



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

Students:

Cebrián Galán, Joan

Foreman Campins, Lluís

Fuentes Muñoz, Óscar

Herrán Albelda, Fernando

Martínez Viol, Víctor

Pla Olea, Laura

Puig Ruiz, Josep

Tarroc Gil, Sergi

Urbano González, Eva María

Fontanes Molina, Pol

Fraixedas Lucea, Roger

González García, Sílvia

Kaloyanov Naydenov, Boyan

Morata Carranza, David

Pons Daza, Marina

Serra Moncunill, Josep Maria

Tió Malo, Xavier

Customer: Pérez Llera, Luís Manuel

Contents

| | |
|---|------------|
| List of Tables | ii |
| List of Figures | iii |
| 1 Satellite design planning | 1 |
| 2 Gantt of the section | 2 |
| 3 Satellite design | 4 |
| 3.1 Structure and mechanics | 4 |
| 3.1.1 Structure | 4 |
| 3.1.2 Deployments | 4 |
| 3.1.3 Thermal protection | 4 |
| 3.1.4 Study of the commercial available options | 5 |
| 3.2 Electrical Power System | 6 |
| 3.2.1 Solar arrays | 6 |
| 3.2.2 Batteries | 7 |
| 3.2.3 Power management | 7 |
| 3.2.4 Study of the commercial available options | 7 |
| 3.3 Propulsion Systems | 7 |
| 3.3.1 Requirements | 8 |
| 3.3.2 Orbit decay | 8 |
| 4 Thruster | 10 |
| 4.1 Communication module | 10 |
| 4.2 Attitude and Orbital Control Systems | 11 |
| 4.2.1 Attitude Determination | 11 |
| 4.2.2 Attitude Control | 11 |
| 4.2.3 Orbital Control | 11 |
| 4.2.4 Study of the commercial available options | 11 |
| 4.3 Payload | 11 |
| 4.3.1 Communications systems | 12 |
| 4.3.1.1 Data Handling Systems | 12 |
| 4.3.1.2 Antenna | 12 |
| 4.3.2 Study of the commercial available options | 12 |

| | |
|----------|-------------------|
| 5 | References |
|----------|-------------------|

| |
|-----------|
| 13 |
|-----------|

List of Tables

| | | |
|-----|-------------------------------|----|
| 1.1 | Prelations and Time | 1 |
| 3.1 | Options studied | 6 |
| 3.2 | Options studied | 7 |
| 4.2 | Options studied | 11 |
| 4.3 | Options studied | 12 |

List of Figures

| | | |
|-----|---------------------------------|---|
| 3.1 | Dimensions of a 1U CubeSat [?] | 4 |
| 3.2 | Basic schematics of the EPS [?] | 6 |

1 Satellite design planning




















Interdependency relationships among tasks, human resources and level of effort

| ID | Work Package | Time (h) | Prelations |
|-----------------------------------|-------------------------|----------|---------------------|
| 1. Preliminary design | | | |
| 1. | Preliminary design | 30 | |
| 2. Structure and mechanics | | | |
| 2.1. | Structure | 6 | BF - 1 |
| 2.2. | Deployments | 6 | BF - 2.1. |
| 2.3. | Thermal protection | 9 | BF - 2.2. |
| 2.4. | Commercial availability | 12 | BF - 2.3. |
| 2.5. | Choose option | 6 | BF - 2.4. |
| 3. Electrical Power System | | | |
| 3.1. | Solar arrays | 9 | BF - 1, BB - 5, 6 |
| 3.2. | Batteries | 9 | BF - 1, BB - 5, 6 |
| 3.3. | Power management | 12 | BF - 3.1, 3.2 |
| 3.4. | Commercial availability | 15 | BF - 3.3. |
| 3.5. | Choose option | 9 | BF - 3.4. |
| 4. Propulsion Systems | | | |
| 4.1 | Motivations | 12 | BF - 1, BB - 2 |
| 4.2 | Commercial availability | 15 | BF - 5 |
| 4.3 | Choose option | 9 | BF - 4.2. |
| 5. Payloads | | | |
| 5.1.1. | Data Handling Systems | 15 | BF - 1 |
| 5.1.2. | Antenna | 12 | BF - 1, FF - 5.1.1. |
| 5.2. | Commercial availability | 15 | BF - 5.1. |
| 5.3. | Choose option | 15 | BF - 5.2. |
| 6. AOCS | | | |
| 6.1. | Attitude determination | 9 | BF - 1, BB - 2 |
| 6.2. | Attitude control | 9 | BF - 1, BB - 2 |
| 6.3. | Orbital Control | 12 | BF - 1, BB - 4 |
| 6.4. | Commercial availability | 20 | BF - 5 |
| 6.5. | Choose option | 4 | BF - 6.4. |

Table 1.1: Prelations and Time

2 Gantt of the section

[illegible]

| | | | | | | | | | | |
|---|----------|---|----------------------|---|---------------------------|---|------------------|---|-----------------|---|
| Proyecto: planning Fecha: mié 19/10/16 | Tarea |  | Resumen del proyecto |  | Tarea manual |  | solo el comienzo |  | Fecha límite |  |
| | División |  | Tarea inactiva |  | solo duración |  | solo fin |  | Progreso |  |
| | Hito |  | Hito inactivo |  | Informe de resumen manual |  | Tareas externas |  | Progreso manual |  |
| | Resumen |  | Resumen inactivo |  | Resumen manual |  | Hito externo |  | | |
| Página 1 | | | | | | | | | | |

3 Satellite design

3.1 Structure and mechanics

INTRODUCCIÓ. FALTA!

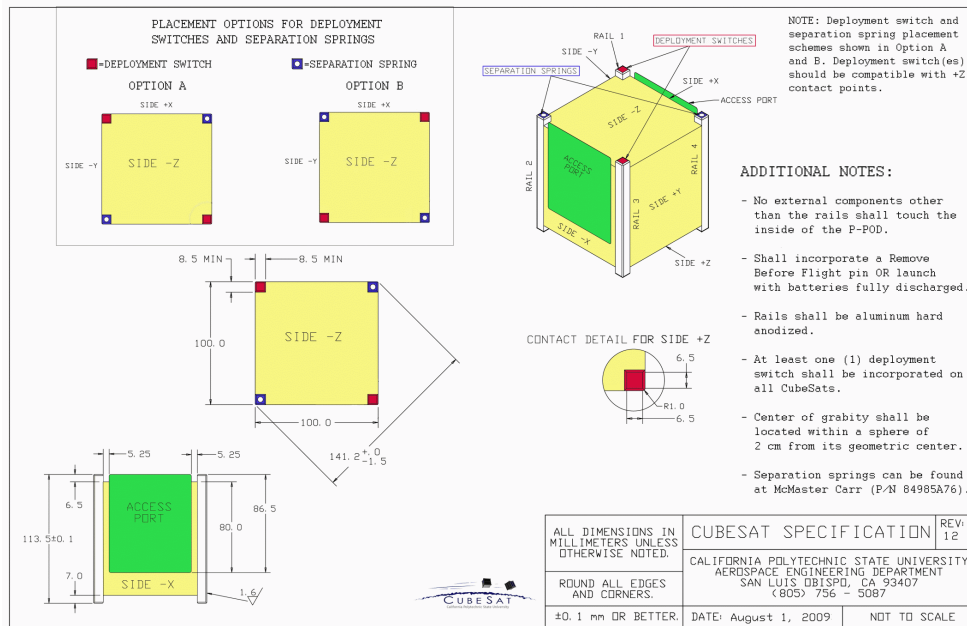


Figure 3.1: Dimensions of a 1U CubeSat [?]

3.1.1 Structure

The mission of the structure is to sustain and protect all the electronic devices carried by the satellite in order to fulfill the mission requirements. In order to ensure that all the electronic and mechanic systems can be mounted upon the structure, a high compatibility between these systems is required.

The structure used will be provided 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 (-40°C to 80°C) and it is highly compatible with almost every physical system that will be used. Additionally, it is a low mass structure (304.3g) and it can support different configurations within it.

Since the configuration within the CubeSat will not be as common as the other configuration within the current operational CubeSats, because the mission of our project is to relay fast and reliable communication with the ground station and the other satellites, it is a really important

3.2 Electrical Power System

point that the structure is highly flexible regarding the arrangement of the subsystems that it will carry.

3.1.2 Deployments

EMPTY

3.1.3 Thermal protection

The thermal protection system protect the CubeSat from thermal shocks. The satellite must remain in a optimal range of temperatures, despite the external temperature. It consists of various insulating materials and thermal conductors in order to maintain it within acceptable temperatures.

3.1.4 Study of the commercial available options

EMPTY

| System | Brand and model | Money (€) |
|--------------|-----------------|-----------|
| 3U Structure | ISIS | 3900) |
| EMPTY 1 | EMPTY | EMPTY |
| EMPTY 1 | EMPTY | EMPTY |

Table 3.1: Options studied

Of all the options in 4.3, we have chosen the following options.

3.2 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. The Electrical Power System of a Cubesat is, probably, the most fundamental requirement of the satellite payload, since its failure would result in the mission failure. The functions of the EPS are to control and distribute power to the Cubesat, to supply a continuous source of electrical power for through the lifetime of the mission, to protect the satellite against bus failiures and to monitor and communicate the system status to the on-board computer. The role of the EPS is very diverse and the following subsystems have to be analyzed in detail.

3.2 Electrical Power System

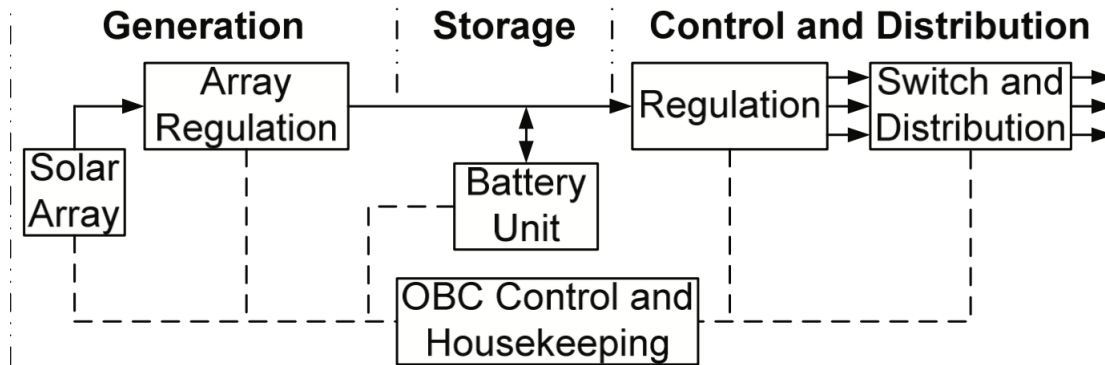


Figure 3.2: Basic schematics of the EPS [?]

3.2.1 Solar arrays

The primary source of electrical power has to be photovoltaic cells, given the size of the CubeSat. The photovoltaic cells will collect and convert the energy of the sun into electrical energy. Since they are main power source, they have to be correctly selected to prevent failure. Among the characteristics we seek for our mission, we are looking specially whether the solar cell has a decent amount of power collection, low mass, protective radiation shield, deployment system, great temperature range and compatibility with the other systems.

The selected option for the Astrea mission will be a set of deployable solar panels provided by EXA (Agencia Espacial Civil Ecuatoriana). These panels are low mass (135g each), have a protective radiation shield (NEMEA Anti Radiation Shield protects the solar panels of EM, High Gamma, X-Ray, Alfa, Beta and low neutron radiation), a very high temperature range (from -80 to 130°C), a gentle release and deployment with artificial muscles (developed by EXA) and provide a power of 16.8W each (19.2V@0.5A).

Every cubesat will have 6 deployable solar panels providing it with 100.8W of power to supply peak demands while it is operating. Additionally, it is worth mentioning that these solar arrays are compatible with the hardware used in each of the satellites.

3.2.2 Power management

The role of the power management systems is to distribute the power and supply the energy to the different systems used in the CubeSat.

3.2.3 Batteries

Batteries are vital 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 (because the subsystems will not

3.3 Propulsion Systems

usually require a peak power and the batteries are just an emergency system), operating at the desired voltages and currents and

3.2.4 Study of the commercial available options

Several commercial options have to be studied. The table provided below organizes some information about the different options purchased.

| System | Brand and model | Money (€) |
|--------------|--|-----------|
| Solar arrays | EXA (Agencia Espacial Civil Ecuatoriana) | 17000) |
| Truñaas 1 | EMPTY | 20000 |
| Cuescas 1 | EMPTY | 20000 |

Table 3.2: Options studied

Of all the options in 4.3, we have chosen the following options.

3.3 Propulsion Systems

EMPTY

3.3.1 Requirements

There is a big risk of a collision with space debris while a spacecraft is operating in Low Earth Orbits. The Inter-Agency Space Debris Coordination Committee recommended to the United Nations (section 5.3.2 ‘Objects Passing Through the LEO Region’): “Whenever possible space systems that are terminating their operational phases in orbits that pass through the LEO region, or have the potential to interfere with the LEO region, should be de-orbited (direct re-entry is preferred) or where appropriate manoeuvred into an orbit with a reduced lifetime. Retrieval is also a disposal option.” and “A space system should be left in an orbit in which, using an accepted nominal projection for solar activity, atmospheric drag will limit the orbital lifetime after completion of operations. A study on the effect of post- mission orbital lifetime limitation on collision rate and debris population growth has been performed by the IADC. This IADC and some other studies and a number of existing national guidelines have found 25 years to be a reasonable and appropriate lifetime limit.”

Thus, a proper propulsion system is needed both for maintaining the satellite’s orbit and for de-orbiting after the mission’s lifetime.

Given the size of the CubeSat, not many effective options are available and a committed solution has to be found in order to follow the recommendations by the IADC.

3.3 Propulsion Systems

3.3.2 Orbit decay

Orbit decay prediction powered by the Bureau of Meteorology by the Australian Government.

To calculate the orbit decay the following parameters are used:

Solar Radio Flux at 10.7cm (F10.7). It is a clear indicator of solar activity and has proven very valuable in forecasting space weather. The extreme UV that impact the ionosphere also modify the upper atmosphere, thus F10.7 data is needed to account for these variations. The value used in this calculation is: 79.54. REF: <http://www.spaceweather.gc.ca/solarflux/sx-5-mavg-en.php>

Cubesat mass of up to 4kg.

The K-index, and by extension the Planetary K-index, are used to characterize the magnitude of geomagnetic storms. Kp is an excellent indicator of disturbances in the Earth's magnetic field and is used by SWPC to decide whether geomagnetic alerts and warnings need to be issued for users who are affected by these disturbances.

The principal users affected by geomagnetic storms are the electrical power grid, spacecraft operations, users of radio signals that reflect off of or pass through the ionosphere, and observers of the aurora.

The geomagnetic index used in this calculation is: 12.

RE-ENTRY EVERY 106.25 DAYS!

Calculations based on day 100, with an altitude of 400Km. Already lost 100Km:

4 Thruster

Thruster is a main part of the structure because it is needed to allow the satellite to realise different maneuvers how incorporate it adequately to the orbit after the deployment of the rocket, can obtain the optimal orientation or to maintain 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 monoprop thrusters. An important aspect to consider is that we are interested in is reducing the mass required although this will cause minor accelerations than conventional engines but it will be suitable for small satellites.

After a market study, an ionic thruster has been elected how the best option. The causes of this election are that the volume of the all propulsion subsystem and its weight are very small, specific impulse is very high, thrust is acceptable and power required can be supplied by the solar panels.

The following table shows the main parameters of this thruster.

| BIT-1 ION THRUSTER | |
|-------------------------------|---------------|
| PARAMETERS | VALUE |
| Total thruster power | 10 W |
| Thrust | 100 μ N |
| Specific impulse | 2150 s |
| Thruster Mass | 53 g |
| Propellant mass flow | 4.9 μ g/s |
| Grid input voltage | 2 kV |
| Ion beam current | 1.5 mA |
| Propellant utilization | 41 percent |
| Energy Efficiency | 27 percent |

4.1 Communication module

100kbps:

1mbps:

¿solo 9600bps?:

4.3 Payload

Links interesantes universidades:

4.2 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).

4.2.1 Attitude Determination

EMPTY

4.2.2 Attitude Control

EMPTY

4.2.3 Orbital Control

Thrusters

4.2.4 Study of the commercial available options

| Brand and model | Features and description | Money (€) |
|---------------------|--------------------------|-----------|
| Solar Panels | | |
| Fabricant 1 | EMPTY | 2000000 |
| Chuscas 1 | EMPTY | 20000 |
| Truñaas 1 | EMPTY | 20000 |
| Cuescas 1 | EMPTY | 20000 |

Table 4.2: Options studied

4.3 Payload

EMPTY

4.3 Payload

4.3.1 Communications systems

The communication system allows us to realize the reception and transmission of data, voice signals, etc. It consists of a group of transponders, that are the combination of a transmitter and a receiver and whose functions are receiving, separating, amplify, process, reamplify and retransmit signals.

The telemetry subsystem analyses the information about the ground station and other sensors of the satellite in order to monitor conditions on board. It allows report to ground station about the conditions of the on board systems.

The command and control subsystem allows the ground station to control the satellite.

4.3.1.1 Data Handling Systems

EMPTY

4.3.1.2 Antenna

EMPTY

4.3.2 Study of the commercial available options

EMPTY

| Brand and model | Features and description | Money (€) |
|---------------------|--------------------------|-----------|
| Solar Panels | | |
| Fabricant 1 | EMPTY | 2000000 |
| Chuscas 1 | EMPTY | 20000 |
| Truñaas 1 | EMPTY | 20000 |
| Cuescas 1 | EMPTY | 20000 |

Table 4.3: Options studied

5 References