NANOSATC-BR – ENERGY GENERATION AND STORAGE

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Abstract. *Students from the Federal University of Santa Maria – UFSM working with scholarships on Scientific and Technologic Initiation Programs at the Southern Regional Space Center Research – CRS/INPE with the support of engineers and scientists from INPE's Headquarters are engaged in a CubeSat-class satellite Project, the NanoSatC-BR that will be the first Brazilian CubeSat. A magnetometer will be the payload and will measure Earth's magnetic field, especially at the region of the South Atlantic Magnetic Anomaly. This anomaly is a Magnetosphere phenomenon that takes place in the Southern Hemisphere, below the magnetic equator, where the Van Allen radiation belt (particles emitted by the Sun and trapped by Earth's magnetic field into a belt following the magnetic equator) is closest to Earth's surface. Engineering solutions for the NanoSatC-BR are presented, with several power-related tasks that shall guarantee the operation of the satellite. They include the power supply for the spacecraft, the batteries for energy store, the distribution, regulation and control of the power supply through electronic microcontrollers. A preliminary power budged for the spacecraft is presented considering a Low Earth Orbit (LEO), showing the maximum power that the satellite can produce, the estimated subsystems power consumption and the depth of discharge of the batteries (DOD) on the cycles of sunlight and eclipse on its orbit.*

Keywords: *CubeSats, Batteries, PSS, EPS*

1. INTRODUCTION

A CubeSat is a type of miniaturized satellite that has a volume of one liter (10x10x10cm), weighs no more than one kilogram, and typically uses commercial off-the-shelf electronic components. Beginning in 1999, the term "CubeSat" was coined to denote nanosatellites that adhere to the standards described in the CubeSat design specification. California Polytechnic State University published the standard in an effort led by aerospace engineering Professor Jordi Puig-Suari, David (2004).

Bob Twiggs, from the Department of Aeronautics & Astronautics at Stanford University has contributed to the CubeSat community. His efforts have focused on CubeSats from educational institutions, David (2006). Compared to traditional multi-million-dollar satellite missions, CubeSat projects have the potential to educate the participants and implement successful and useful missions at a much lower costs. Project timelines are typically 9-24 months from inception to launch.

The main objective of this work is to present a proposal for power generation and storage for the first Brazilian CubeSat, the NANOSATC-BR.

2. THE POWER SUPPLY SUBSYSTEM

The Power Supply Subsystem, also known as Electrical Power Subsystem, is one of the most important subsystems of the satellite and is responsible for many essential tasks that shall ensure the operation of the spacecraft. These tasks include supplying power to the satellite, to distribute storage, regulate and control the power supply through electronic microcontrollers, Larson and Wertz (1992). The work discusses solutions for the power generation and storage.

2.1. Power Generation

When the satellite is in orbit, the power supply subsystem shall generate enough power to supply all other subsystems, the payload and to recharge the batteries. The power generation will be done from the Sun, which is the only available energy source in space.

The energy from the Sun must be transformed into useful electricity for the satellite and in this particular case will be used photovoltaic solar cells, the most common power source for Earth-orbiting spacecraft that convert incident solar radiation directly to electrical energy, Larson and Wertz (1992).

The satellite attitude probably will not be determined, so it is not possible to know the direction of incidence of the solar radiation in the cells. In this case we consider that only one side will be illuminated at a time and we can calculate the average power that the satellite can generate.

In order to estimate the power available for the subsystems of the satellite the following conditions need to be considered, University of Leicester (2007):

- *The solar irradiance (Φ).* We require solar irradiance distribution at a distance of 1 AU (Astronomical Unit). The value recommended by the American Society of Testing and Materials (ASTM) is 1366.1 W/m^2.
- *The solar cell efficiency (ε):* Clyde Space will supply the solar panels for the NanoSatC-BR. Clyde Space uses two types of solar cells, EMCORE's Advance Triple-Junction cells (ATJ) with efficiency 27.5%, Figure 1.

Figure 1. Advanced Triple-Junction EMCORE photovoltaic cell
(http://www.emcore.com)

- *The efficiency of the power supply unit (k).* The power supply unit consists of components such as the battery charge regulators (BCR) and power bus regulators that dissipate energy. This reduces the power available for the other subsystems. According to Clyde Space who is one power supply unit's supplier, the total efficiency of the power supply unit is 90%, Figure 2.

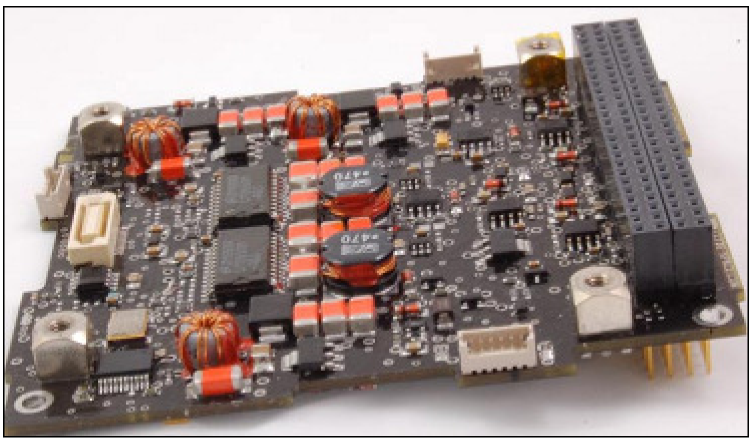

Figure 2. Clyde Space 1U CubeSat Power
(http://www.clyde-space.com)

- *The effective area of the solar cells (A).* The effective area of the solar panels is the total area of the solar panels exposed to the Sun. The effective area will depend on the way the satellite is spinning. It was decided that only one side will be illuminated at a time to calculate the average power that the satellite can generate. The ATJ cells size from EMCORE is 40x70 mm and only two cells assembled per side, Figure 3. The area of each cell is 26.6 cm^2, so we will have an effective area of 53.2 cm^2 (0.0532 m^2).

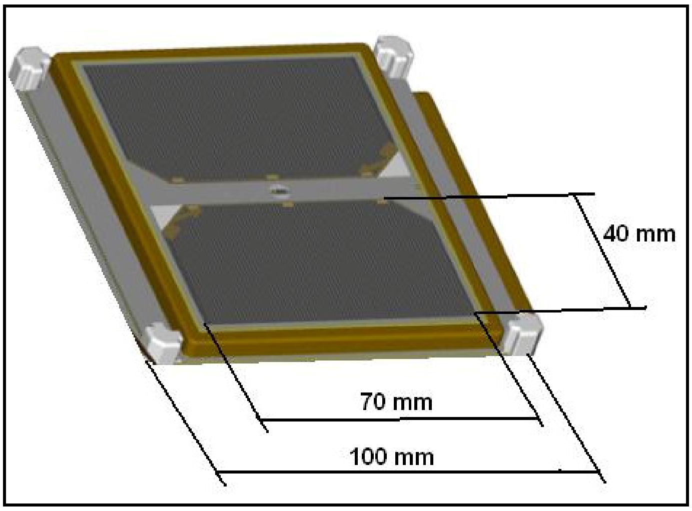

Figure 3. Photovoltaic cells fixed on the satellite
(http://www.lcto.dk/download/CubeSat4.jpg)

The power available for the spacecraft subsystems is approximately 1.8 W that is obtained by Equation 1 combined with the values listed above.

$$P = \phi \cdot \varepsilon \cdot k \cdot A \tag{1}$$

2.2. Energy Storage

The energy produced by the solar array that is not used immediately should be stored in rechargeable batteries. When the satellite is illuminated by the Sun, the power that is generated supplies all the subsystems that require energy and, in parallel, charges the batteries. When the satellite is not illuminated, the subsystems are supplied by batteries. The batteries are also used when a subsystem of the satellite requires a power peak.

Clyde-Space lithium polymer battery cells will be used to store energy to supply the satellite during eclipse periods. The capacity of each battery is 1.25 Ah and the end of discharge limit voltage is 4.1 V, Figure 4.

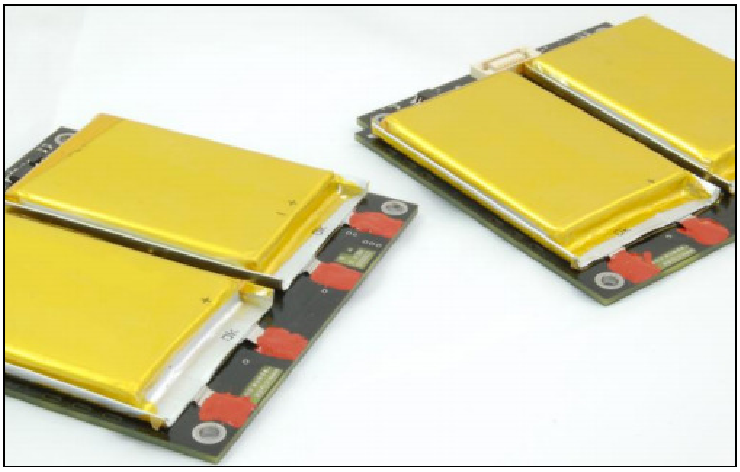

Figure 4. Clyde Space lithium polymer battery cells
(http://www.clyde-space.com/documents/14/14-small.jpg)

To determine the depth of discharge at the eclipse periods, a power budget is necessary, presenting the subsystems power consumption at the different operation modes, Table 1. The satellite will have two operating modes: “Standby”, when all the subsystems and the payload are working without transmission and "Transmitting", when all the subsystems and the payload are working and the satellite transmit data to the earth during 15 minutes.

Table 1. Power consumption at the different operating modes

SUBSYSTEM	STANDBY (W)	TRANSMITTING (W)
Structure Subsystem	0	0
Thermal Control Subsystem	0	0
Power Supply Subsystem	0.1	0.1
TTCS Band Subsystem	0	1
Attitude and Orbit Control Subsystem	0	0
On-Board Data Handling Subsystem	0.025	0.025
Payload	0.02	0.02
TOTAL CONSUMPTION	**0.145**	**1.145**

Depth of discharge (DOD) is simply the percent of total battery capacity removed during a discharge period. We used this power consumption table, considering a bus voltage of 5 V and an orbit period of 100 minutes (65 minutes sunlight and 35 minutes eclipse) and 14 orbits/day. Table 2 presents the DOD of the batteries for each orbit.

Table 2. Depth of discharge for each orbit

ORBIT NUMBER	MODE IN ECLIPSE	DOD (%)
1	Standby	1,35
2	Standby	1,35
3	Standby	1,35
4	Standby	1,35
5	Standby	1,35
6	Standby	1,35
7	Standby	1,35
8	Standby	1,35
9	Standby	1,35
10	Transmitting	5,35
11	Transmitting	5,35
12	Standby	1,35
13	Standby	1,35
14	Standby	1,35

These DOD's was calculated considering two lithium polymer battery cells and can be better seen through the diagram in Figure 5.

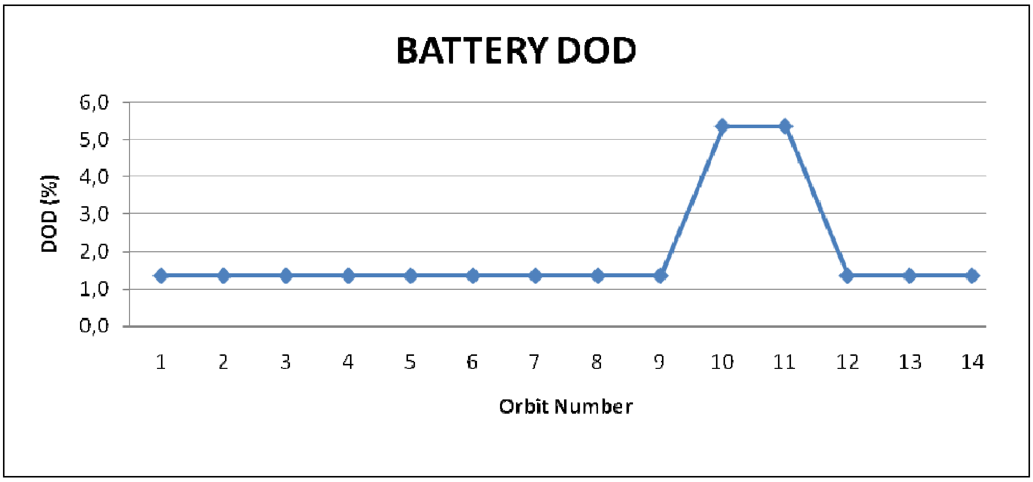

Figure 5. Battery DOD diagram

3. CONCLUSIONS

This work presents the importance of the Power Supply Subsystem, especially the generation and storage of energy showing the average power consumption of the satellite on different operating modes and the DOD for each orbit, considering 14 orbit periods/day. The launch date of NanoSatC-BR is scheduled for the end of 2010, thus allowing the initiation of the acquisition of data for scientists.

4. ACKNOWLEDGEMENTS

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