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MODAL ANALYSIS OF A SATELLITE WITH DIFFERENT MATERIALS

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Abstract. *For placing an object in any Earth orbit, it is extremely necessary to follow safety rules. The non-use of this can be destroyable for the launching system. Because of that, the launching company Kosmotras® requires that the satellite UniSat7 from GAUSS srl® pursue a high level of structural security. The Kosmotras® requests a modal analysis and that the natural frequencies of the satellite must be higher than 20 Hertz in longitudinal direction and 10 Hertz in lateral. For achieving this results, it is needed to use materials that increase the total stiffness and decrease the mass of the satellite. It was used 3 types of materials to be applied in this study: Aluminium alloy plate, honeycomb composite material made of aluminium and aluminium honeycomb core with carbon fiber plate sandwich composite. Through computational analysis made in ANSYS®, it was proved that the last one material is the most suitable for aerospace uses. This is explained by the fact that the composite materials (mainly the honeycomb sandwich panels) have the lowest density and highest stiffness.*

Keywords: *Natural frequencies, Modal analysis, Composite materials, Structural dynamics*

1. INTRODUCTION

During the last years, the use of satellites became primordial for the development of a nation. According to (OECD, 2011), the space progress can be seen as a potential source of politic, economic growing and sustainable development.

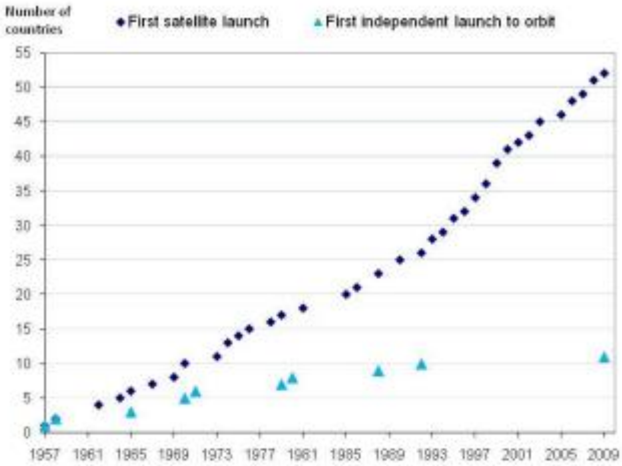

Figure 1: Graphic of the progress of the space area (OECD, 2011)

After the Cold War, it can be noticed that the space technologies raised in many countries, like China and India, and it was responsible for the improvement in the sectors of telecommunication and meteorology.

For inserting an object in the space, it is necessary to use a launcher vehicle. During the stage of launching, several loads are applied to the entire structures, as aerodynamic and inertial loads. Then, it is crucial to study the geometric and material parameters, in order to avoid catastrophic failure of the system.

The expenses for releasing a satellite in the space is proportional to the weight. Because of that, it is primordial to make an intense structural analysis by the engineering technical team of the company for the purpose of reduction the mass of the system. One of the solution is testing new materials for the frame of the satellite.

1.1 Context of the problem and objectives

The company Kosmotras® is responsible of releasing the Italian satellite UniSat7® (G.A.U.S.S. srl®) to the Low Earth Orbit (700km). For this, the launching company requires that the responsible of the development of the satellite accomplish the dynamic structural necessities.

This work is concerned to perform a modal analysis in the UniSat7® in order to meet the Komostras® requirements using 3 types of materials.

It is important to state that this analysis have the preliminary feature and it belongs to the stage of pre sizing and examination of alternative materials of the satellite

1.2 Approach of the problem

The company Kosmotras (2011) requires that the natural frequencies in the lateral direction are higher than 10 Hz and 20 Hz in the longitudinal direction. These providences have the objective to avoid the effect of resonance in the structure of the satellite.

2.METODOLOGY

2.1 Object of study

The satellite UniSat® is a satellite that will be insert in Low Earth Orbit. It has octagonal prism shape with 4 CubeSat deployers and 2 PocketSat deployers. The main function is to keep small satellite in its interior and release it in the space. First of all, the modal analysis will be executed using the Aluminium Alloy AA6061 T6.

Table 1: Mechanical properties of AA6061 T6 (Metal Handbook, 1990)

Properties	AA6061 T6
Density (Kg/m³)	2700
Yield strength (MPa)	276
Ultimate strength (MPa)	310
Young's Modulus (GPa)	68.9
Poisson ratio	0.33

The second material used in the frame of UniSat7® is the composite sandwich material with aluminium alloy AA5056 honeycomb core and aluminium alloy AA5051 T6 sheet.

Table 2: Mechanical properties of AA5056. (Metal Handbook, 1990)

Properties	AA5056
Density (Kg/m³)	2640
Yield strength (MPa)	405
Ultimate strength (MPa)	435
Young's Modulus (GPa)	70-80
Poisson ratio	0.33

The third material is composite sandwich with aluminium alloy AA5056 honeycomb core and carbon fiber with epoxy plate.

Table 3: Mechanical properties of carbon fiber (Torayca, 2016)

Properties	Carbon fiber
Density (Kg/m³)	1800
Yield strength (MPa)	490
Young's Modulus (GPa)	230

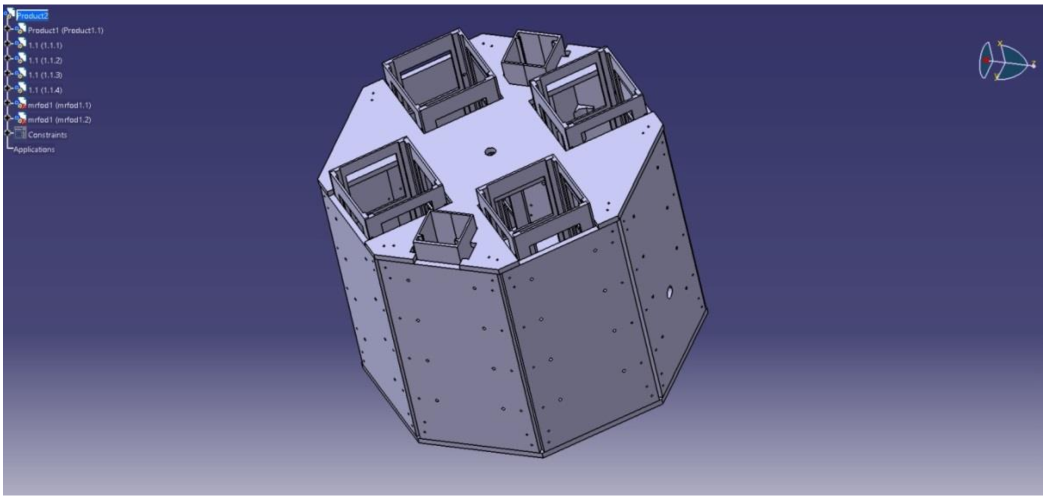

Figure 2: Tridimensional view of UniSat7®

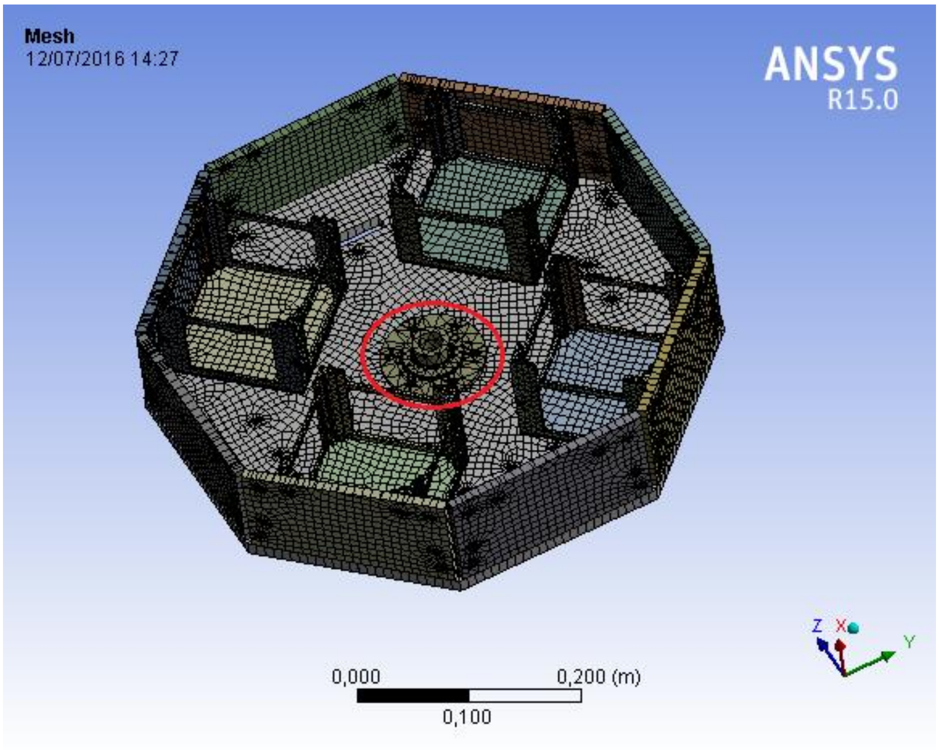

Figure 3: UniSat7® adapter highlighted

2.2 Procedure

Firstly, it was used the software CATIA® in Part Design for drawing all the geometry and Assembly Design for its assemblage.

Then, it was exported to the software ANSYS® with the aim to make the numerical simulation using Finite Element Method. It was used the ACP (Ansys Composite PrePost) extension to create the composite materials and determine their mechanical properties.

At the modal section of Ansys®, it was created the connection between the component of the satellite and the mesh was generated. It was assumed that the inner part of the adapter is completely fixed with the purpose of obtaining the natural frequencies and mode vibration.

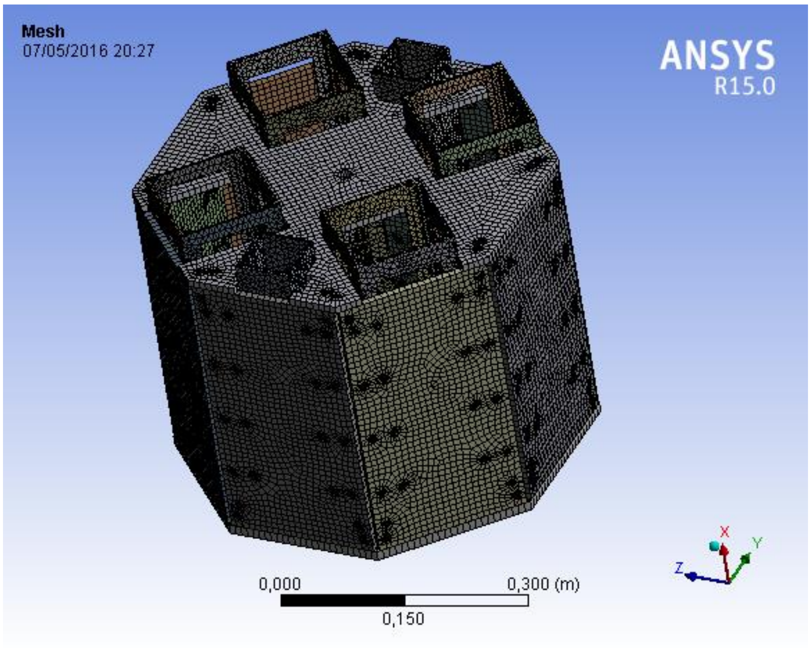

Figure 4: Mesh of UniSat7®

3. RESULTS

3.1 Aluminium Alloy

With the objective of obtaining the first 3 natural frequencies and shape mode using the aluminium alloy AA6061 T6, it was determined the material of the frame of the satellite and generate the results:

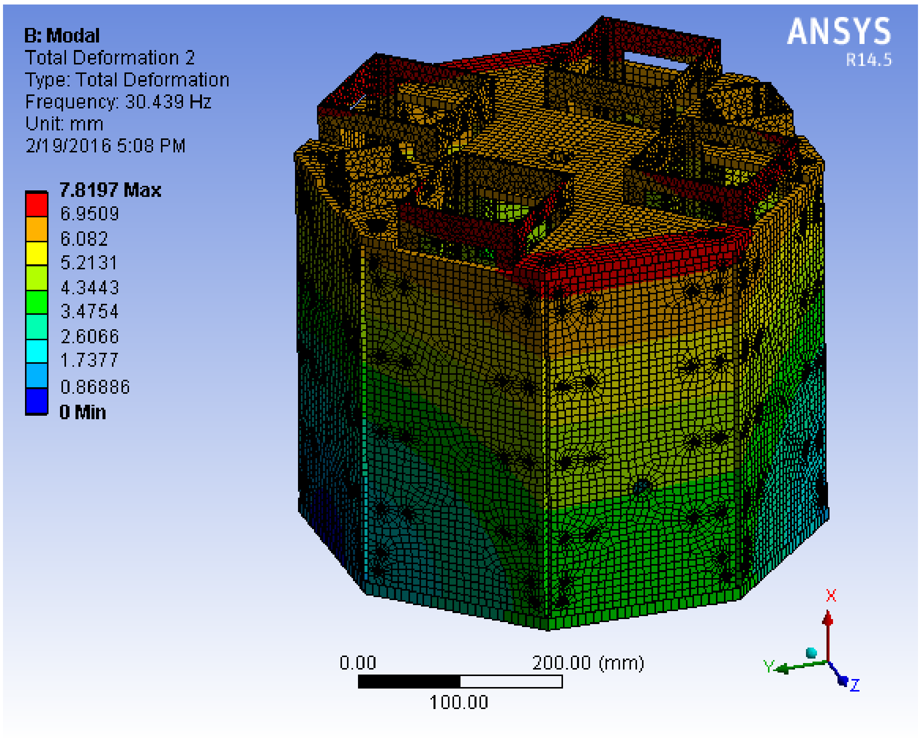

Figure 5: First lateral mode of vibration using the aluminium alloy material

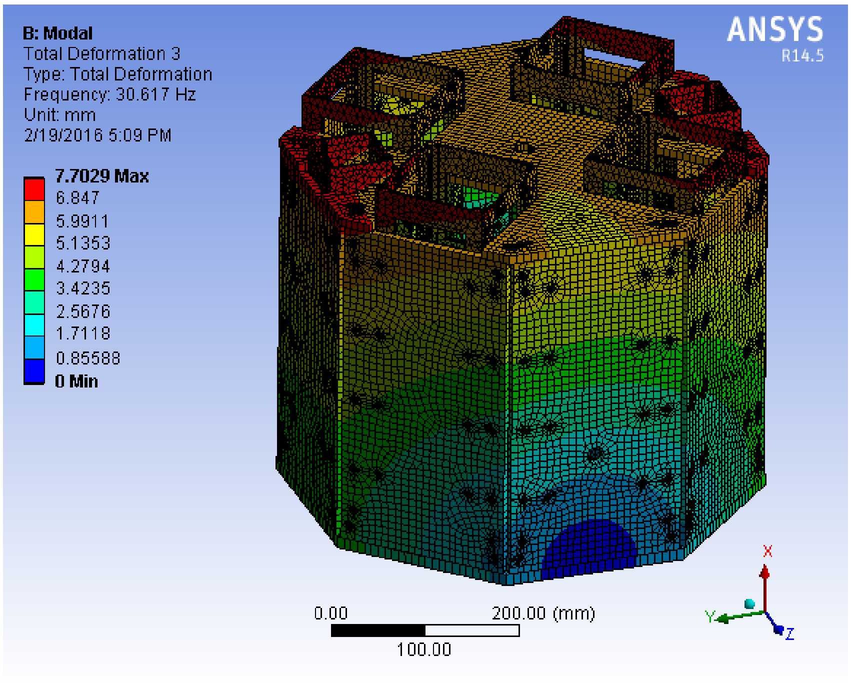

Figure 6: Second lateral mode of vibration using the aluminium alloy material

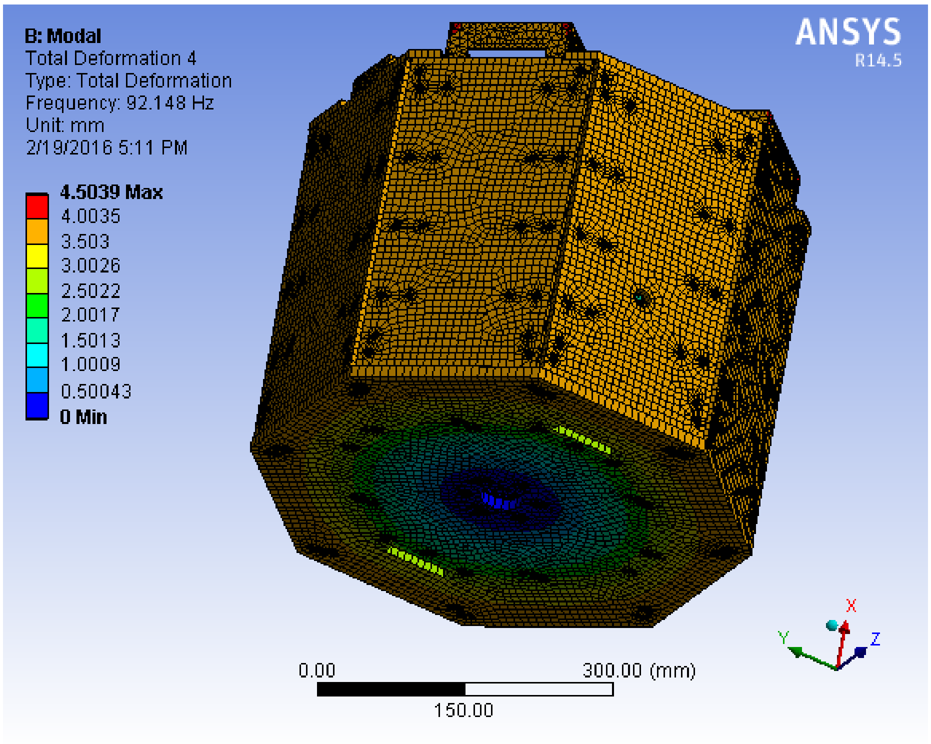

Figure 7: longitudinal mode of vibration using the aluminium alloy material

Table 4: Results of modal analysis using the aluminium alloy

	First lateral mode	Second lateral mode	longitudinal mode
Natural frequency (Hz)	30.4	30.6	92.1

Through the Figure (5) and (6), it can be noticed that they represent the lateral mode of vibration and they are geometrically orthogonal. Their natural frequencies are 30.4 Hz and 30.6 Hz. The longitudinal mode is represented in the figure above and its natural frequency is 92.1. All the natural frequencies are much higher than the required by the launching company.

3.2 Aluminium alloy composite material

Using the extension of Ansys ACP®, it was created the composite material with the core and plates made aluminium alloy. The results of the modal analysis are following:

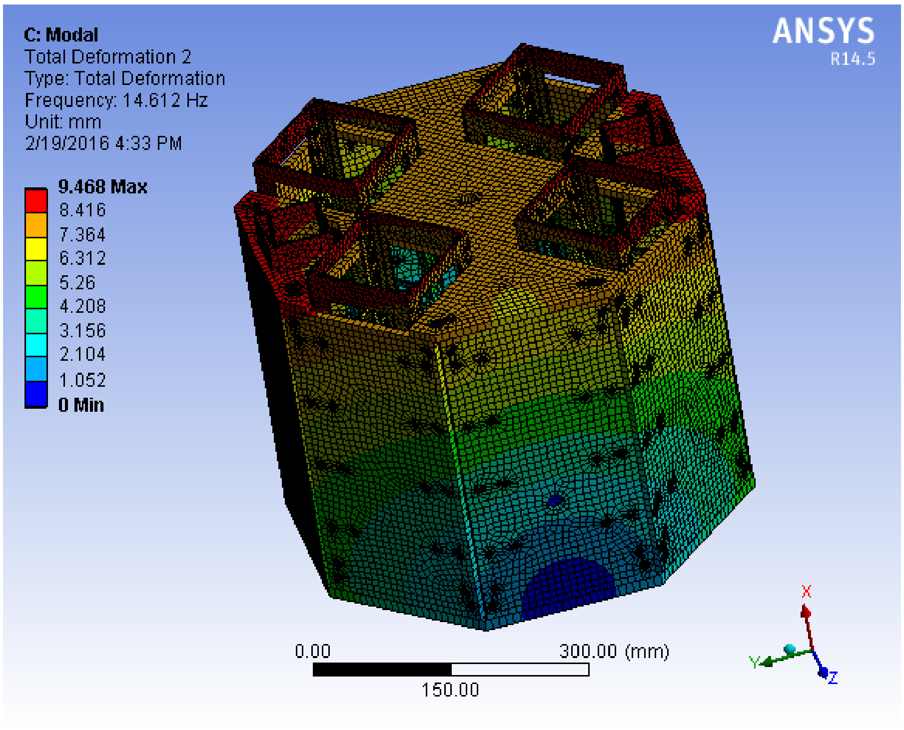

Figure 8: First lateral mode of vibration using the aluminium alloy composite material

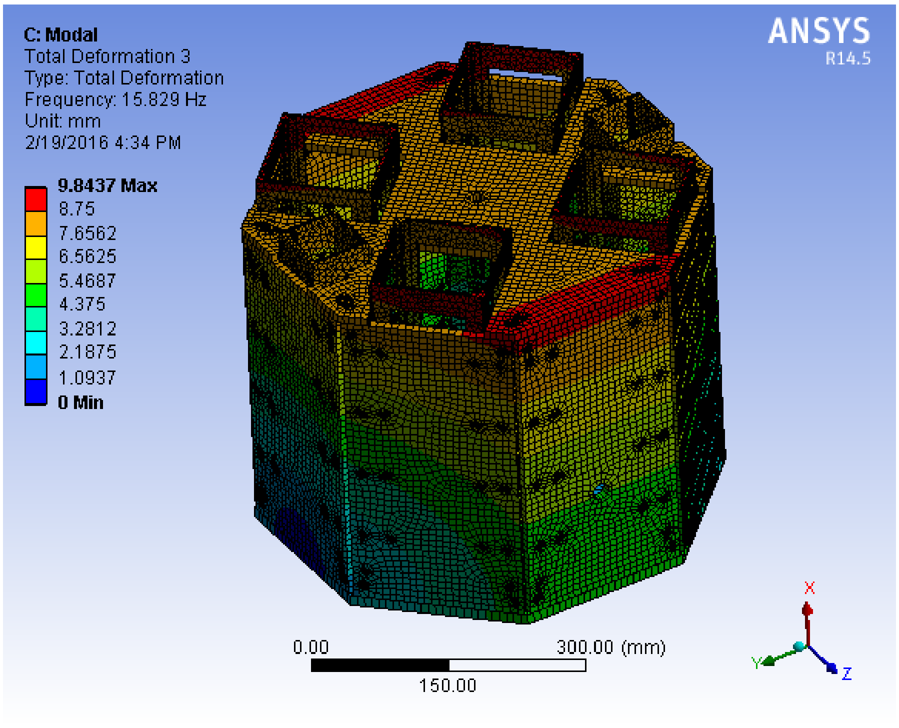

Figure 9: Second lateral mode of vibration using the aluminium alloy composite material

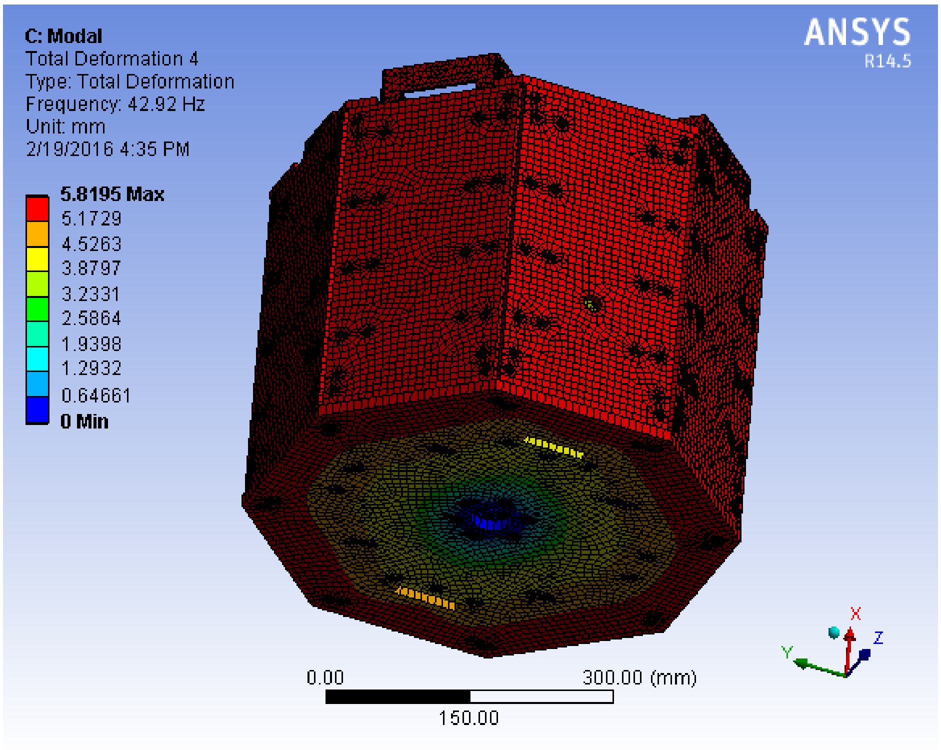

Figure 10: longitudinal mode of vibration using the aluminium alloy composite material

Table 5: Results of modal analysis using aluminium alloy composite material

	First lateral mode	Second lateral mode	longitudinal mode
Natural frequency (Hz)	14.6	15.8	42.9

According to the figures (8) and (9), the lateral modes of vibration are orthogonal and their natural frequencies are 14.6 Hz and 15.8 Hz. The longitudinal mode has the natural frequency around 43 Hz. Then, all the natural frequencies using this material satisfy the requirement imposed by Kosmotras®.

3.3 Aluminium alloy and carbon fiber composite material

Using the ACP extension of Ansys®, it was created the aluminium alloy and carbon fiber composite material applied in the frame of satellite. The results obtained in the modal analysis is then:

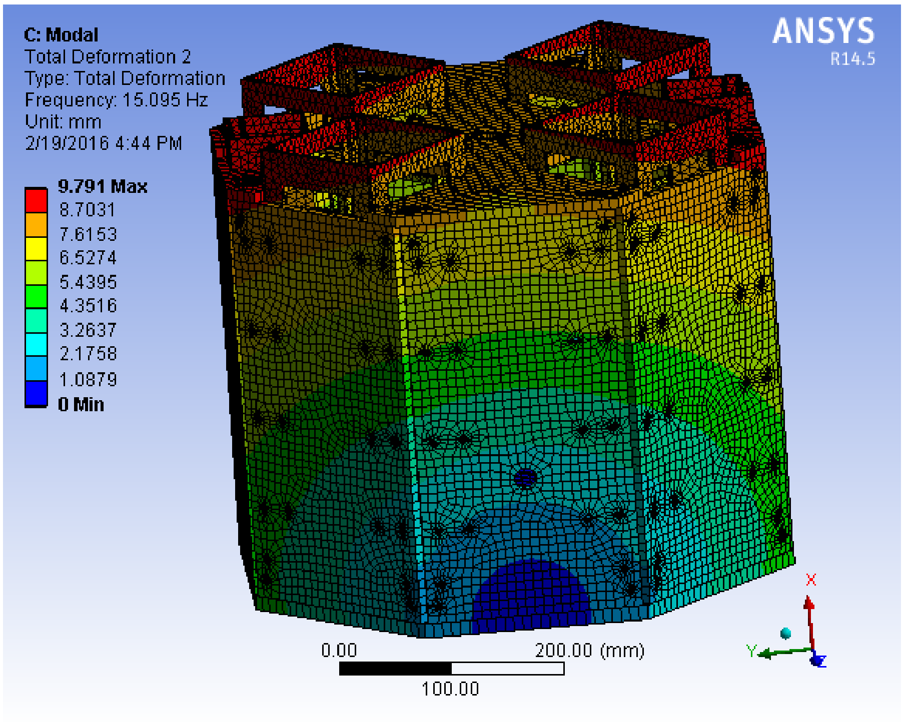

Figure 11:First lateral mode of vibration using the aluminium alloy and carbon fiber composite material

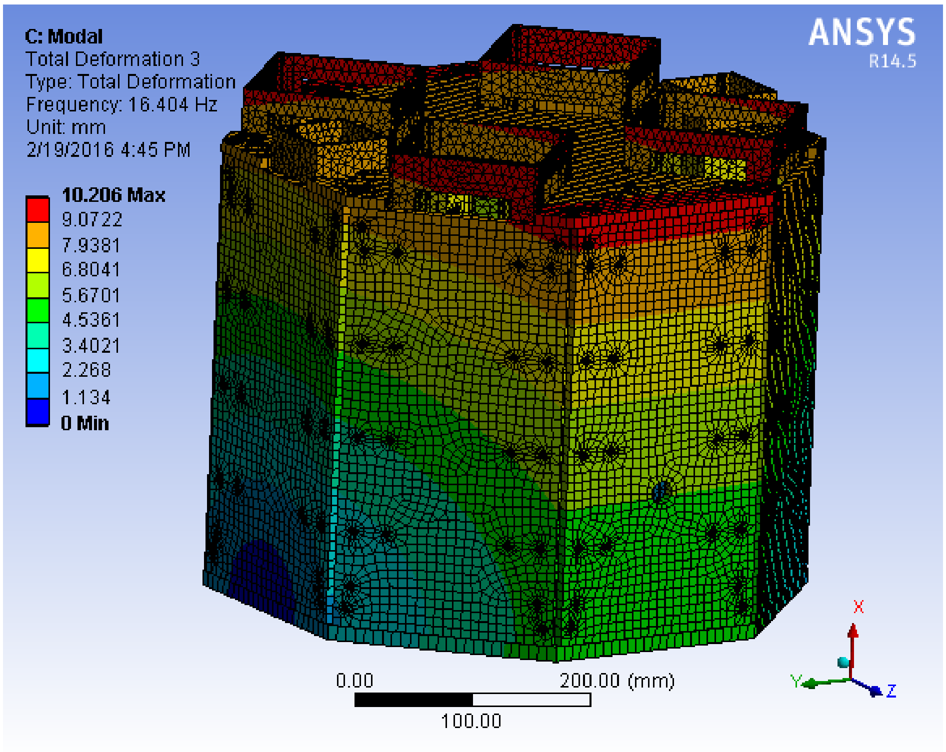

Figure 12: Second lateral mode of vibration using the aluminium alloy and carbon fiber composite material

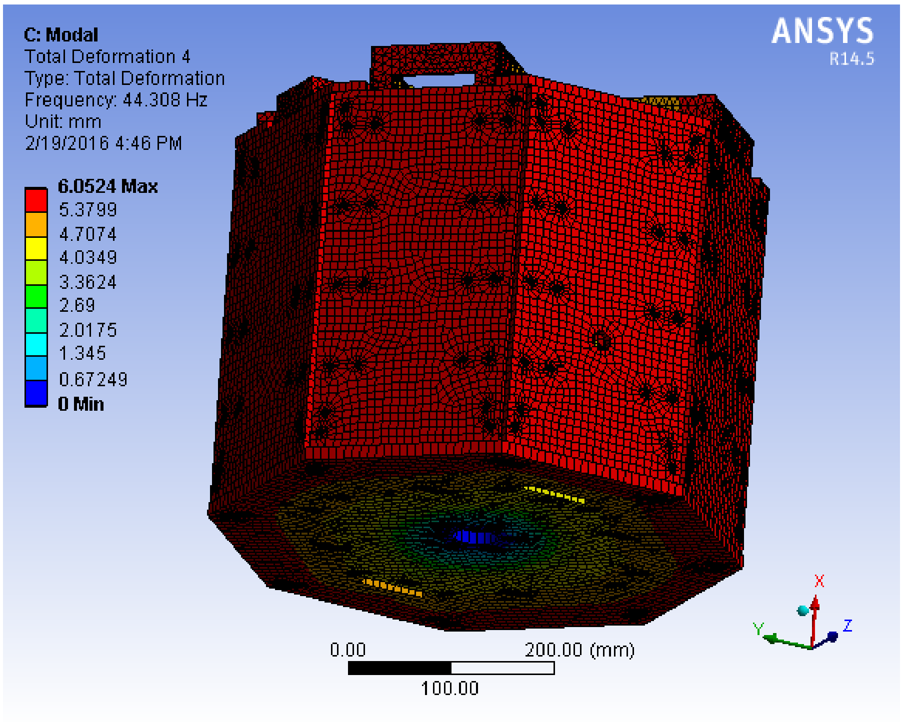

Figure 13: longitudinal mode of vibration using the aluminium alloy and carbon fiber composite material

Table 6: Results of modal analysis using aluminium alloy composite material

	First lateral mode	Second lateral mode	longitudinal mode
Natural frequency (Hz)	15.0	16.4	44.3

As reported above, it can be stated that the lateral frequencies are 15.0 Hz and 16.4 Hz and they are geometrically orthogonal. The longitudinal mode of vibration has the natural frequency of 44.3 Hz. All the strucutural specification of the launching company are satisfied using this material.

4. CONCLUSION

The results of the natural frequencies and mode shape of UniSat7® are obtained in the section 4. They state the accomplishment of the modal requirements of Kosmotras®.

When the aluminium alloy is used in the structure of UniSat7®, the natural frequencies are much higher than required, because the stiffness of this material higher when compared to the other two options However, its density is very high, causing an increasing of mass of the satellite, and consequently, the costs of launching.

As the composite materials, meanly the sandwich honeycomb, the obtained natural frequencies are close to the limit required by the company. Then, concerning the modal analysis, the composite material is not a suitable material in relation of non-composite material. However, the density of this type of material is lower, reducing significantly the expenses of launching.

It is important to notice that the presented results are a preliminary study, focused on material selection for the main structure. Further investigation is required in order to evaluate whether design changes are necessary to reduce the total structural mass of the satellite. Forced response calculations will also be performed I the next steps of the project.

5. ACKNOWLEDGEMENTS

This section should be positioned between the end of the text and the reference list. Type ***Acknowledgements*** in boldface italics, skip one line of space and type the text in regular type.

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