ESEIAAT

Escola Superior d'Enginyeries Industrials, Aeroespacial i Audiovisual de Terrassa

UNIVERSITAT POLITÈCNICA DE CATALUNYA

Cubesat Constellation
Astrea

Report

Degree: Aerospace Engineering
Course: Engineering Projects
Group: G4 EA-T2016

Delivery date: 22-12-2016

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Contents

List of Tables

List of Figures

1 Satellite design

1.1 Structure and mechanics

The design and operation of a CubeSat is a complex process that must be completed keeping in mind the huge differences between all subsystems as well as the role they will play during the lifetime of the mission. And since these systems will operate in space, they have to be prepared and certified to withstand extreme temperature and radiation conditions.

The satellite used by Astrea must have high compatibility between all the systems to avoid potential problems and has to be tested (either all the systems together or one by one). Their correct functioning has to be ensured, especially the critical systems such as the solar arrays, batteries and antennas should be fully operational for at least four years.

1.1.1 Structure

The mission of the structure is to sustain and protect all the electronic devices carried by the satellite. In order to ensure that all the electronic and mechanical systems can be mounted upon the structure, a high compatibility between these systems is required; therefore, the structure must be very flexible regarding the arrangement of the subsystems.

The structure chosen is manufactured by **Innovative Solutions In Space (ISIS)**. Among its features it is worth mentioning that it can withstand the high range of temperature it will face in the space (from -40ºC to 80ºC) and it is highly compatible; almost every physical system used can be placed within the structure or on its faces (such as the antennas or the deployable solar arrays). Finally, the mass of the structure is relatively low, and given that the mass of the other subsystems is sometimes a drawback, it is plus point.

1.1.2 Thermal protection

The CubeSat is vulnerable to suffer extreme temperatures while operating in space, both below zero and above zero. The thermal protection system consists of a set of layers (MLI) made of insulating materials and it aims to protect the CubeSat from potential thermal shocks. The satellite must remain within an optimal range of temperature, despite of the variation of the external temperature, in order to work properly. Furthermore, the thermal protection system should also dissipate the heat produced by the other systems.

Dunmore Aerospace has been chosen to provide us its MLI product. The product, **Dunmore Aerospace Satkit**, has been designed for small satellites operating in LEO and it will provide the CubeSat with the protection required during operation.

1.1.3 Options chosen for the structure and thermal protection

The options chosen are presented in the table 1.1.

System	Brand and model	Price per unit (€)	N. of units
3U Structure	ISIS	3900	1
Thermal Protection	Dunmore Satkit	1000	1

Table 1.1: Options chosen for the structure and thermal protection

1.2 Electrical Power System

The electric power system of the satellite must provide and manage the energy generated efficiently in order to have all the systems operating under normal conditions during the lifetime of the mission. The EPS of the Cubesat is, probably, the most fundamental requirement of the satellite, since its failure would result in a mission failure. Therefore, the role of this system is to control and distribute power to the Cubesat, to suppy a continuous source of electrical power during the length of the mission, to protect the satellite against electrical bus failiures and to monitor and communicate the status of the EPS to the on-board computer.

1.2.1 Estimation of the power required

To select the adequate electrical power systems it is essential that the power consumed by the CubeSat is known *a priori*. Thus, to select the solar arrays and the batteries, as well as the power management system, an estimation of the power consumed has to be made.

The total estimated power required is 52W. The calculations and reasoning can be checked on the **ANNEX**.

1.2.2 Solar arrays

Given that the space of a 3U CubeSat is very limited, the primary source of electrical power has to be photovoltaic cells. The photovoltaic cells will collect and convert the energy of the sun into electrical energy and they have to be fully efficient for at least four years.

Every cubesat will come with at least 4 deployable solar panels (manufactured by **EXA-Agencia Espacial Civil Ecuatoriana** providing it with 67.2W of power, approximately, to supply peak demands during the lifetime of the mission. Note that these 4 deployable solar panels are a basic requirement. If more space is available on the faces of the satellite, additional panels can be placed providing extra power.

1.2.3 Power management system

The role of the power management system is to distribute the power and supply the energy to the different systems used in the CubeSat. Since the systems of the CubeSat have different power and energy needs, the power management system has to be highly compatible and must have a number of buses high enough to supply the different voltage and intensity required to the systems.

The selected option for the mission is the **NanoPower P60** by **Gomspace**, a high-power EPS for small satellites that comes with 1 motherboard, 1 ACU module (Array Conditioning Unit) and 1 PDU (Power Distribution Unit), allowing multiple configurations in just one motherboard; saving a lot of space.

1.2.4 Batteries

Batteries are essential for a proper mission operation. They will provide the spacecraft subsystems with the power needed when the solar arrays are working less efficiently or not properly. Astrea is looking for decent capacity batteries that provide a slightly high typical energy and power supply, since all the systems will not usually operate under peak conditions. Additionally, through the lifetime of the mission, the solar arrays will face an important unfavorable condition; in the worst case scenario, the satellite will be in the dark during half of the period of the orbit. So, it is clear that the batteries are a critical system of the CubeSat

Astrea has chosen the **BA01/D** batteries manufactured by **EXA-Agencia Espacial Civil Ecuatoriana**. The CubeSat will have two of these batteries, with a total capacity of 28800mAh or 106,4Wh.

As mentioned above, if the satellite was in the dark during half of the period of the orbit, the estimated energy that it would need would be 50W. Thereby, the capacity of the batteries is more than enough to supply the required energy in the worst case scenario. In fact, they will supply energy when the energy demand of the CubeSat is higher than the energy collected by the solar cells. And logically, they will store the energy collected by the solar arrays when the energy demand of the systems is lower than the energy collected.

1.2.5 Options chosen for the EPS

Finally, the options chosen are presented in the table 1.2.

System	Brand and model	Price per unit (€)	N. of units
Solar arrays	EXA	17000	4
Additional solar arrays	-	4000-12000	depends
Batteries	EXA	6300	2
Power Management	Gomspace NanoPower P60	16000	1

Table 1.2: Options studied for the Electric Power System

1.3 Propulsion Systems

Thruster is a main part of the structure because it is needed to allow the satellite to realise different maneuvers how incorporate it adequatly to the orbit after the deployment of the rocket, can obtain the optimal orientation or to mantain the satellite in the orbital and avoid its fallen.

The main parameters that must consider are thrust, total specific impulse, power required, weight of the propulsion subsystem and its volume.

At the moment, the most used and more modern thrusters for satellites are: ionic, pulsed plasma, electrothermal and green monopropellant thrusters. An important aspect to consider is that the goal is to reduce the mass required although this will cause minor accelerations than conventional engines but it will be suitable for small satellites.

BGT-X5 has been chosen how the CubeSat thruster. With the high thrust and delta V that BGT-X5 provides, the CubeSat will be able to carry out the necessary actions to keep the satellite in orbit, to relocate the satellite or to change its orbit.

The option chosen is presented in the table below 1.3.

System	Brand and model	Price per unit (€)
Propulsion	Busek BGT-X5	50000)

Table 1.3: Option chosen for the propulsion system

1.4 Attitude and Orbital Control Systems

Attitude and orbital control subsystem is needed to enable the satellite to keep a specific position within its orbit and to control the antennas in order to remain oriented to assigned area, because the satellite tends to change its orientation due to torque. The AOCS receives telecommands from the central computer and acquires measurements (satellite attitude and orbital position) from sensors. We will also refer to the attitude control as ADACS (Attitude Determination and Attitude control system).

Attitude control for CubeSats relies on miniaturizing technology without significant performance degradation. Tumbling typically occurs as soon as a CubeSat is deployed, due to asymmetric deployment forces and bumping with other CubeSats. Some CubeSats operate normally while tumbling, but those that require pointing in a certain direction or cannot operate safely while spinning, must be detumbled. Systems that perform attitude determination and control include **reaction wheels**, **magnetorquers**, **thrusters**, **star trackers**, **Sun sensors**, **Earth sensors**, **angular rate sensors**, and **GPS receivers and antennas**. Combinations of these systems are typically seen in order to take each method's advantages and mitigate their shortcomings. (*wikipedia extract*, [**?**]).

Pointing in a specific direction is necessary for Earth observation, orbital maneuvers, maximizing solar power, and some scientific instruments. Directional pointing accuracy can be achieved by sensing Earth and its horizon, the Sun, or specific stars. Determination of a CubeSat's location can be done through the use of on-board GPS, which is relatively expensive for a CubeSat, or by relaying radar tracking data to the craft from Earth-based tracking systems (*wikipedia extract*, [**?**]).

1.4.1 Orbital Control

Orbital control will be achieved as a combination of two systems. ADCS will orient the thrust, this thrust will be given by the propulsion system and all the operation will be controlled on the On-Board Computer. Principally, the orbit control will be necessary to mitigate orbital debris effect on every satellite.

1.4.2 Option chosen for the Attitude and Orbital Control System

Decision Taking into account that we need: low power consumption, low, weight and size, high pointing accuracy and really versatile systems that can integrate multiple subsystems; **CUBE ADCS** is chosen. It has the lowest mass and power consumption, it also offers a higher attitude determination systems and integrates also and On-Board Computer (OBC). http://www.cubespace.co.za/cubecomputer

2 ANNEXES

2.1 Structure and mechanics

2.1.1 Structure

There are several types of commercial structures. According to the needs of the project, the structure that Astrea is looking for has to be very flexible regarding the placement of the subsystems. It has to adapt to the needs of the project continuously given that the satellite do not have a typical configuration.
A basic schematics can be found in the figure 2.1.

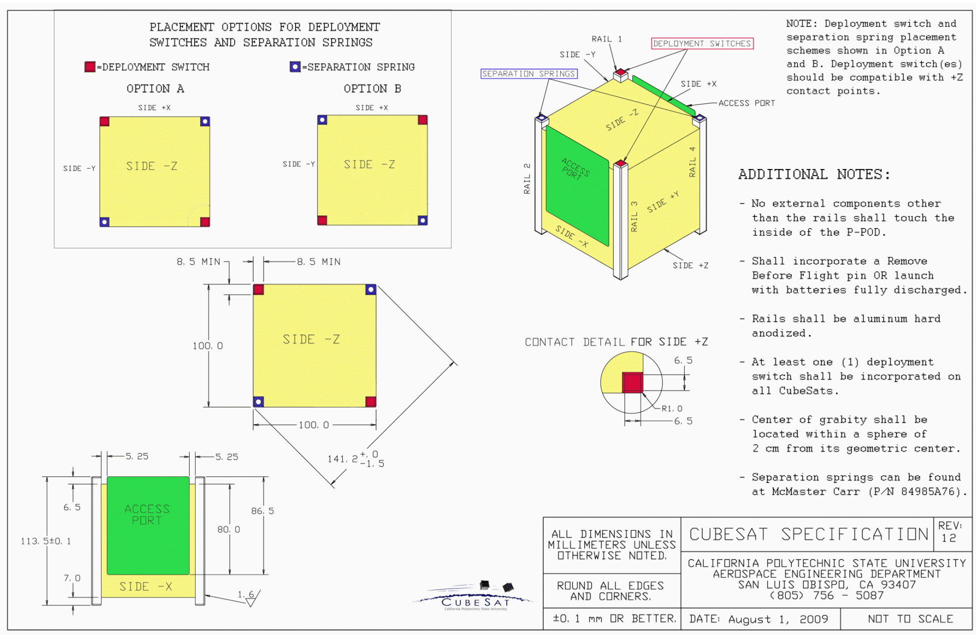

Figure 2.1: Dimensions of a 1U CubeSat. Source [?]

The two most interesting options that were considered when the structure had to be chosen are presented below.

Brand and model	**Features**	**Total price (€)**
Structure		
ISIS 3U structure	Low mass (304.3g) Highly compatible High temperature range	3900

Gomspace GOMX-Platform	High mass (1500g) Comes fully equipped (basic systems) High temperature range	11000

Table 2.1: Options studied for the structure

2.1.2 Thermal protection

The thermal protection system consists of various insulating materials that aim to protect the CubeSat from potential thermal shocks. Currently, the most used element as thermal protection in the aerospace industry is the multilayer insulation (MLI), a set of multiple thin insulation layers. The MLI fulfills all the requirements of this mission and its main objective is to reduce the heat generated by radiation, given that the heat generated by convection or conduction does not have such a high impact on the on-board systems.

A few options were studied when the thermal protection had to be selected. These options are presented in 2.2 red in this section, the table 2.1 is presented below.

Brand and model	**Features**	**Total price (€)**
Thermal protection		
Dunmore Aerospace Satkit	Lightweight Durability Made for small satellites	1000
Dupont Kapton Aircraft Thermal	Lightweight Durability Non-flammable	1200

Table 2.2: Options studied for the thermal protection