COMPOSITE STRUCTURE FOR DEEP SPACE CUBESATS

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Abstract

The structural development of a nanosatellite is a challenging process due to the complexity of the space environment. Many of these issues were handled by the first year of the structural work-package of SIRONA (Selenocentric platform hOsting iNternational pAyloads), a project led by the space center (CS^3) of CentraleSupélec, such as the radiation shielding problematic, the elevated mechanical stress during the launching and the structure optimization.

The work presented in this poster has followed the objectives and requirements of the SIRONA mission, a lunar orbiter. This CubeSat is a 12U (ISIS 12U XL), hence 22.4 x 22.4 x 34 cm^3 [1] and will travel from Earth to the Moon during a maximum of 6 months and perform its scientific mission around the Moon for at least 6 additional months.

The strict mission requirements impose structural optimization for two main reasons:

- The high costs of launch opportunities constrain the economic viability of the entire mission according to the total mass of the vehicle.
- All CubeSat missions have an associated scientific or technological goal, thus the volume and mass minimization of the structure provide more room for additional payloads. For instance, in the case of SIRONA, those devices will be a deployable telescope, which will enable the study of the lunar topology, and petri dishes for biological experiment testing the effects of radiation on organisms, which can provide a new perspective on the possibility of Moon bases or Cislunar space stations.

Mission system requirements

The strict mission requirements forces the structural optimization to be a crucial problem to be handle, since the volume in extremely limited, due to the CubeSat standard. Therefore this study aims not only to gain mass by modifying the geometric parameters that describe the structure but also to verify that the spacecraft will withstand launch loads. The latter can be mainly summarized into four main groups:

- Radiation: all inner components must be protected from the hostile environment when the spacecraft will be orbiting the moon (dose < 15 krad).
- Vibration: after a modal analysis, the structure must have the first resonance frequency beneath 90 Hz.
- Acceleration: a static analysis must be done in order to verify that the structure will withstand accelerations of module of 10g in each direction.
- Shocks: the Cubesat has to withstand a series of shock loads along each axes, with accelerations that vary between 5g and 2000g and to frequencies that vary between 30 Hz and 10kHz.

Radiation shielding panels conception

A spacecraft in transit between Earth and the Moon is subjected to intense radiations, especially if, like SIRONA, it uses an ionic propulsion system and spend months to reach its target. Furthermore, due to the practically non-existent lunar atmosphere and the weak magnetic fields, lifetime of the onboard electronics could also be affected by the choice of scientific orbit.

Therefore, the strategy that was considered was to use a dual composite assembly. The skeleton of the structure will be made out of aluminum and optimized to withstand the launch loads. Free of the necessity of adding mass for structural integrity, the rest of the structure will be composed of panels optimized for radiation shielding with and minimal weight. For this matter, one has to determine for each material, the thickness needed in order to absorb the radiation energy and protect the electronics of the spacecraft.

Hence, a material catalog was conceived regarding their performance regarding radiation absorption when submitted to same conditions as the lunar environment. In order to simulate this conditions, one can input the same characteristics of the cosmic galactic rays (CGR) [2], since other sources of radiation – for instance the solar wind and solar energetic particle events - have a neglectable effect when CGR is applied simultaneously. In this analysis, the radiation effect over a thick planar slab was observed in order to calculate the mean path length of alpha particles and protons, the main constituents of the CGR (see Figure 1). The simulations were done using GRAS Monte Carlo method in SPENVIS [3] and they enabled to provide for each material the thickness needed in order to attenuate the radiation energy.

The results of this study shown that the Mylar is best material tested in terms of the ratio radiation absorption over mass. However due to its fragility, the composite panel is comprised not only of Mylar but also HDPE (High Density Polyethylene).

Thus, the final design could be done and it is shown in Figure 2. These panels will have a final volume of 45 cm^3 and a mass of 46g.

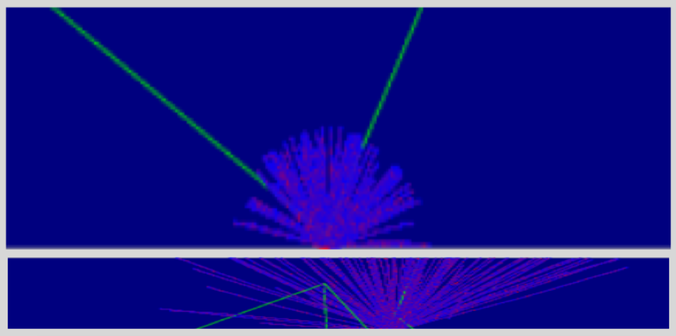


Figure 1: particle interaction with the medium

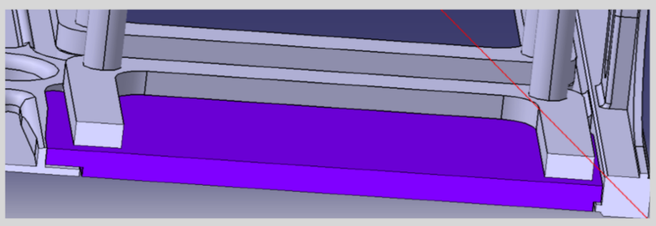


Figure 2: radiation shielding panels

Structure optimization and simulation

The structural simulation were done using the finite element method in CATIA (see Figure 3a/3b/3c). For each simulation, a convergence analysis had to be done in order to determine the maximal size of the mesh elements that allowed to obtain an accurate solution. The optimization was performed by choosing the key parameters defining the structure (width of the beams, size of the holes…) and dichotomy was used other a wide range of cases to reduce the structure mass as well as to reach a factor of security of 2 (see Figure 3a). The optimization enable to reduce the mass of the chassis down to 1.426 kg. Moreover, the results of the modal analysis found the first resonance frequency to be 209.4 Hz, which is above the minimal required value of 90 Hz. Finally, the Figure 3c shows the final configuration of the structure with the radiation panels.

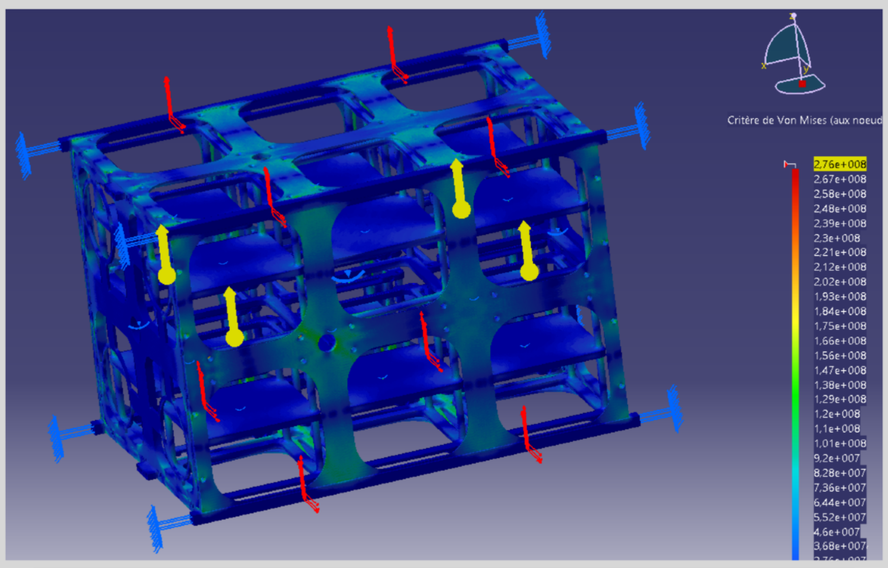


Figure 3a: acceleration load simulation

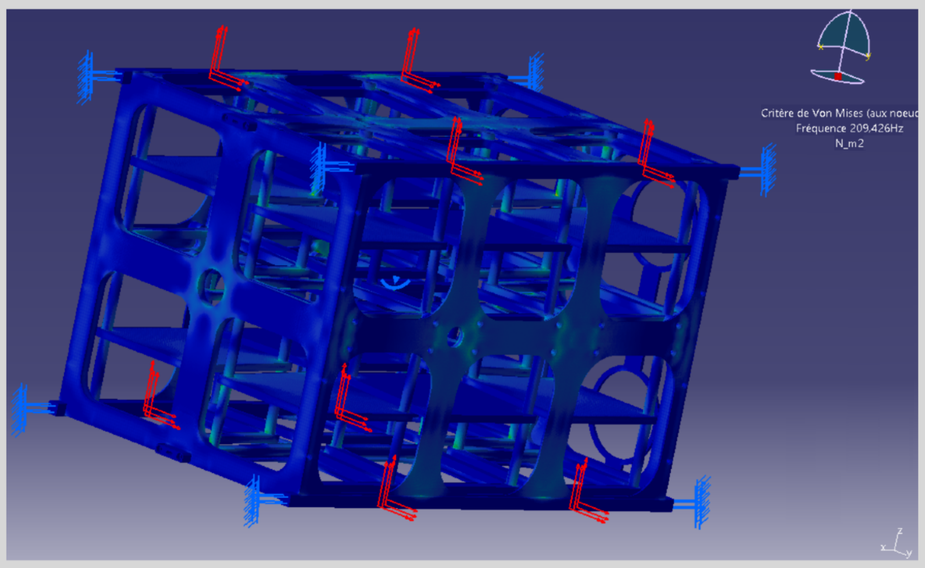


Figure 3b: frequency load simulation

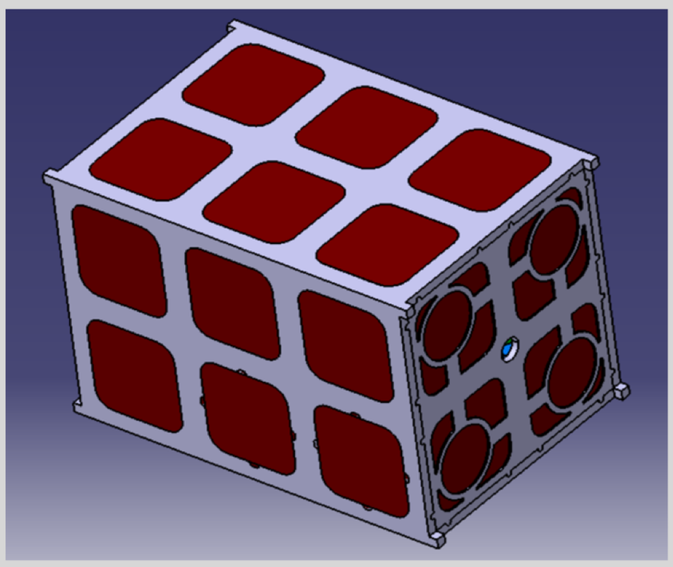


Figure 3c: structure with radiation panels

Conclusion

The present study exposed a new kind of composite structure for CubeSat missions that can not only withstand the strict requirements of the launch loads but also provide shielding against radiations. We demonstrate that an aluminum chassis of a 12U nanosatellite of mass under 1.5 kg can withstand acceleration of 10g and still have the first resonance frequency over 90 Hz. Concerning the radiation shielding problematic, the simulation done have shown that panels composed of Mylar and HDPE fitting within the holes of the chassis represent an optimized solution when mass and the thickness are taken as decision criteria. This configuration provides a safe environment inside the spacecraft by attenuating the cosmic galactic rays, an thus avoiding the damage of on board electronic circuits.

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