MECÂNICA ESTRUTURAL – 10391/10411

2019/2020

Mini-Project 2

1. OBJECTIVES

The main objectives of this project are:

- To perform static, thermal and modal analyses on the structure of a CubeSat using the finite element method.
- To size the structure parts for structural efficiency according to strength and stiffness requirements.
- To develop critical thinking when analysing and optimizing the structure.

2. PROBLEM

It is necessary to analyse and optimize the structure of a micro satellite whose purpose is to carry an experiment in the upper atmosphere to measure the effect of the communications blackout during re-entry. The objective of the experiment is to validate the theory that a magnetic field can reduce the plasma density surrounding the spacecraft during atmospheric re-entry. This phenomenon is known as RF blackout. It is caused while a vehicle re-enters or flies through the Earth’s atmosphere at hypersonic velocities creating a shock wave in front of the vehicle. The created shock will significantly rise the temperature of the air surrounding the spacecraft ionizing the gas and creating a plasma layer around the vehicle. The communications with the vehicle will be cutoff whenever the plasma frequency exceeds the transmitting frequency of the communication signals. The signal attenuation mainly depends on the plasma’s density. The radio waves emitted from and to the vehicle cannot reach a ground station or a Global Positioning System (GPS) satellite and so the vehicle loses voice communication, data telemetry, GPS navigation, and electric countermeasures capability during RF blackout. RF blackout blocks communications of the vehicle for several minutes, depending on the angle of re-entry and the properties of the atmosphere.

The micro satellite that is considered is a three-unit (3U) CubeSat (Figure 1). The CubeSat must carry several systems to work properly: central processing unit (on-board computer - OBC); communications modem (transceiver) and antennas; battery packs (battery 1 and battery 2); attitude control system (magnetic torque board); power management unit (power management board – PMB); solar panels; and the experiment (payload). The payload will be placed in the upper 1U, the battery packs will use the central 1U and the remaining systems the lower 1U of the CubeSat. The mass of these components and its location in the 3U CubeSat are as per Table 1.

The critical loading conditions usually take place during the launch procedure. The static loading conditions that need to be considered are shown in Table 2 taking $g = 9.8065$ m/s^2. These conditions result from the launcher accelerations and must be used in the possible combinations that may occur to create analysis load cases. Due to the vibrations produced by the launcher, the natural frequencies of the CubeSat must be higher than 90 Hz. Operational temperatures between -50ºC and +100ºC must also be considered. The effects of temperature gradients across opposite faces need to be considered in the stress and displacement distributions analyses.

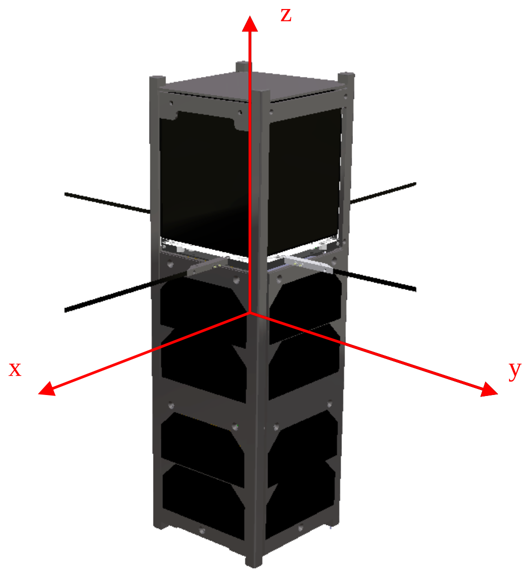

Figure 1: 3U CubeSat example and cartesian coordinate system.

Table 1: Systems' mass and centre of gravity position. The origin of the coordinate system is placed at the geometrical centre of the CubeSat.

System	**mass, kg**	***x*, mm**	***y*, mm**	***z*, mm**
payload	1.200	3.00	2.00	69.75
antenna	0.100	-1.03	0.00	52.30
battery 1	0.270	-1.64	4.02	-19.61
battery 2	0.270	-1.64	4.02	-44.96
PMB	0.200	-2.82	6.18	-91.57
transceiver	0.075	-2.94	0.57	-108.34
torque board	0.206	31.73	0.94	-125.28
OBC	0.077	0.67	8.00	-141.70

Table 2: Load conditions to be considered (load factor and acceleration direction).

Load condition	***n***	***x***	***y***	***z***
1	14.5	0	+1	0
2	10.5	0	-1	0
3	3	+1	0	0
4	3	-1	0	0
5	3	0	0	+1
6	3	0	0	-1

3. PROJECT REQUIREMENTS

In this mini-project it is necessary to perform the detailed design of the structure of the 3U CubeSat. Different aspects of the design must be considered. The topics that need to be addressed in this detailed design are:

1. Structural analysis approaches, methods and tools.
2. Loading cases and boundary conditions.
3. Static analysis.
4. Thermal and static analysis.
5. Modal analysis.
6. Structure sizing for minimum mass considering strength and stiffness constraints.

A final report describing the design analysis and optimization methodology and results, including drawings, should be produced by each team. The report should not have more than 20 pages.

4. TASK RESPONSIBLITY

This is a group project where each team of three students should propose a solution for the CubeSat structure.

Table 3: Teams and students' names.

Team	**Names**