MASTA 2015 (Micro-Satellite Technology) Team Pilot Project Final Poster

TP Group Advisor: **Dr. Wang Xinsheng**

STRUCTURE SUBSYSTEM

Submitted by: **Fatih Avcı, Pedro Nogueira, Renan Oliveira**

CUBESAT DESIGN SPECIFICATIONS

The bulk of the specifications set for the structure of the CubeSat consist of dimension requirements in order to ensure compatibility of CubeSats with the P-POD. The critical dimensions for each basic CubeSat configuration are listed in the Table 1 and some schematic diagram of a 2U CubeSat is shown in Figure 2, Figure 3 and Figure 4. As shown in the diagram, The CubeSat consists of six 10 cm by 10 cm walls assembled into a cube and rectangular rails along the corners which make contact with the P-POD during integration. A coordinate system defined in the design specifications orients the Z-axis parallel to the four rails.

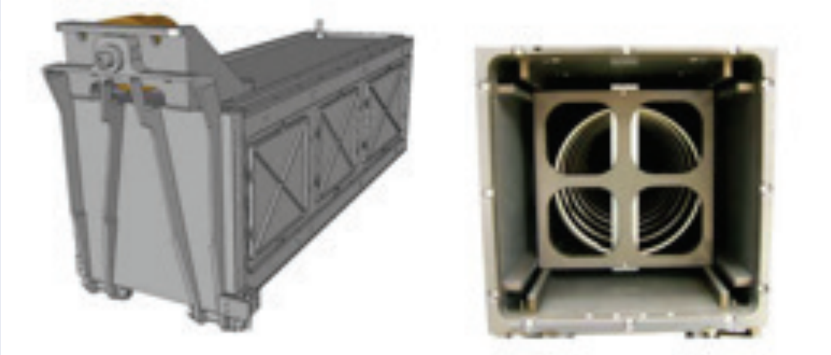


Figure 1: The P-POD System

CubeSat Size	1U	2U	3U
X and Y Dimensions [mm]	100 ± 0.1		
Z Dimension [mm]	113.5 ± 0.1	227 ± 0.2	340.5 ± 0.3
Rail Width [mm]	8.5 x 8.5 mm MIN		
Rail Contact w/ P-POD (75 % of Z Dimension) [mm]	85.1 (minimum)	170.2 (minimum)	255.4 (minimum)
Component Protrusion normal to cube surface [mm]	6.5 mm (maximum)		
Mass [g]	1330 (maximum)	2660 (maximum)	4000 (maximum)

Table 1: Critical Dimensions for 3 Primary CubeSat Sizes

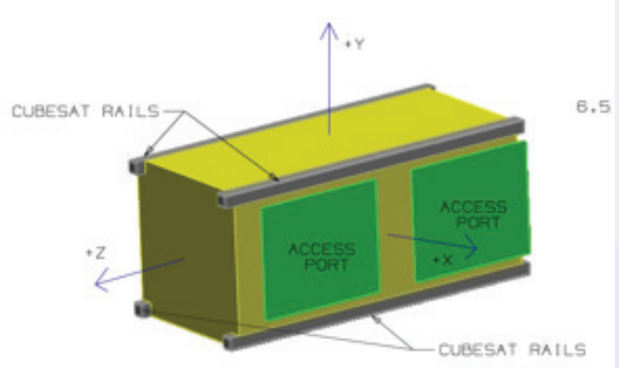


Figure 2: The General View of a 2U-Size CubeSat

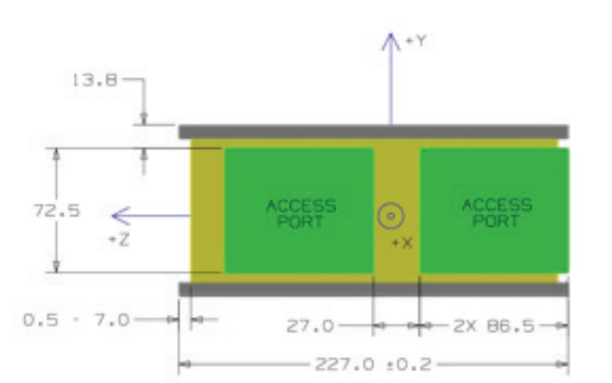


Figure 3: 2U Size CubeSat's Side View

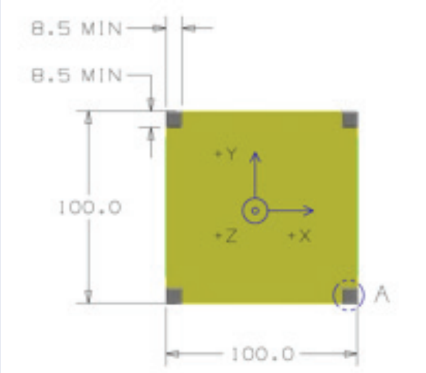


Figure 4: 2U-Size CubeSat's Top View

ISIS 2-U CUBESAT

FEATURES

- Highly modular design
- Detachable side panels for maximum accessibility
- Multiple PCB sizes supported
- Dual Kill-switch mechanism
- Scalable design to larger CubeSat form factors
- Compatible with most of CubeSat products

PROPERTY	VALUE	UNIT
Primary Structure Mass	200	gram
Primary + Secondary Structure Mass	390	gram
Outside Envelope *(l x w x h)*	100 x 100 x 227.0	mm
Inside 1U Avionics Envelope *(l x w x h)*	98.4 x 98.4 x 98.4	mm
Inside 1U Payload Envelope *(l x w x h)*	98.4 x 98.4 x 98.4	mm
Thermal Range (min - max)	-40 to +80	°C

Material Selection

The selection of material is one of the significant steps on design of satellite structure. Since weightiness is an important factor for on-orbit object. Specially, for a 2U and 2,7 kg CubeSat, small changes on the structure can result in valuable space for other subsystems and components. Not only weight factor, but also strength, stiffness, thermal conductivity, thermal expansion, manufacturability, and cost factor are considered during the satellite design. Material requirements, in line with the space environment, are given.

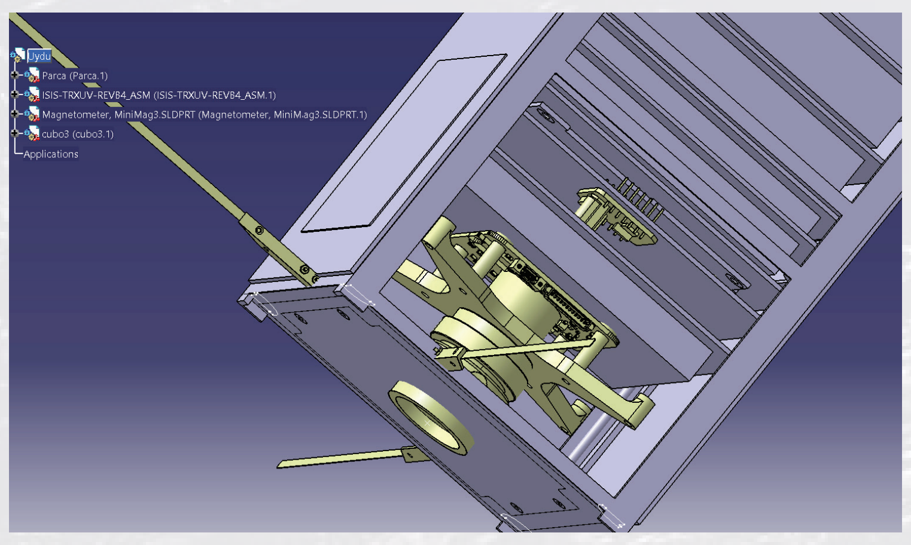
- All materials that will use in satellite should be selected from list that NASA determined.
- Thermal expansion coefficient of the selected material should be similar with the material of deployment mechanism.
- Yield strength of the selected material should be bigger than max Von Mises stress.
- The material should be easy manufacturability.
- To minimize the mass the material that has low density should be selected.
- The material that has low out-gassing property should be selected. CDS provides AL 6061 and AL 7075 as the mainstream two alternatives for CubeSat structure materials.

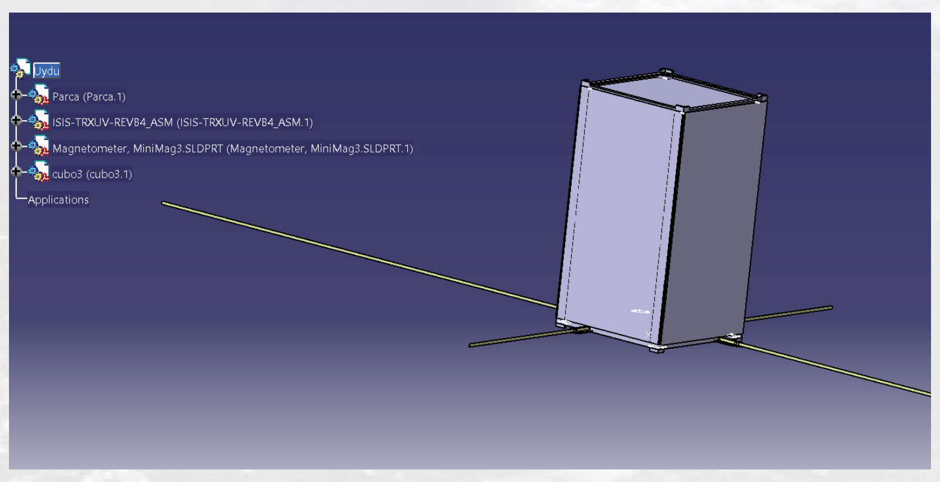
By considering weight, strength, coefficient of thermal expansion, manufacturability, and the cost criteria, AL-7075 is selected for the material selection of the QY-1 structure. Even though AL 6061 T6 is lighter than AL 7075, we selected AL 7075 because of the fact that it has easier manufacturability. This is in compliance since the major material of the launch PODs is usually AL-7073-T73.

Modelling

The aim of this work is to develop a highly modular **2U main structure** for CubeSat satellites. Towards this goal, we have designed an innovative modular CubeSat structure around structural columns. The envisioned structure provides the much-needed flexibility to the satellite designers during the design, development and test cycle. Specifically, the structure allows us to change the location of subsystems or perform design modifications to the subsystems without the need and the necessity to re-design the main structure.

This new modular structure is also in accordance with standards that are determined by Cal Poly State University for the CubeSat and thus carries one-to-one compatibility with launch pods. The sizing of the satellite in the main three dimensions, the design of rails in corners and solar panels, and protrusions for the six sides of the satellite are decided according to the "**CubeSat Design Specifications**" constraints. Also, by considering material criteria, the material selection of **AL-7075** is made for the structure of the CubeSat. **CATIA V5R21** is used for modeling of QY-1 structure and components as a CAD programming.





DRAG SAIL

A better sail concept and design for the CubeSat mission proposed is based on Aerodynamic End Of Life DeOrbit System (AEOLDOS) module (Harkness, et. al., 2014). The energy used to deploy the sail is the strain stored in tape-springs. Instead of an asymmetrical membrane deployment, in this system, the petal-hub allows the booms to deploy and settle radially about the hub (Figure 8), preventing excessive bendintg stresses near the connection point (Figure 9). The guide bearings at the corner are used to prevent spool expansion and guide the booms away from the device.

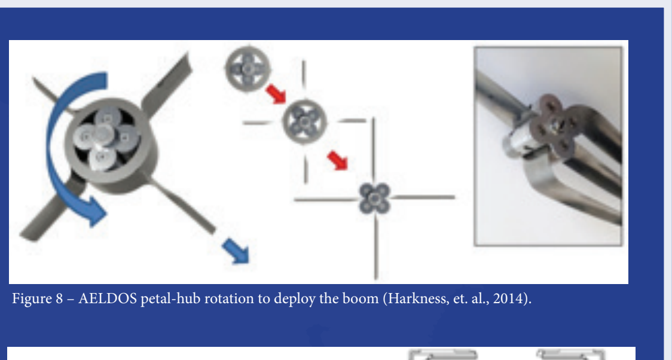


Figure 8 – AELDOS petal-hub rotation to deploy the boom (Harkness, et. al., 2014).

For the QY-1 mission, a sail of 0.1 m2 is enough to perform the mission objectives. This area estimation for the sail is based on STK simulation and analysis of mission lifetime and orbit decay. The initial orbit altitude is 400 km and, therefore, with an aerobrake sail of 0.1 m2 the decay time to 250 km is 36 days totalizing 561 orbits (Figure 11).

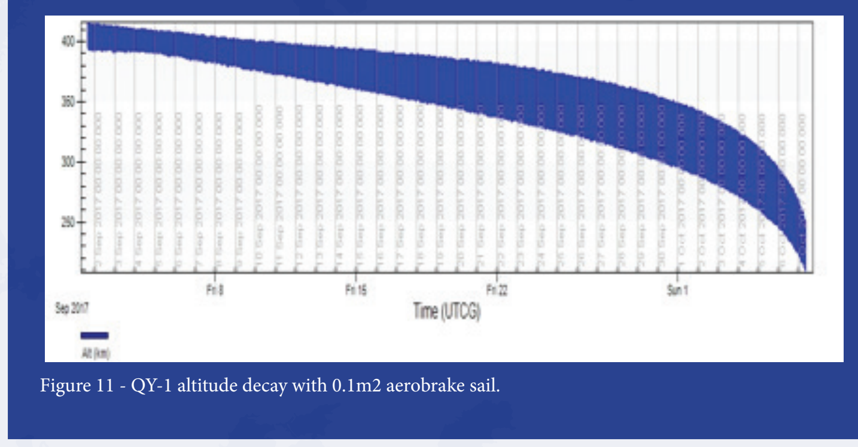


Figure 11 - QY-1 altitude decay with 0.1m2 aerobrake sail.

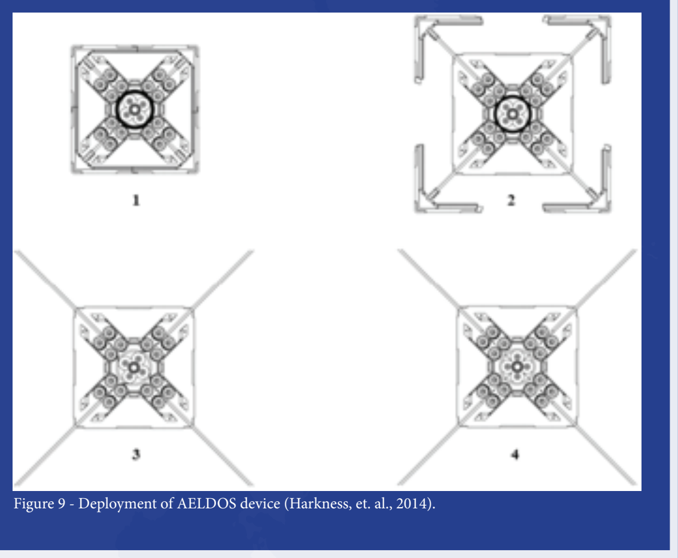


Figure 9 - Deployment of AELDOS device (Harkness, et. al., 2014).

Separation Mechanism

Spring Devices

In this device, the separation force is produced by the restorative force of the compressive spring. To improve the precision and reliability of the separation, usually, a set of tubes is produced on the spring exterior to form a spring-loaded separation pushrod. A commercial device of this tape for CubeSat application is commercialized by Elegant Systems Engineering (ELSE) company (Figure 14). This mechanism is composed of a stem, a bolt and a stainless steel spring.

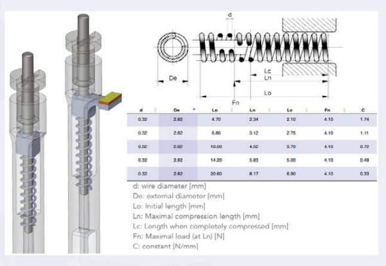


Figure 14 - ELSE separation mechanism

Another possible device configuration is a torsion-spring-driven hinge like the one developed by Pfeil Trawid Company (Figure 15). The torsion spring of this device has a diameter of 21.8 mm, a length of 32 mm and generates a maximum torque of 2.1 N m. The whole hinge weighs 68 g.

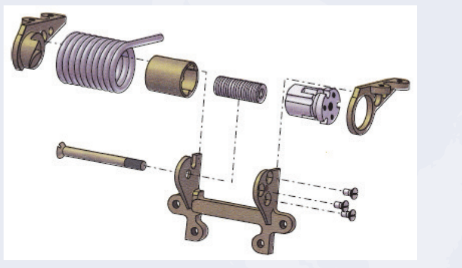
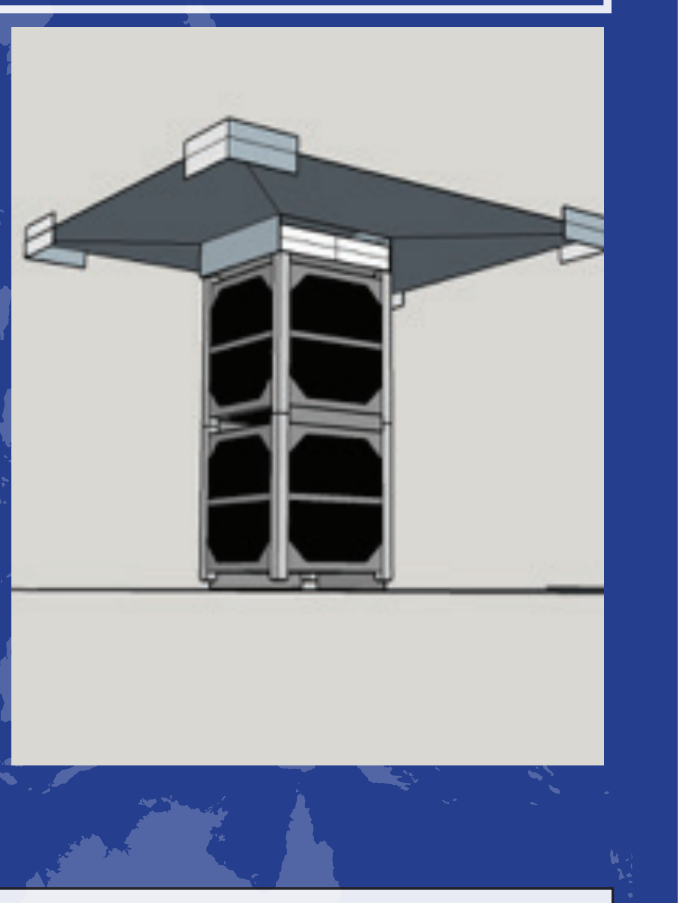
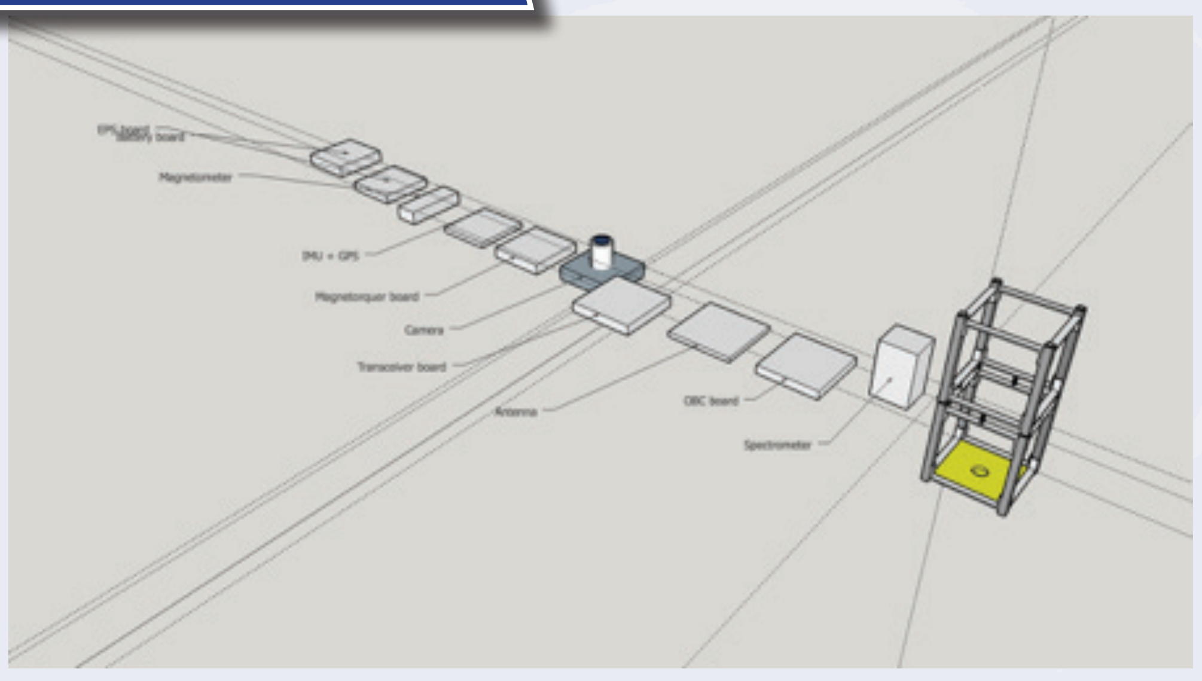


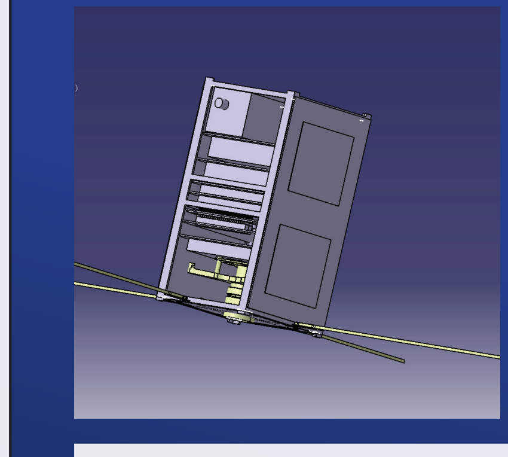
Figure 15 - Schematic of a torsion-spring-driven hinge

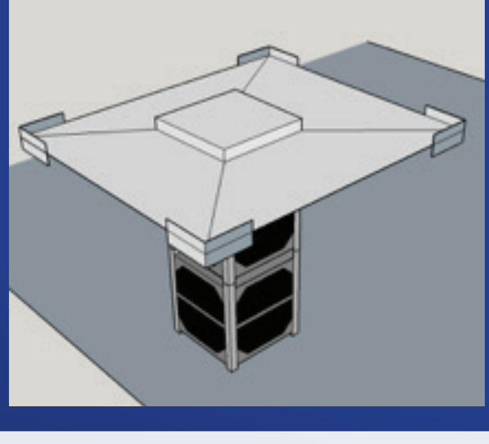


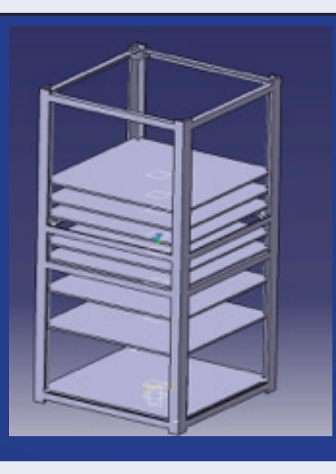
MASS BUDGET

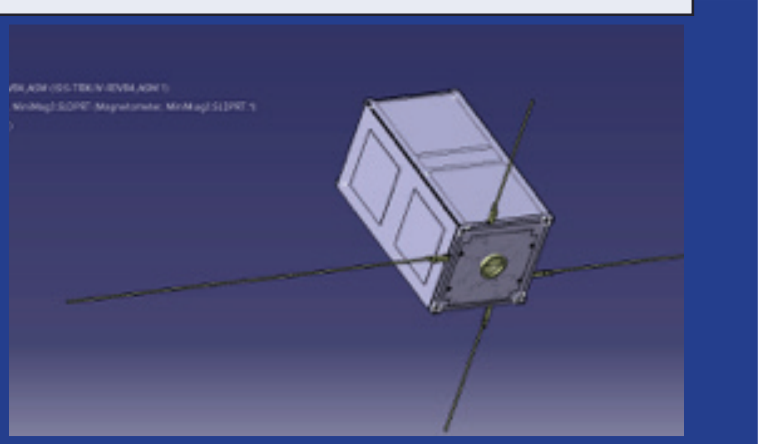
Component	Quantity	Mass (g)	Length (mm)	Width (mm)	Height (mm)	Total Mass (g)
Structural Subsystem						
2U CubeSat Structure	1	390,00	100	100	227	390
Electrical Power Subsystem						
Solar Panels 2U Side	4	69,00	82,5	196	2,4	276
Solar Panels 1U Side	1	42,00	82,5	98	2,4	42
Battery board	1	260,00	96	90	20,44	260
EPS board	1	88,00	95	90	15,24	88
OBC-ACS Subsystem						
Magnetometer	1	98,00	106,7	38,2	22,3	98
IMU + GPS	1	100,00	96	90	8,25	100
Magnetorquer board	1	196,00	96	90,1	17	196
OBC board	1	94,00	96	90	12,4	94
PAYLOAD Subsystem						
Spectrometer	1	215,00	45	50	80	215
Camera	1	166,00	96	90	58	166
TT&C Subsystem						
Transceiver board	1	85,00	96	90	15	85
Antenna	1	100,00	98	98	7	100
THERMAL Subsystem						
Passive thermal control	1	50	-	-	-	50
					Total (Kg)	2,16











Analysing

In order to analyze the strains on the main structure, various structural analyses of the satellite structure are performed.

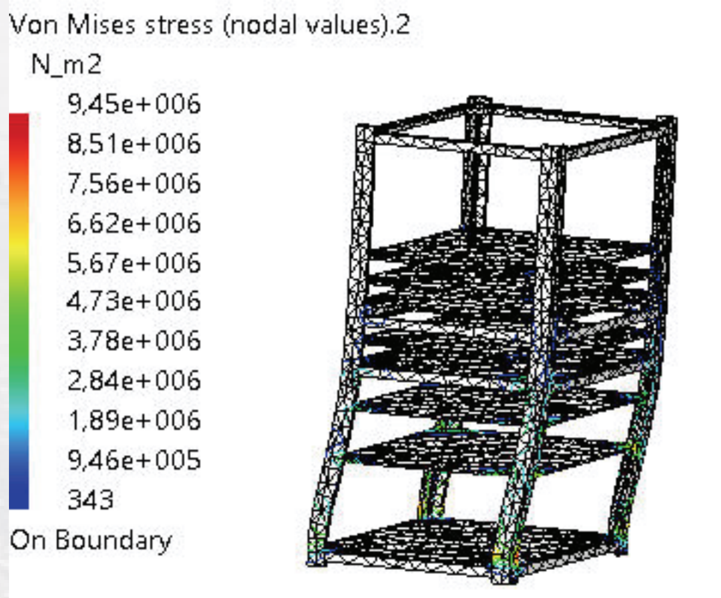
First, satellite main structure and representatives of the subsystems are built in 3D through the CAD program. Later **static and modal analyses** are completed using the loads that are projected to come from the **launch vehicle**.

During the conceptual design, we are expecting that the satellite will be launched with Launch Vehicle from China. By considering the **worst-case scenario** on Launch Vehicle (using static acceleration and vibration data from previous flights), **static loads** and **natural frequencies** and **boundary conditions** of the P-POD, total deformation across the structure and Von Mises stresses are evaluated.

In order to prevent a resonance, the natural frequencies calculated by the analysis must be above these constraint values. The first mode of the structure is **352,491 Hz**. All modes are shown in Table 6.

The maximum deformation is 0,043 mm

The maximum Von Mises stress is 9,45 MPa



MODAL AND STATIC ANALYSIS

Quasi-static launch loads are 11 g in the longitudinal direction and 6 g in the lateral direction for auxiliary satellites inside the LV rocket. Because the ultimate load factor is 1.25, the maximum quasi-static acceleration is 13.2 g. Therefore, we used 13.2 g for all three directions to apply worst case scenario. Boundary conditions, which are basically support of the satellite are determined according to the allocation inside the P-POD.

Structure Total deformation and the stresses on the satellite are shown in next slight respectively. The analysis indicates that the total deformation is 0.043 mm and it is very small in comparison to the satellite dimensions. In addition, the analysis indicates that Von Mises stress is observed as 9,45 MPa, and this value is within the specifications since AL-7075 yield strength is 300 MPa.