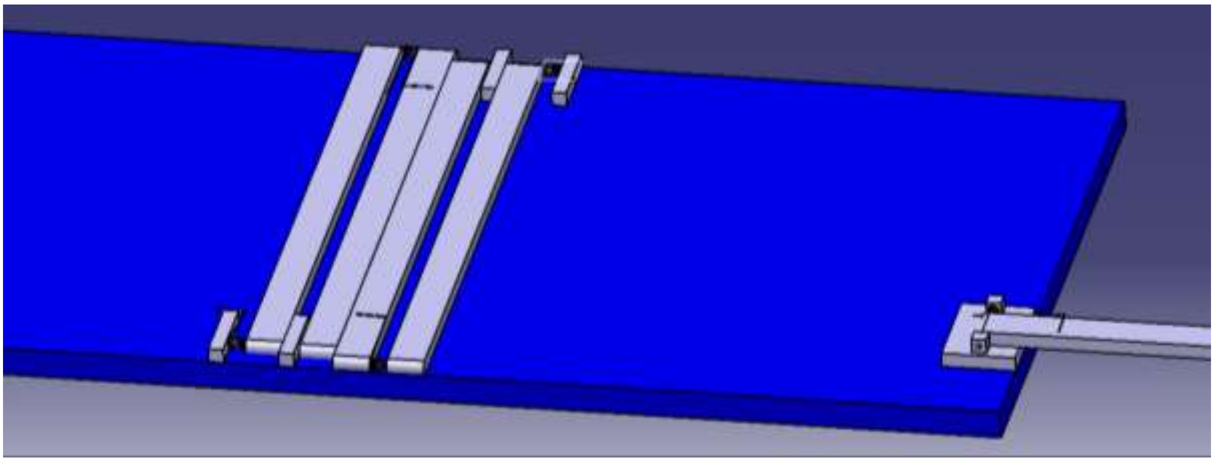

Figure 6. Rods system architecture.

The chosen material for the deorbiting sail is Mylar due to its excellent strain resistance and lightness. In fact, Mylar sheets can be extremely thin, around micrometers, and the folded sheets have the tendency of sticking very well. These features permit to optimally exploit the limited available volume and to design springs with an adequate torsional rigidity to achieve the correct sail deployment.

A preliminary study about the main budgets has been performed and **Table *1*** reports the estimated values for each different category.

Volume	**Mass**
0.3x0.08x0.005 m	**0.25 kg**

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0.3x0.08x0.005 m	**0.25 kg**

Table 1

Hence, the volume encumbrance matches with the unused volume offered by the P-POD and the required power to deploy the SSDC device can be supplied by CubeSat batteries – the available power at the end of its operative lifetime is enough for the deployment of the designed configuration.

The SSDC added value consists in allowing the re-entry of the spacecraft by exploiting in the optimal way a standardized volume available in each CubeSat orbital deployer. Moreover, the integration of the SSCD into the nano-satellite subsystems does not require any variation in the structure or in the system architecture and it can be scaled for different nano-satellites only by varying the length of the supporting rods. For these reasons, SSCD proves to be an interesting and different solution for the disposal of the space debris by small satellites to be placed also in the market of the small satellites subsystems.

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