International Journal of Scientific Research in Engineering and Management (IJSREM)
Volume: 03 Issue: 06 | June -2019 ISSN: 2590-1892

# ONEUNIT CUBESAT/NANOSATELLITE STRUCTURE DESIGN AND ANALYSIS

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***ABSTRACT:*** TheStructure design and analysis of a 1U Nano Satellite, which will demonstrate an innovative advanced space structure in orbit. Development of the 1U CubeSat Structure having size of 10 x 10 x 10 cmworkspace is design for realization of innovation space deployment structure.The design objectives to satisfy the structural requirementsaccording to CubeSat standards- California Polytechnic State University. Thereby, itrelates the structural dynamics as a result of the loads and other forces. Also, it includes a verification process that assesses numerical simulations performed using ANSYS 16.0, such as static analysis on theCubeSat structure.

The project describes the CubeSat structure design from the bigger development objective and explains the system design of the CubeSat.

**Keywords: - CubeSat, nanosatellite, design,center of gravity, static analysis.**

## I. INTRODUCTION

The "CubeSat" compared to other small satellites, Nanosatellite mass less than 300 kg is generally considered. However,factors obey specific criteriasuch as itsshape, size, and weight that can be control.The standards for CubeSat help reduce costs of missions and standardized feature of CubeSat make it possible for industries to mass produce components. The standardized shape in addition to size also reduce costs connected with transporting them to, in addition to deploying them into space [1].

CubeSat available in different sizes and shapes. CubeSat is based on the standard CubeSat "**Unit**" referred as a 1U, 2U, 3U, and 6U. The 1U CubeSat is a 100 mm cube having a mass of1 to 1.33 kg. [2].1U Nanosatellite structure of 10x10 x 10 cm dimensionform with a Structure maximum weight is 400 grams.The scope of the projectin. a) high performance 1 unit satellite structure design b)innovative 1 unit satellite assemblymechanism of structures and c)a reliable 1 unit satellite design that can use for upcoming future missions.Theobjectives are: 1) to remove screw and rivets, 2) easy integration with CubeSat subsystem, 3) easy to manufacture and 4)maintain CG (center of gravity) of the structure.

## II. MODELLING

1 unit CubeSat structure design which is used for analyzein this paper,designsare made in solid works software. The parts of CubeSat structure are shown in figure 1.Figure 1 consist of the top part and bottom part, 4 lock roads,4 additional part, that connect the bottom part with the structure on the side face the size face width and heightare 100mm 100mm. The top and bottom face dimensions are 100mm X 100mm. also, having located deployment switch and separation spring slots in 4 additional volume on bottom part.
Thestructure is made using the Solid Works software (www.solidworks.com).

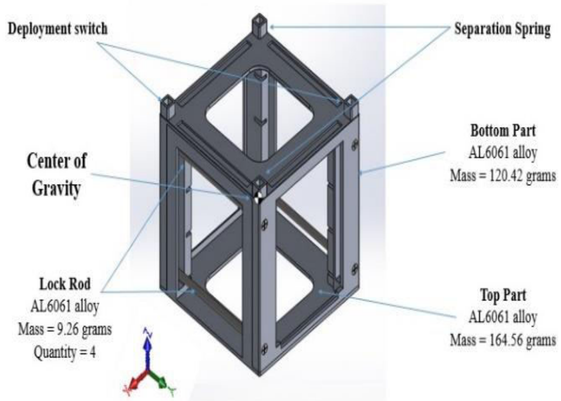


Figure 1. CubeSat Structure

## III. CUBESAT STANDARDIZATION

CubeSat design specifications are given:

1. Mostly the Dimension of 1 unit satellite CubeSat structure is a 10mm x 10mm x 10mm (millimeter) cube.
2. Structure rails having a minimum width of 8.5mm (millimeter) also having maximum 1.6 µm roughness value.
3. Edges of the structure rails should be curved from corner and having minimum 1 mmradius.

4. Mass of a 1U CubeSat structure shall be1/3 ofits satellite weight 1.33 kg (Standard satellite weight with payloads).
5. CG (center of gravity) CubeSat located center or within 1 to 2 cm from its structure geometric center.
6. The 1U, CubeSat shall use separation springs to ensure adequate separation.

All these specifications are considered from the public journal document [3].

## IV. MATERIAL SELECTION

The material selectionisimportant step in the design of 1 unit nanosatellite structure. In this paperespecially for a 1U and 1.33 kg, small or littlechanges in design made on the satellite structure can changes result for other components. Weight factor, strength, thermal conductivity, stiffness, thermal expansion, manufacturability, and cost factor are considered during the satellite design.

Material requirements are given[4]:

1) ISRO, NASA or any other space research organization determined materials are used in satellite structure.
2) Material having high yield strength.
3) Thestructure material can easy manufacturability.
4) Low density material should be selected for structure material to minimize the mass of the structure.

NASA and other research organizationsassign AL 6061(aluminum alloy) and AL 7075 the material for any CubeSat structure materials. Also, carbon fibercan also use for structure design.With considering strength, weight,the coefficient of thermal expansion, manufacturability and cost of material, AL-6061(aluminum alloy) is select for the material of the 1 unit Nano CubeSatstructure. AL 6061 is light in weightthen space grade material.AL 6061 select because it has easier manufacturability.

## V. MODELLING AND ANALYZING

The aim ofproject work is to make a new innovative modularis structure for1 unit CubeSat satellites. Design the innovative model of 1 unit CubeSat structure around structural rack and columns, which support rack like operation similar to the standard nanosatellite. The first objective is to remove screw and rivets design the lock rod system for assembly of structure apart of screw and rivets. The lock rod fixes the whole structure assembly of the top and bottom part. The beams are modeled in top and bottom partwith a corner radius of 1 mm as per standard specifications. The new 1 unit structure is also with standards are consider fromjournal by California Polytechnic State University for the new CubeSat [4].

The 1 unit satellite design of rails in thetop and bottom part corners and solar panels according to the California Polytechnic State Universitylimitations. Also, consideringthe criteria of material, the material select of AL-6061 is use for the structure of Nano CubeSat [5].

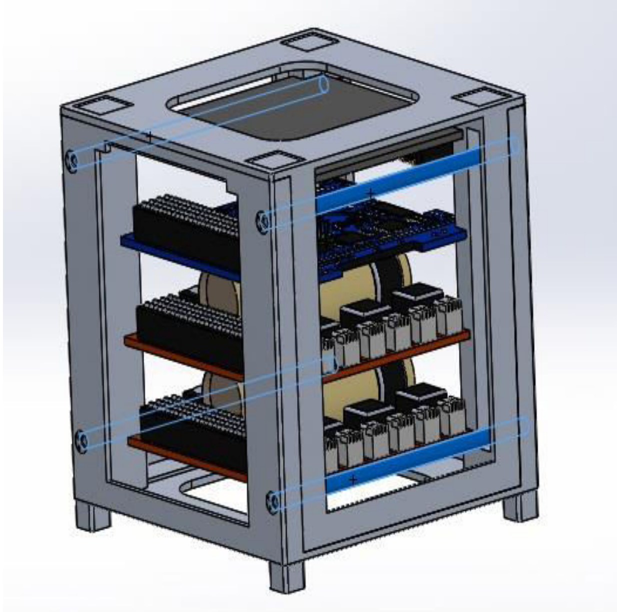

Figure2. Structure and CAD program components

Table 1. Aregiven the details of weight (mass) and main characteristics of components:

Table 1. Mass and characteristics of components

| COMPONENT | MASS (grams) | CHARACTERISTICS |
|---|---|---|
| Lock Rod | 3.34 x 4=13.36 | 1) Use for remove screw and rivets in assembly process.<br>2) Also use tie for solar panels perpendicular to side face of structure |
| Top Part | 164.56 | 1) To carry maximum loads.<br>2) Having slot for fix the inner components in satellite |
| Bottom Part | 120.42 | Having replica design method use to assemble the top part [12]. |

Those are characteristics are better and innovative design with compare to normal standard 1 Unit satellite structure.

SOLID WORKS is used for modeling of 1 unit cube satellite structure as well as components as shown in figure 2CAD programming. In structural requirements for design are provide in the “CubeSat Design Specifications”.

The requirements are highlighted for our design:

- The weight of 1 unit Nanosatellite structure is less than 400grams, its 298.679 grams.
- 4 lock rod having material of aluminum alloy use for connecting subsystems, payloads, solar panels andthe main structure.
- Change in a mission thesatellite structure is flexible tofulfill the new mission requirements.
- CubeSat having internal volume is maximum, and external volume modularis to add deployable for solar panel when required. The volume of the satellite structure is 110621.727460 cubic millimeters.

The designed structure is made of a frame structure in which the cornersof top and bottom part columns are design to carry maximum loads. The second objective of the structure is easy integration with CubeSat subsystem, for that, the design of structural columns is design as a rack system, subsystems are slides and fix into the slotted rack on the top part of the structure is shown in figure 3.Dummy programed payloads are only design for the concept of integration seen in figure 3 [9]. The main advantage of all parts it is easily manufacture on any vertical milling machine.

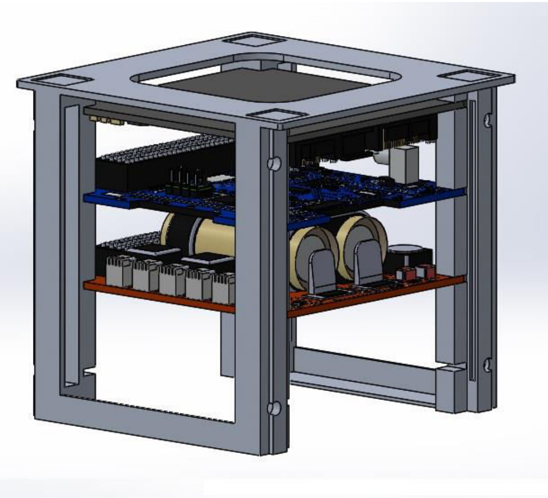

Figure 3. Slotted rack and dummy payloads

In order to analyze the stresses on the 1 unit Nanosatellite structure, analyses of the satellite structure are perform in ANSYS 16.0. Satellite main structure and the subsystems are design in 3D software. The design is symmetrical in all direction horizontal as well as vertical the center of gravity is in the center as according to Journal CubeSat standards-California Polytechnic State University [3].

Assuming the satellite launch with PSLV (Polar satellite launch vehicle)from anywhere from earth. By taking static loads, total deformation covering the structure and stresses are assessing. "ANSYS WORKBENCH 16.0" (https://www.ansys.com/) is used for analyzing CubeSat structure [8].Static launch loads areconsidered as 9.81 G x 1.33 kg(1 unit Nanosatellite standard weight)at maximum temperature +150 degree Celsius is 13.4 N consider approximate maximum lode that 15N inall direction of axis for Nanosatellites. The mash generates in Triangle Surface Masher systemwith number of nodes is 42943 and elements are 21935in ANSYS Workbench Software(https://www.ansys.com/en-in/products/platform/ansys-meshing)[9].

Boundary conditions, which currently are basically fixed support on a face of 4 extra volume rails on the bottom part of the1 unit CubeSat structure, are resolved according to the allotment inside the P-POD as shown in figure 4.In Figure 4 extra volume of attached with the bottom part of the structure are fixed in deployer. The spring plunger is fitted in that fixed volume [10].

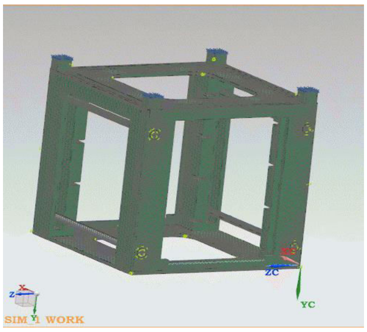

Figure 4. Fix Support in software analysis

## VI. RESULT ANALYSIS

The total deformation analysis indicates that is 0.090517 mm(minimum) occurs on the bottom partand 0.37204 mm (maximum) occurs on the top part of the satellite and it is vastly small in analogizing to satellite structure dimensions.Total deformation on satellite are shown in Figure 5(a). Themaximum equivalent (von-mises) static stress is getting as0.0023443MPa(minimum) occurs on lock rod 103.15 MPa(maximum) occurs on the top part are shown in Figure 5(b), and this value is within the specifications Aluminum alloy yield strength iscurrently exists300 MPa.

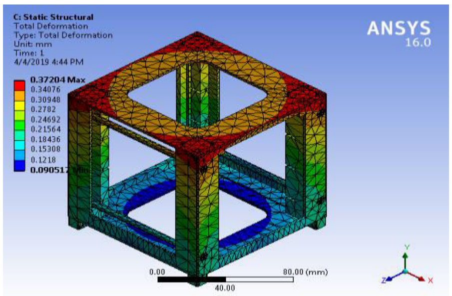


Figure 5(a). Total deformation

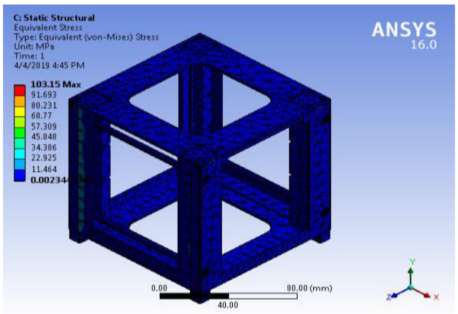


Figure 5(b) (von-mises) stress

In mode analysis natural frequencies of the Nanosatellite CubeSat structure is in between a range of 0 to 3800 Hz. has been analyzed in following. The first mode of the structure is 600.92 Hz and the last mode of the structure is 3780.1 Hz. All modes are shown in Table 1.

Table 1. Natural frequency of 1 unit satellite structure

| MODE | NATURAL FREQUENCY [Hz] | MODE | NATURAL FREQUENCY [Hz] |
|---|---|---|---|
| 1 | 600.92 | 11 | 2551.8 |
| 2 | 611.31 | 12 | 2554.7 |
| 3 | 978.42 | 13 | 2556.5 |
| 4 | 2340.8 | 14 | 2590.0 |
| 5 | 2350.2 | 15 | 2947.6 |
| 6 | 2519.1 | 16 | 3102.2 |
| 7 | 2533.8 | 17 | 3178.5 |
| 8 | 2544.6 | 18 | 3427.1 |
| 9 | 2546.1 | 19 | 3662.3 |
| 10 | 2547.8 | 20 | 3780.1 |

## VII. CONCLUSION

In this project paperwork, present the innovativedesign and stress analysis of a design model 1U CubeSat structure. Also, it's overcome the main aim of project 1) to remove screw and rivets, 2) easy integration with CubeSat subsystem, 3) easy to manufacture and 4) maintain CG (center of gravity) of the structure in new innovative design of Nanosatellite structure.Using FEA (Finite Element Analysis) is 0.37204 mm (maximum) deformation,it isvery little in comparison to satellite design, and Von-Mises static is 103.15 MPa (maximum). The satellite design structure provide the flexibility to any spacemissions.

## VIII. FUTURE SCOPE

The standard Specifications of 1U Nanosatellite is visualizing to be used for future missions. The satellite designed structure provides the flexibility to support placements on the vertical and horizontal planes.1 Unit cube satellites might never fully replace bigger satellites, but they will offer new service of increase the capability of them when used in coordination. It also allow for a very responsive access to space. Nanosatellite are the future in both, commercial and science missions.

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