# Chapter 2
# *Specifications of the system*

## *Abstract*

*This chapter presents the characteristics of the satellite, seen as a whole system. The most important problems in respect with the project, reside from the characteristics of the power supply subsystem. Other important aspects, like orbit and space environment or mechanical structure are presented as general requirements for the system.*

## 2.1. Introduction

For the purpose of understanding the role of the power supply in good-functioning of the satellite and to design it in a proper way, the specifications for the entire system must be known. The job of the electrical power subsystem is to provide uninterrupted power to on-board electronics both in sunlight and in eclipse.

There are five types of power sources in use today:

- Solar cells also denoted Photovoltaic (Silicon,Gallium-Arsenide)
- Secondary batteries (rechargeable) – used as energy storage medium to supply power during eclipse or adverse pointing of the solar arrays.
- Primary batteries (non-rechargeable) – used only on launchers and on small experimental missions with a lifetime of a few days.
- Fuel cells – producing electricity by electrochemically “burning” oxygen and hydrogen to water. Used presently only on the Space Shuttle.
- Radioisotope Thermal Generators (RTG) – using the heat produced by radioactive decay of Plutonium-238 to produce electricity via thermo-electrical cells. Used only on interplanetary missions to the outer planets.

For the CubeSat mission, two types of power sources are used: photovoltaic and rechargeable Li-Ion batteries.

## 2.2. General requirements

In this section, a few specifications for the system, named as “general” requirements, will be presented. Note that some values are absolute, others will provide only guidelines for final design.

- Efficiency for the power subsystem is not stated. An objective of the current project work is, therefore, to achieve as high efficiency, as possible. Also, reliability of the components, which will reflect into entire power subsystem reliability, must be taken into account.
- EMC characteristics must meet actual standards.
- Temperature inside the satellite must not exceed the limits for normal operation of the components.

- Dimensions and weight. For PSU is at disposal at most 290 grams mass which must be divided into batteries, solar cells, etc. For solar cells are also given maximum dimensions: solar cells on each hand side 80 x 95 mm and on the top side 80 x 80 mm. For each battery is given 83.3 x 39 x 4.9 mm [Conceptual-Structural-Design-271001-rev1-0-pdf.pdf].

## 2.3. Electrical specifications

### 2.3.1. Inputs and outputs specifications for power subsystem

Energy from the Sun is the main source of power for the satellite. However, there are lot of other sources of radiation in space (cosmic radiation, albedo from the Moon etc), but only a few of them are significant.

In table 2.1, three sources of energy, at disposal for Cubesat, are shown.

| Type of heat | Solar radiation | Albedo of the Earth | Infrared radiation of the Earth |
|---|---|---|---|
| Energy ($W/m^2$) | 1353 | 406 | 237 |

*Table 2.1 Main energy sources*

As can be seen in a table 2.1, the solar irradiation is the most powerful source of energy. This source can be taken into account only when the satellite is illuminated from the Sun. Due to the multi junction technology (used in solar cells) the infrared spectrum (from 700 nm to 1000 nm) can also be included [http://www.ipac.caltech.edu/Outreach/Edu/infrared.html].

*Albedo* is the fraction of light that is reflected by a surface. It is commonly used in astronomy to describe the reflective properties of planets, satellites, and asteroids. Bond albedo, defined as the fraction of the total incident solar radiation reflected by a planet back to space, is a measure of the planet's energy balance. The value of bond albedo is dependent on the spectrum of the incident radiation because such albedo is defined over the entire range of wavelengths. Earth-orbiting satellites have been used to measure the Earth's bond albedo. The most recent values obtained are approximately 33% [ http://zebu.uoregon.edu/~js/glossary/albedo.html ].

The power subsystem is designated to supply all the users in the satellite. The users, in the CubeSat satellite are: OBC (Onboard Computer), ACS (Attitude Control System), CAM (Camera), COM (Communication module).

In Table 2.2, the power budget for the loads is presented.

| Consumer | Voltage [V] | Current [A] | Power [W] |
|---|---|---|---|
| OBC | 5 | 0.092 | 0.46 |
| COM module | 5 | 1.8 | 9 (16min) |
| Camera | 5 | 0.06 | 0.3 |
| ACS | 5 | 0.05 | 0.25 |
| **Total Power** | | | **10.01** |

*Table 2.2 Power budget for the loads*

In designing of the power supply subsystem, it has to be decided as the most convenient and high-efficient solution as possible.

## 2.3.2. Batteries and solar panels requirements

During the time eclipse, when the satellite is in shadow and also when bus needs more power than solar cells can provide, batteries must be used. They will be also back up in the case of failure on the solar cells and simultaneously as storage for redundancy energy. Due to the orbit conditions they must operate in big amount of temperatures. Weight and size must be kept as low as possible.

Due to these brief considerations, batteries chosen to equip CubeSat have the following specifications [ http://www.danionics.dk ]:

- Type: Li-Ion Polymer
- Dimensions: 69 x 39 x 4.9 [mm]
- Weight: 26 [g]
- Capacity: 920 [mAh]
- Nominal voltage: 3.7 [V]
- Voltage range: 3.0 – 4.2 [V]

Solar cells are semiconductor devices that convert sunlight directly into electricity. Conventional solar electric systems use solar cells, encapsulated in "flat-plate" weatherproof "modules". Solar cells cover the entire flat-plate module area and are uniformly illuminated with unconcentrated sunlight. The solar cells selected for the current application have the following specifications [ http://www.emcore.com ]:

- Size of one cell: 69 x 40 [mm]
- Thickness: 140 [μm]
- Weight: 2.25 [g]
- Advanced triple junction InGaP/GaAs, Ge substrate cell
- Efficiency (BOL) = min. 27.5 [%]
- Efficiency (EOL) = min. 25 [%]
- Open circuit voltage: 2.616 [V]
- Short circuit current: 462 [mA]

## 2.4. Interface and orbit specifications

There are two main parts of the interface – data and power. The power bus will provide energy for all systems in the satellite and the data bus will provide communication with OBC.
The loads on the satellite, as described in section 1.3, are: onboard computer, attitude control system, communication system (radio, associated circuits) and camera circuits.

The power bus must deliver energy from power source to these loads and must grant all values (ripple, voltage level etc.) with as high accuracy as possible. All systems are using 5V as an input voltage. For the radio transmitter, this comprises an internal converter, to transform 5V voltage to required voltage level (9V). This is done completely independent, so in respect with the tasks of the power supply, the transmitter module is seen as another user supplied at 5V. Another important task for PSU is to provide protections for the users, these protections must avoid any dangerous situations which can occur in user's circuits.

The data bus should provide communication to/from onboard computer. All housekeeping data will flow through this bus and all control signals will also use this bus.

The satellite will be placed on a circular Low Earth Orbit with the inclination of 96 degrees and height of approx. 600 km. Velocity of the satellite on orbit is estimated to be 27000 km/h.
Based on these parameters, revolution time has been computed:

- $T_{orbit}$: 100 min
- $T_{sun}$: 65 min
- $T_{eclipse}$: 35min

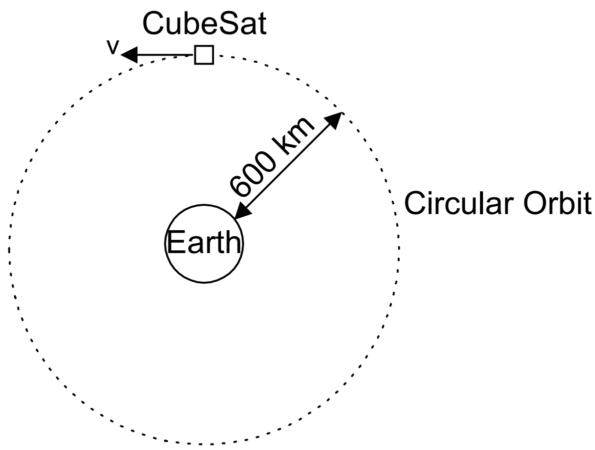


*Figure 2.1 Sketch of the satellite orbit*

## 2.5. Summary

In this chapter, general and special requirements for the system and for the Power Supply Unit, respectively, are presented. In section 2.2, requirements for the power subsystem regarding dimensions and weight are presented.

Some of them will be detailed in the next chapter, where a more detailed analysis of the system will be done.