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Florida Space Grant Consortium FUNSAT Design Competition
25% Report

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This B.S. thesis is written in partial fulfillment of the requirements in EML 4905. The contents represent the opinion of the authors and not the Department of Mechanical and Materials Engineering.

Ethics Statement and Signatures

The work submitted in this B.S. thesis is solely prepared by a team consisting of Gonzalo Vivanco, Giampiero Revelo, Luis Fernandez, and Henry Vazquez and it is original. Excerpts from others' work have been clearly identified, their work acknowledged within the text and listed in the list of references. All of the engineering drawings, computer programs, formulations, design work, prototype development and testing reported in this document are also original and prepared by the same team of students.

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Abstract

The Florida Space Grant Consortium FUNSAT Design competition gives university students in the state of Florida the opportunity to design and eventually build a working satellite. Throughout the competition the students will be faced with many factors that go into designing a satellite while also teaching them about concepts that they may have had no knowledge about. On May 8, 2014 the team's findings will then be presented to a panel of judges which will verify the designs feasibility for working and later distribute funding to those teams who have provided accurate findings for the final build. These teams will then have the opportunity to have their built satellite launched into low earth orbit.

Throughout the design and building of this satellite the team will explore the method of using solar sails as a means of propulsion which will allow the satellite to change its orbit without the need of propellant. This will equate to giving the satellite the ability to have a free range of motion when required and lengthen its service life. The satellite will incorporate common satellite communications components while also housing imaging devices so as to monitor the Earth. Testing will then be performed to ensure the integrity of the system and all of its components through the means of vibrations testing, thermal testing, and deployment testing.

1 Introduction

1.1 Problem Statement

The Florida Space Grant Consortium hosts every year the Florida University Satellite (FUNSAT) Design Competition where students from universities all across Florida are given the opportunity to design a satellite. The design restrictions that are placed on all competing teams are that the satellite must meet all requirements as stated in the CubeSat Design Specification document [2]. These restrictions however do not limit the possibilities of what our payload will consist of therefore each satellite will have similar designs but will each have unique functions when compared to others. The competition will consist of a conceptual design phase followed by a detailed design phase [1]. After completing both phases the design must be presented on May 8, 2014 in order to obtain funding for the construction of the satellite as well as determining whether or not the satellite will be launched into low earth orbit [1].

1.2 Motivation

The motivating factor behind this project is the chance to apply all knowledge that has been obtained through several semesters of studying engineering principals. This encompasses the opportunity to work on a project that allows free reign as to the possibilities of what a satellite can do as well as being one of the top teams chosen to have their satellite built and then launched into space. More importantly, it gives us the chance to represent Florida International University in the competition while inspiring future undergraduate students to take part in such project oriented competitions which could eventually lead to the creation of a new field at Florida International University.

1.3 Literature Survey

The first mathematical conception of an artificial satellite was thought of by Sir Isaac Newton through a thought experiment referred to as Newton’s Cannonball [4] in which he hypothesized that the force of gravity was universal and explains that the velocity of an object must be equal to the orbital velocity in order to maintain a constant orbit any faster or slower will cause its orbit to change [3]. In 1903 Konstantin Tsiolkovsky introduced insights into space travel and rocket science [5] which would later on have a role in modern rocketry and space flight. Then in 1945 an English science fiction writer by the name of Arthur C. Clarke would then introduce in detail the concept of mass communication through the use of communications satellites [4]. We can see that space travel has been an idea that humans have thought of whether it was theoretical or fictional but all of these ideas would later lead to the first successful creation and launch of a satellite. This artificial satellite was named Sputnik 1 which was launched by the Soviet Union in October 4, 1975 [6].

Figure 1: Sputnik I [7]

At the onset of this achievement by a rival nation the United States would later successfully launch a satellite of their own named the Explorer I which carried a small payload which allowed the discovery of the magnetic radiation belts around the Earth [6].

Figure 2: Explorer I [8]

This would eventually lead to the creation of National Aeronautics and Space Administration (NASA) in October 1, 1958 and the creation of and the start of the race to space [6]. The creation of a satellite was mostly limited to governments with the ability to fund such large projects but it was in the year 1999 that professors Jordi Puig-Suari of California Polytechnic State University and Bob Twiggs of Stanford University came up with the reference design for a cube satellite known today as a CubeSat [13]. The introduction of the CubeSat would later become adopted over time by different universities, governments, and countries as an affordable alternative to launching satellites into space as compared to launching larger satellites which may require complex launching mechanisms [14]. Through these achievements it is now a common thing to hear about satellites being used for many applications that have a purpose in our daily lives such as communications, weather monitoring, and even reconnaissance. But what should be noted is that satellites will continue to be needed and the technology behind them will only further advance simply because of an idea or concept one person has in mind.

2 Project Formulation

The FUNSAT competition is a way to not only build a working satellite but is also a means to demonstrate different iterations of what a satellite can do. In this case this project will emphasize on the use of a solar sail for propulsion. Satellites tend to have a certain life expectancy in which they function until they eventually reach that end-life and become nothing more than another piece of debris floating around earth's orbit. With the use of the solar sail not only will the satellite be able to change orbits at a controlled rate but it can do it without having to worry about the addition of weight caused by a form of propulsion system along with its required propellant. With this concept it is desired that the project will gain recognition at the FUNSAT competition in order to have it implemented on a satellite which will then be launched into low earth orbit.

3 Conceptual design

3.1 Overview

For this competition it should be noted that the basic layout of the satellite will be relatively the same for all competitors the only difference being that the size will vary. The satellites, called CubeSat, are categorized as 1U, 2U, and 3U where 1U is a satellite whose dimension must be 10 cm X 10 cm X 10 cm and a weigh of no more than 1.3 kg [9]. The other corresponding U's are simply the number of 1U stacked on top of each other. Figure 3 will give a better representation as to the basic design of a CubeSat.

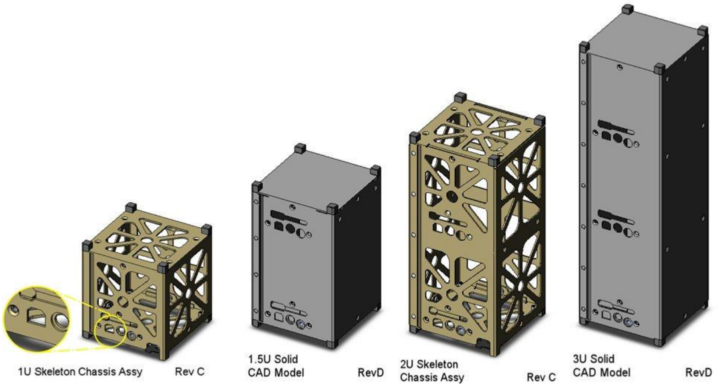


Figure 3: 1U, 1.5U, 2U, & 3U respectively [10]

3.2 Proposed Design

The initial design will consist of a 3U satellite with the dimensions as stated previously and will house the necessary payload while trying to maintain a weight of less than 4 kg. For this to be achieved, the weight of all the components inside of the specified volume as well as the support structure needs to be taken into account. The design will implement the use of a solar sail which will be housed within the satellite and will serve as a form of propulsion once deployed. The deployment system will consist of a set of 4 equal length supports which will be flexible enough that they can be rolled around a central hub. When this hub rotates it will allow the supports to extend fully from the center of the 3U satellite and form a rigid support structure which will allow the sections of the sail to extend.

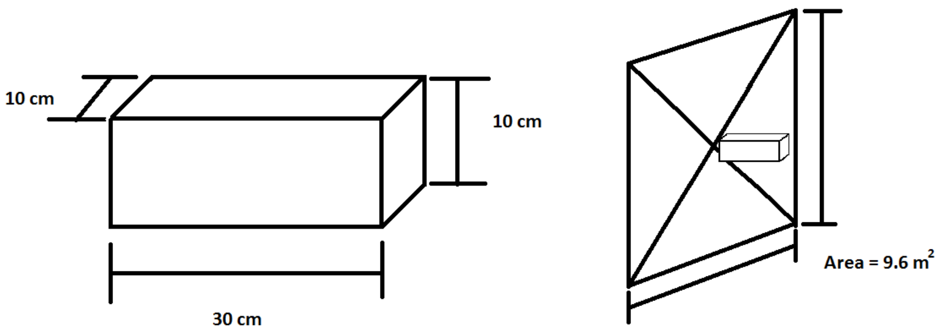


Figure 4: Un-deployed and Deployed orientation (Not to scale)

The sail will consist of 4 equal triangular section that when extended will form a symmetrical square shape. It should be noted that in order to avoid any form of tearing or cuts in the solar sail material a specific type of fold will need to be implemented so as to avoid damage. For this design it has been determined that a frog leg fold will be implemented. It consists of folding a triangular section from the peak to the base on its self in alternating from back to front then taking both ends of the fold section and performing the same fold as shown in figure 3. This fold allows for movement in one direction and provides three anchor points to hold the sail in place. Two of these anchor points, located at each end of the base of the triangular section, will be attached to the ends of the extendable supports while the tip of the triangle will be the third anchor. When these supports start to extend, the anchor at the tip of the triangle will provide the necessary tension to allow the supports to start stretching the sail material causing it to unfold. Once the supports are fully extended there will be enough tension in the sail material to fully expand the triangular shape and form one section of the square sail. All four triangular sections will expand simultaneously but a specific speed of extension will need to be determined in order to avoid any unnecessary damage to the sail material.

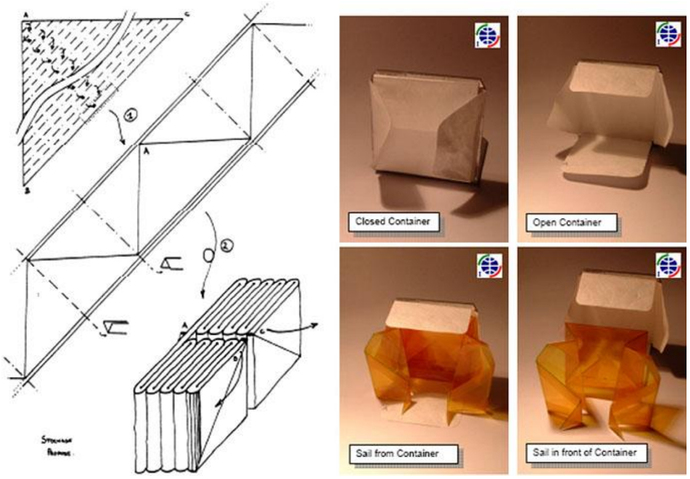


Figure 5: Frog leg folding method [11]

A square shape was chosen as it maximized the most surface area as well as aid in the simplicity of the design based on the required constraints when compared to the other orientations shown in the figure below.

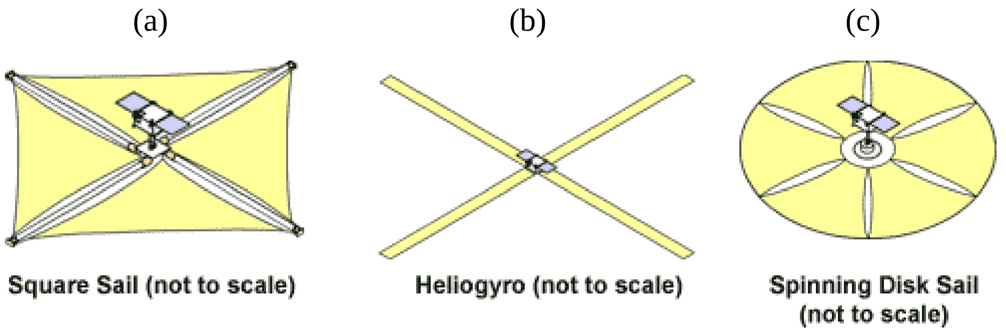


Figure 6: Sail Design Types [12]

In order for the sail to take advantage of the solar radiation it must be light and have some reflective properties which will allow the solar radiation to reflect off of the sail surface. Materials which are most commonly used are Aluminized PET film (Mylar), LaRC-CP1 Polyimide, and Polyimide resin (Kapton); all of which have been used in previous projects from different institutions. For the initial design it has been decided that polyimide resin also known as Kapton will be used for it has properties that make it favorable for use as well as remaining cost effective. Such properties include its high tensile strength while still having a low density as compared to other materials with higher equal or higher tensile strengths, as well as its thermal conductivity.

The satellite will also require the use of several components in order for it to function such as a power subsystem, a communications subsystem, and an attitude control subsystem. Each subsystem will each require different components to operate all of which will be housed in 1U of the 3U available space. The power subsystem of course will have one of its components on the outside of the frame which is the solar panels.

This is necessary as they need to be exposed to the sun in order to provide not only power to the satellite but as well as charge the onboard batteries.

4 Project Management

The following table is an estimated plan in regards to the process of the project. This plan is preliminary at the moment and may change with time depending on any difficulties that may arise or if the project is ahead of schedule.

Table 1: Suggested Timeline for Project

	Jan-14	Feb-14	Mar-14	Apr-14	May-14	Jun-14	Jul-14	Aug-14	Sep-14	Oct-14	Nov-14	Dec-14
Project Discussion	🟩											
Research		🟩	🟩									
Initial Design			🟩	🟩								
3D Modeling & Simulations			🟩	🟩	🟩	🟩						
Final Design				🟩	🟩	🟩						
Obtain Materials						🟩	🟩					
Manufacture Prototype							🟩	🟩	🟩			
Prototype Testing									🟩	🟩	🟩	

5 Analytical Analysis

The solar sail takes advantage of the solar radiation pressure which can calculated based on the amount of power of electromagnetic radiation per unit area is incident on a surface. This means that depending on the angle that the solar radiation is initially moving towards the solar sail, the sail will experience a certain amount of radiation pressure. [2] The force that the solar sail will experience due to the solar radiation pressure can be calculated as,

$$F = F_o \cos^2 \alpha \qquad (1)$$

This force of course can only be obtained by determining the force of the solar radiation pressure per square meter of sail which is,

$$F_o = 2PA \qquad (2)$$

As well as taking into consideration the angle α which is the angle of the net force to the perpendicular force. The angle will dictate the amount of force exerted on the sale as well as the direction in which it will move in. The value of 2P is considered to be the solar radiation pressure experienced at 1 AU from the sun which in this case happens to be near the area of the earth,

$$2P \text{ at } 1\text{AU} = 9.073\ \mu\text{N/m}^2 \tag{3}$$

This calculation of course pertains to an ideal solar sail meaning little to no imperfections and assuming 100% reflection. From this it is then possible to calculate the acceleration of the satellite which is based on the force exerted on the sail mass ratio.

$$a = F/m \tag{4}$$

It should be noted that these equations are taking into account that it’s within a 1 AU distance meaning that as long as the satellite does not cross a significant threshold which will cause a significant change greater than 1 AU.

6 Major Components

A satellite can be as complex or as simple as the designer wants but it all depends on the required objective and desired function one wishes’ to have in said satellite. In the case of this project a solar sail will be employed which will require special devices in order to allow it to work. These components consist of:

6.1 Solar Sail

The solar sail is composed of a thin plastic material with a reflective coating which allows the solar radiation to reflect off of the reflective surface and imparting the momentum of its particles to the sail resulting in motion. A square shaped design was chosen as it provided a large enough area and aided in its simplicity.

6.2 Solar Sail Deployment Mechanism

The deployment mechanism of the solar sail is a critical subsystem which usually has a high risk associated with it. The mechanism of the CubeSail consists of two main sections. The first is concerned with boom storage and deployment and the second is the storage of the sail. The booms will be roll around a spindle at the center of the bottom plate and a motor will have the function of deploying the booms out to space. The booms will be attached in the corner to the sail and they will be pulling the sail out of their compartments. Once the deployment is complete the satellite is ready to change its orbit.

6.2.1 Booms

The booms have to occupy a small volume during stowage which is confined to a 10cm by 10 cm base area and leave a reasonable amount of space for the folded sail. This is on top of the fact that they have to extend to about 2.9 meters in length. The diameter of the booms roll around, along with the inner hub, is 90 mm, so it will fit perfectly in the satellite.

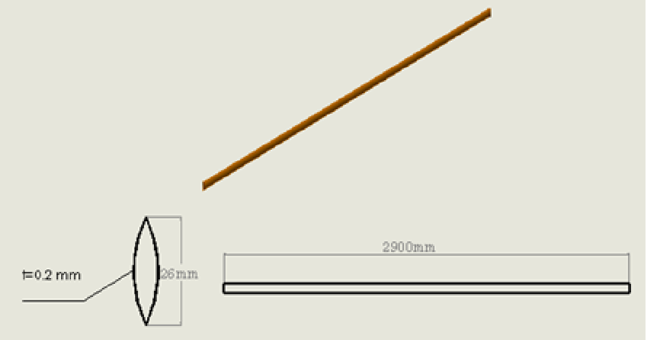


Figure 7: Boom Dimensions

The CubeSail booms are made of tape-spring blades, similar to the ones used in tape measures. Due to its flexible nature, a long blade is able to roll back out and hold its straight shape. These blade show a very good stiffness when held curve down. Some tape measures are claimed to stand horizontally up to 4 meters. This kind of bending stiffness is more than sufficient in a very low gravity environment to extend the sail film and make it taught while enduring the solar radiation pressure but when the blades are flipped upside down they quickly buckle under gravity and bend under the smallest of forces.

To strengthen the blade, two of the blades are attached to each other front to front. This solves the buckling problem and increases the stiffness of the booms. It should be noted that the ends of the booms will attached to the ends of the sail.

6.2.2 Motor

To control the deployment, a DC electric motor is added to the system. This motor drives the booms out of the mechanism at a slow speed to avoid damage to the sail. The motor will be located above the sail compartments and is going to be fixed to the plate with two screws, leaving enough space in the satellite for the other components. The solar sail compartment will have a hole in the middle to connect the motor to the spindle; the hole is bigger than the shaft diameter in order to avoid friction between both surfaces. The weight and dimensions of the engine are the most important aspects that were taken into account to choose the model. The model chosen is the HS-645MG because it will fit perfectly inside the satellite and with 8.0 to 10.0 kg/cm^2 is able to move the metal component of the system.

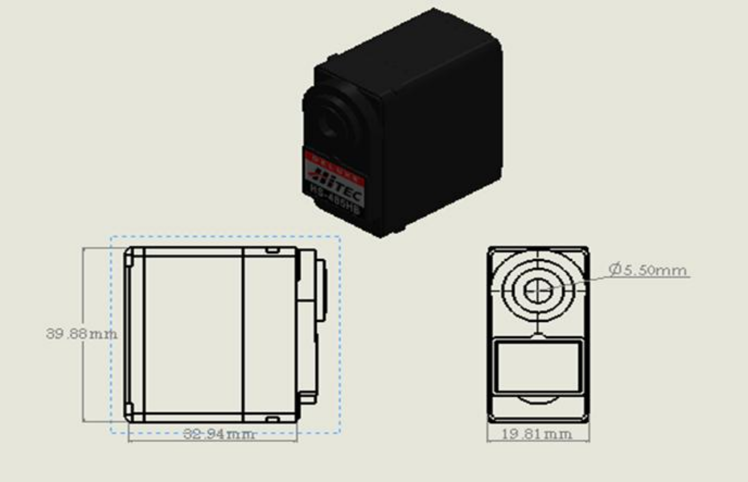


Figure 8: Motor Dimensions

6.2.3 Spindle

The spindle consists of two parts, both made of aluminum. This material was chosen because it is resistant to corrosion and maintains a light weight while having high strength properties. The outer hub is where the booms are going to be rolled around. The inner hub is going to hold the booms and it will be connected to the shaft motor to rotate the whole spindle. The diameter of the spindle, 26 mm, will allow enough space for the booms. Once the tapes have wrapped around the spindle, we can measure the total diameter to be 90 mm.

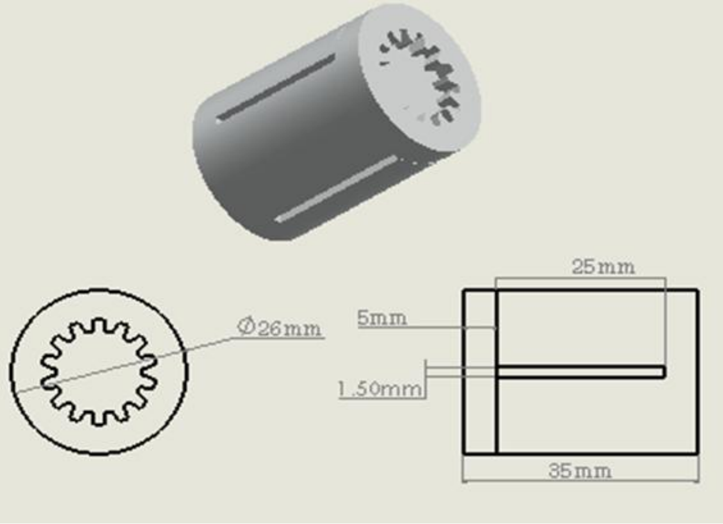


Figure 9: Spindle Dimensions

6.2.4 Sail Compartment

The sail compartment function is to store the solar sail until deployment. It will also be made of aluminum like many of the other parts. The center of the compartment will have a center hole to let the motor shaft through; the diameter of the hole is going to be bigger than the shaft to avoid friction. A small gab between the center and wall was designed to decrease the weight. This was possible because the area needed for the solar sale once it’s folded is just 20 mm^2

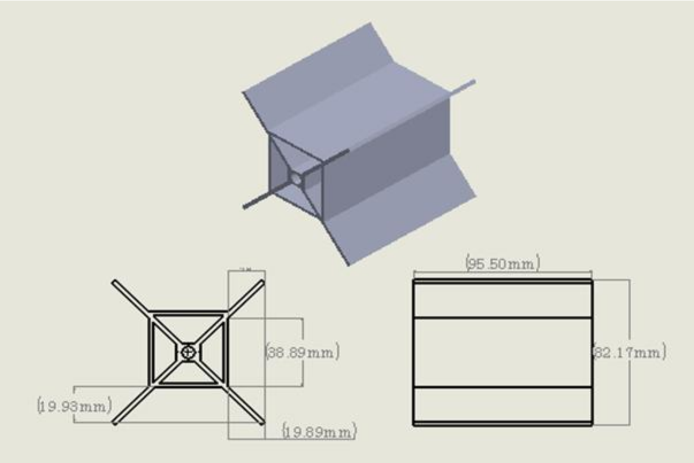


Figure 10: Sail Compartment Dimensions

6.3 Power Subsystem

The purpose of the power sub system is to provide uninterrupted and adequate power to on-board electronics in sunlight as well as in eclipse. The power subsystem is designated to supply power to the Attitude Determination and Control System (ADCS), communication system, and payload as well as the temperature sensors in the satellite.

6.3.1 Solar Cells

We have selected 29.5% NeXT Triple Junction solar cells in the design of our 3U satellite because they are very accessible and highly efficient. The efficiency of the cells in our design is very important due to the limited surface area available on the satellite. The triple junction cells are composed of a germanium substrate and a GalnP2, GaAs, and Germanium solar cell. XTJ solar cells produce 135-mW/cm^2.

6.3.2 Battery

Batteries are essentially needed to supply power at times when there is no direct solar radiation to the satellite's solar cells. It is also of great necessity in situations when there is a need of great power than the one obtained from the solar cells. Such batteries should be able to operate in high temperature conditions and they need to be compact and lightweight to comply with the NASA restrictions. In our design, we have selected Lithium-Polymer batteries.

6.4 Communications

Communication subsystem is one of the important subsystems for the satellite operation. The main goal of the communication subsystem is to establish a communication link between the satellite and the earth ground station. Telemetry and command are the two forms of communication between a satellite and the earth ground station. In telemetry communication, satellite transmits to the ground station regarding its attitude and station. Similarly, in the command communication information is transmitted to the satellite. These two types of commutations require an antenna, RF transceiver, TNC, PIC microcontroller, GPS and a beagle board.

6.4.1 Beagle Board

The Beagle board provides the satellite information through the serial port connected to PIC microcontroller. The beagle board provides the control subsystems to other subsystems.

6.4.2 PIC Microcontroller

The PIC microcontroller has two sets of UART terminals, where each set contains two terminals for transmission and reception

6.4.3 TNC & RF Transceiver

TNC is responsible for assembly data (bits) from the microcontroller into packets before sending to the RF transceiver. Similarly the RF transceiver dissembles the packets into bits before sending to the microcontroller. The TNC has two full duplex serial ports; one is for the GPS and the other for the RF transceiver

6.4.4 Antennas

Antennas are essential for radio communications they provide the ability to send all satellite functions and receive any and all commands from ground control.

6.5 Attitude Control

The sensors, which are mainly used in the attitude control subsystem, are Razor 9 degrees of freedom sensor and Sun sensor. Basically, it consists of a gyroscope, accelerometer and magnetometer with an ATmega328 host controller. These sensors can provide the feedback signals necessary for the attitude control of the Panther SAT and are interfaced with the Beagle board via a serial interface port. A magnetic torque driven by a H-bridge generates control torque required to rotate the satellite. The Beagle board through the general-purpose digital output pins provides the control signals to the H-bridge. We can also manage to control the orientation of the satellite through the use of torque coils. Magnetic torque coils can be chosen for the attitude control for their low weight, low power, small size and relative ease of use

6.5.1 Gyroscopes

Gyroscopes are devices that sense rotation in three-dimensional space without reliance on the observation of external objects.

6.5.2 Magnetometer

Magnetometer is a device that senses magnetic field strength and, when used in a three-axis triad, magnetic field direction.

7 Structural Design

The structural design of our CubeSat structure has been designed in such a way that it meets the constraints of a 3U satellite. Our chassis will consist of four separate walls of aluminum 6061-T6511 grade that are welded to four external rails. This material has been chosen because of its high material properties and ease of welding and machinability. Referring to outside resources that show experiments similar to ours also helped us reinforce our reason for choosing this material. Considerations for using the aerospace standard aluminum 7075 T-6 material were made but after conducting a cost analysis, it was decided that the material vs. cost was more in favor of the aluminum 6061 T-6 grade.

When developing our structure, we have to keep in mind that there is a possibility of having external forces acting on our system and for that reason four rails have been added to absorb these external forces. These rails are specifically created for the forces acting on our system including those of the other satellites that we take under assumption to be placed on top of our structure. We must make sure that the structural integrity of our proposed system will be able to withstand these forces while maintaining a lightweight design so that it does not prematurely collapse before deployment from the rocket once in space. Sections of the chassis have removed material so as to accommodate a light weight design. We must keep in mind that our entire system including electronics cannot exceed the 4kg limit of weight.

For our current progress, a static analysis was conducted using Solidworks Simulation. Our current design has not been fully assembled so we cannot assume that the results obtained now will reflect those of the finalized structure because we will have different downward force values because of our lack of internal components. When the satellites are stacked within the rocket, they are assembled in stacks of 9U high. Since we cannot simulate the components that we are lacking just yet, we will assume an extra 3U satellite is going to be stacked on top of our system. This means that we want to make an assumption that there will be 3 sets of 3U satellites stacked on top of ours to account for our lack of weight for the current static simulation. To determine the force acting on each rail we follow the equation as follows: (mass of 3U satellite) x (force experienced during flight)/number of rails.

For our case it will be a max of 4kg multiplied by the 3 sets of satellites. We take this result and multiply it once again by the launch force of 14g to yield a result of 412.02N.

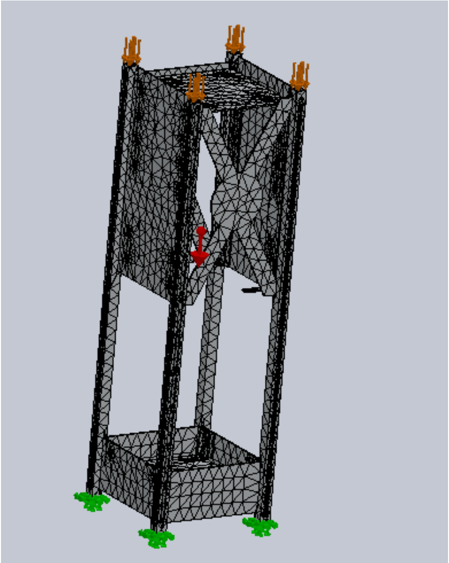
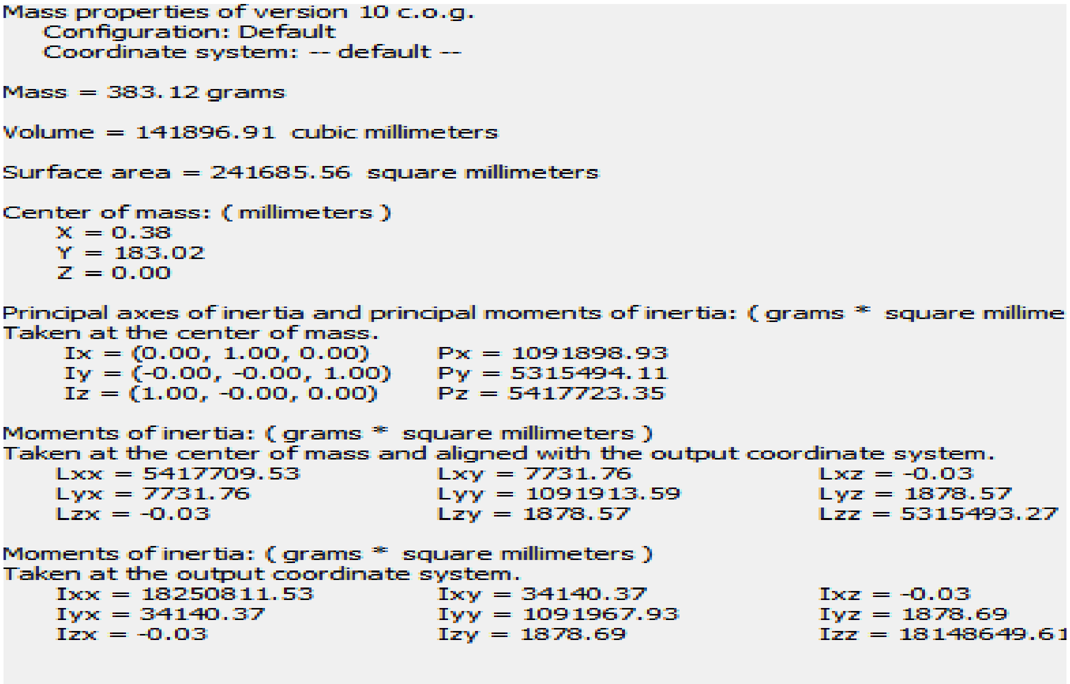


Figure 11: Frame undergoing simulated force

Using the Solidworks program, we can see below the properties of the chassis which include but are not limited to mass and volume:



```
Mass properties of version 10 c.o.g.
   Configuration: Default
   Coordinate system: -- default --

Mass = 383.12 grams

Volume = 141896.91  cubic millimeters

Surface area = 241685.56  square millimeters

Center of mass: ( millimeters )
    X = 0.38
    Y = 183.02
    Z = 0.00

Principal axes of inertia and principal moments of inertia: ( grams *  square millime
Taken at the center of mass.
     Ix = (0.00, 1.00, 0.00)       Px = 1091898.93
     Iy = (-0.00, -0.00, 1.00)     Py = 5315494.11
     Iz = (1.00, -0.00, 0.00)      Pz = 5417723.35

Moments of inertia: ( grams *  square millimeters )
Taken at the center of mass and aligned with the output coordinate system.
    Lxx = 5417709.53               Lxy = 7731.76                  Lxz = -0.03
    Lyx = 7731.76                  Lyy = 1091913.59               Lyz = 1878.57
    Lzx = -0.03                    Lzy = 1878.57                  Lzz = 5315493.27

Moments of inertia: ( grams *  square millimeters )
Taken at the output coordinate system.
    Ixx = 18250811.53              Ixy = 34140.37                 Ixz = -0.03
    Iyx = 34140.37                 Iyy = 1091967.93               Iyz = 1878.69
    Izx = -0.03                    Izy = 1878.69                  Izz = 18148649.61
```

Figure 12: Proprietary information of structure

It is good to take note that the slots in the rails and the material reduction in the side panels played a significant factor in our weight from our previous design which weighed in at 520g. The positioning of each slot was specifically placed so as to not reduce the integrity of the overall structure.

8 Cost Analysis

The cost of the satellite hasn’t fully been taken into consideration at the moment for the time being the current cost is based on current materials that have been taken into account for the solar sail. The following table also does not take into consideration the cost of machining of the components.

Table 2: Cost of Components and Materials

Components	**Cost ($)**
Booms	15.90
Spindle	4.17
Sail Compartment	35.00
Plate Bottom	0.88
Plate Top	0.88
Sail Compartment Plate	0.92
Motor	31.49
Rail	2.01
Bottom/Top Plate	0.88
Chassis	4.48
L Brackets	0.96
Top Plate L Brackets	0.96
Total	98.53

Table 3 consists of total hours worked along with salary earned based on an hourly rate of $15 per hour this of course will change with time depending on the amount of time needed for the project.

Table 3: Hours and Salary

Name	Hours	Salary ($)
Gonzalo Vivanco	40	600
Luis Fernandez	40	600
Giampiero Revelo	40	600
Henry Vazquez	40	600
	Total	2400

9 Prototype

Table 4: Material Cost Analysis

Components	**Cost ($)**
Booms	15.9
Spindle	4.17
Sail Compartment	35.0
Plate Bottom	0.88
Plate Top	0.88
Sail Compartment Plate	0.92
Motor	31.49
Rail	2.01
Bottom/Top Plate	0.88
Chassis	4.48
L Brackets	0.96
Top Plate L Brackets	0.96
Solar Sail Material	648.10
Total	746.63

10 Testing

Certain testing will need to be implemented in order to determine the integrity and function of the satellite components, solar sail, and solar sail deployment system. These include but are not limited to:

Test 1. Vibration Testing: Will provide information as to whether or not vibrations, which can be experienced, during launch will affect the deployment system, packaging of the solar sail or other components. This can be achieved by subjecting the entire satellite to low and high levels of vibration.

Test 2. Thermal Testing: In order to determine the characteristic behaviors of the kapton material under different operating temperatures as well as to test the performance of the deployment system under varying temperature. Subjecting the satellite to varying temperature as experienced at 800 km above sea level in initial state as well as fully deployed state.

Test 3. Solar Sail deployment testing: Allows the testing of the deployment system as well as provide insight on how the sail will deploy as well has to determine if any obstructions are present which can cause damage to the sail. Can be conducted during thermal testing to determine reaction to varying temperatures.

Test 4. Solar Sail Reflectivity Testing: Provides information as to the efficiency of the material to reflect solar radiation. Folding of the sail is required to package it inside the required dimensions of the satellite; this will cause creases which can affect sail reflectivity. Testing will consist of reflecting light on the sail material and measuring the amount of light initially hitting the sail and afterwards measuring the amount of light reflected from the surface in order to compare. Testing must be conducted on material which has not been folded, on material that has been folded and opened, as well as material with a worst case scenario such as completely crumpled and then opened.

11 Conclusions

Current design requires that the sail and the deployment system must be stored within the dimensions of the 3U CubeSat. The solar sail must have a reflective coating therefore the Kapton material that will be obtained must be verified to have one, in the event that it is not possible then the material will have to be sent to have one placed on it usually in the form of an aluminized coating. The solar sail material will then be cut into 4 equal triangular sections which will have a combined area of the original material area.

Applying reinforcement to the three corners of the triangular section is crucial as it will allow the ends of the support booms to pull on the thin Kapton material and avoiding damage to the sail material. This can be achieved through the use of light weight metal grommets and thicker material added and attached to the corners. Kapton material will then have to be folded according to the corresponding packaging method and stored in its stowed compartment. It should be noted that the top corner will need to be attached to the satellite so as to give it a point of tension when being deployed. The other two remaining corners from the bottom of the base will need to be facing outside of the satellite so as to attach them to the end of the booms.

The deployment system will consist of a rotating component attached to a system of gears and an electric motor which will drive it. The rotating component will house the flexible booms around it and be placed beneath the compartment which will house the solar sail. The ends of the booms will be attached to the corners of the four sections of the solar sail at this point. When the deployment system is activated it will cause the rotating component to start to spin causing the flexible booms to extend which at the same time will be pulling the corners of the solar sail sections and allow it to extend. Once the booms have fully extended they will provide the necessary tension to the triangular sections giving the sail sufficient stretch to form a flat surface which will allow adequate reflection of the solar radiation. This deployment system along with the solar sail will occupy a section of the 3U satellite along with all the necessary components.

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