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DESIGN, ANALYSIS AND FABRICATION OF A POCKETQUBE DEPLOYER

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A PROJECT REPORT SUBMITTED TO THE DEPARTMENT OF MECHANICAL AND AEROSPACE ENGINEERING IN PARTIAL FULFILLMENT OF THE REQUIREMENT FOR THE BACHELOR'S DEGREE IN AEROSPACE ENGINEERING

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The undersigned certify that they have read, and recommended to the Institute of Engineering for acceptance, a project report entitled **"Design, Analysis and Fabrication of PocketQube Deployer"** submitted by **Amit Dhakal, Pramish Dahal and Sparsh Bhattarai** in partial fulfillment of the requirements for the degree of Bachelor in Aerospace Engineering.

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ABSTRACT

The objective of this project is to develop a PocketQube Deployer that can efficiently deploy small satellite payloads into space. To achieve this goal, the project involves conducting extensive research to analyze various deployment mechanisms and selecting the most suitable design for the PocketQube Deployer. The design process will involve modeling and simulation to ensure that the device is reliable and meets the required specifications.

The fabrication stage of the project involves constructing and testing a prototype device using various materials and manufacturing techniques. The aim is to create a low-cost and efficient solution for deploying small satellite payloads, which will contribute to the growth of the space industry and advance space research.

This project seeks to design, analyze, and fabricate a PocketQube Deployer that can meet the needs of the space industry by providing a reliable and cost-effective means of deploying small satellite payloads.

Keywords: *PocketQube, PocketQube Deployer, Small Satellite Payloads*

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LIST OF ABBREVIATIONS

CAD	Computer Aided Design
CNC	Computer Numerical Control
IC	Integrated Circuit
IDE	Integrated Development Environment
IR	Infrared Radiation
LEO	Low Earth Orbit
MOSFET	Metal-Oxide-Semiconductor Field-Effect Transistor
PCB	Printed Circuit Board
PLA	Polyacetic Acid
PQ	PocketQube
PQD	PocketQube Deployer
PSD	Power Spectral Density

CHAPTER ONE: INTRODUCTION

1.1 PocketQube

PocketQube is a type of miniaturized satellite that is smaller in size compared to traditional satellites. It measures 5 cm x 5 cm x 5 cm and has a volume of about one liter, making it one of the smallest satellites in existence[1]. These tiny satellites are designed to be low-cost, quick to build and launch, and capable of performing a variety of functions in space, such as communication, remote sensing, and scientific experiments[2]. The small size and low cost of PocketQubes make them accessible to a wider range of organizations, including universities, research institutions, and even individuals, for their space-related projects[3].

PocketQubes were first developed in 2009 by the company called Alba Orbital, which is based in Scotland. They are designed to be launched into space as a secondary payload, meaning they can be placed in orbit alongside larger satellites, reducing the cost of space missions[4].

The PocketQube is built using off-the-shelf components, which makes it cheaper and easier to manufacture than traditional satellites. This has opened up the possibility of conducting space research to a much wider audience than was previously possible.

One of the main advantages of PocketQubes is their versatility. They can be used for a wide range of applications, including Earth observation, climate monitoring, communication, and scientific research[1]. For example, they can be equipped with cameras to capture images of the Earth's surface, or with sensors to measure atmospheric conditions and detect changes in the environment.

The rise of PocketQubes is part of a larger trend in the space industry towards smaller, cheaper, and more flexible satellites. This trend is often referred to as "New Space," and it is being driven by a combination of technological advancements, market demand, and increased access to funding[3].

In the past, space research was primarily the domain of government entities, such as NASA, which had the resources and funding to develop and launch large, expensive satellites into orbit. Private companies and individuals had limited access to space, and the cost of conducting space research was prohibitively expensive for most people[3].

However, with the rise of PocketQubes and other miniature satellites, the landscape of space research has shifted dramatically[5]. These tiny satellites can be built using off-the-shelf components and launched as secondary payloads alongside larger satellites, dramatically reducing the cost and time required to get them into space[3]. This has opened up new possibilities for space research and exploration, enabling universities, startups, and even hobbyists to conduct experiments and gather data in space[4].

The democratization of space research has the potential to accelerate scientific discovery and innovation in a range of fields[3]. For example, PocketQubes can be used to study the effects of space radiation on electronics, test new propulsion technologies, and monitor the Earth's environment for signs of climate change.

The rise of New Space and miniature satellites like PocketQubes is also creating new opportunities for entrepreneurship and economic growth[5]. Startups are emerging to provide services such as satellite design, launch services, and data analysis, creating new jobs and driving innovation in the space industry[3].

The development of PocketQubes and other miniature satellites is transforming the field of space research and exploration, making it more accessible and affordable to a wider range of people and organizations. As the technology continues to evolve, we can expect to see even more innovation and growth in the New Space industry, creating new opportunities for scientific discovery and economic development.

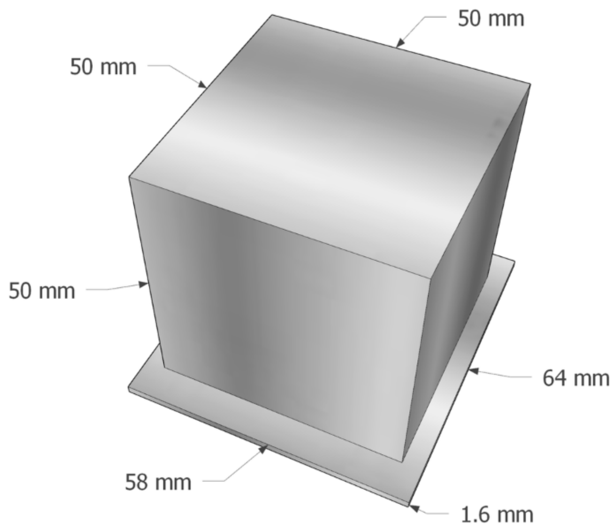


Figure 1.1: PocketQube Dimensions
[1]

1.2 PocketQube Deployer

PocketQube deployers are an essential component of the New Space ecosystem, playing a critical role in launching miniature satellites into orbit[5]. Deployers are necessary because they provide a safe and reliable way to get PocketQubes into orbit. These miniature satellites are too small to launch on their own and must be launched as secondary payloads alongside larger satellites[6][4]. Deployers provide a way to ensure that the PocketQubes are securely held in place during launch and are released at the correct time and in the correct orientation to achieve their intended orbit. However, if you want to launch a PocketQube into space, you will need to work with a launch provider that has a deployer capable of releasing your satellite into orbit. This can be a limiting factor, as not all launch providers may have the deployer you need or may have limited availability for launch opportunities.

While having your own deployer can provide greater flexibility and control over the launch process, it is also a complex and challenging endeavor that requires significant resources and expertise. Developing and building a deployer requires specialized knowledge in areas such as aerospace engineering, mechanical design, and materials science. Additionally, there are regulatory and safety considerations that must be taken into account when designing and operating a deployer.

Despite these challenges, the development of deployers has enabled a new era of space exploration and research. PocketQube deployers have allowed universities and small companies to conduct space experiments and research that were previously only possible for large corporations or government entities. Deployers have also facilitated the development of new applications for miniature satellites, such as space-based Internet of Things (IoT) networks and satellite constellations for global communications[3].

PocketQube deployers have played a critical role in the democratization of space and have opened up new opportunities for space research and exploration. The continued development of deployers will be instrumental in enabling new innovations and applications in the rapidly evolving New Space ecosystem.

1.3 Objectives

1.3.1 Main Objectives

To design, analyze and fabricate a working model of a PocketQube deployer.

1.3.2 Specific Objectivs

1. To develop and optimize deployer design using CAD software to meet the design requirements and constraints.

2. To conduct FEA to evaluate the structural integrity of the deployer design under various launch and deployment scenarios.

3. To fabricate a working prototype of the deployer using locally available materials and manufacturing processes.

1.4 Applications

1. Low-cost Satellites Launch: With the help of PocketQube Deployer, more businesses and people can now participate in space exploration by launching small, inexpensive satellites into orbit.

2. Research and Educational Purpose: PocketQubes are used for various research and educational purposes, such as remote sensing, environmental monitoring, and technology demonstrations.

3. IoT and Communication Network Expansion: To provide access in isolated and underserved locations, PocketQubes can be used to enhance satellite communication networks and Internet of Things (IoT) networks.

4. Disaster Response and Humanitarian Aid: By establishing communication and remote sensing in affected areas, PocketQubes can help disaster response and humanitarian aid initiatives.

1.5 Features

1. Compact size: PocketQube Deployers are designed to be small and lightweight, to minimize the amount of payload required to launch them into space.

2. Efficient deployment: PocketQube Deployers are designed to efficiently deploy PocketQubes into orbit, without the need for complex deployment mechanisms.

3. Automated deployment: Many PocketQube Deployers are equipped with automated systems that can control the deployment process, reducing the need for manual intervention.

4. Cost-effective: PocketQube Deployers are designed to be cost-effective, making them accessible to a wider range of organizations and individuals.

5. Flexible: PocketQube Deployers are designed to be compatible with a variety of launch vehicles and payloads, allowing for greater flexibility in terms of deployment options.

6. Customizable: PocketQube Deployers can be customized to meet the specific requirements of different missions, enabling the deployment of PocketQubes for a wide range of applications.

1.6 Feasibility Analysis

1.6.1 Economic Feasibility

Traditional satellites are large and expensive to produce. The size of satellites is drastically shrinking because of technological advancement, and this has led to the development of a significant number of Pico and nano satellites. The most popular type of micro satellite among these is the CubeSat, but the popularity of PocketQube has been rising quickly and significantly both in industrialized and emerging nations, such as Nepal and South Asia. The manufacturing cost has been significantly reduced due to the size reduction. These mini satellites are quite popular among students and academics around the world due to their modest size and excellent potential for technological improvement.

1.6.2 Technical Feasibility

The technical feasibility of a PocketQube deployer in Nepal depends on a number of factors, including the availability and reliability of power and communication infrastructure, the presence of skilled staff to run the system, and the legal climate for small satellite launches. It is appropriate to launch such a small satellite since Nepal's power and communication infrastructure is expanding quickly, there is an increase in the number of trained workers available to carry out this type of work there, and there will likely be strong government regulation in the future.

1.6.3 Operational Feasibility

The operational feasibility of a PocketQube in Nepal is dependent on several variables, including the accessibility of technology, the state of the local infrastructure, funding, and legal framework. It's probable that Nepal lacks the infrastructure and technology needed to launch and run a PocketQube, and that there are some limitations on satellite launches there. Nepal has limited satellite technological capabilities, which could make it difficult to launch and run a PocketQube. The operational viability of a PocketQube in Nepal is certain to rise soon as the country continues to develop its technology and infrastructure.

1.7 System Requirements

1.7.1 Software Requirements

1. CATIA V5 for making CAD models.
2. ANSYS for vibration and thermal analysis.
3. KiCAD for PCB design.
4. ArduinoIDE for programming the microcontroller

1.7.2 Hardware Requirements

1. Arduino Nano as a microcontroller for the system.
2. MOSFET as a switch.
3. 12V Li-ion battery for powering the system.
4. Nichrome wire for thermal knife.
5. IC 7805 for voltage regulation.
6. Resistors and capacitors.

CHAPTER TWO: LITERATURE REVIEW

Development of satellites increased rapidly after the second world war, and the launch of micro satellites started during the period 1957-to 1966. A significant number of mini and microsatellites were launched from 1981 to 1999 from countries all over the globe, so a rapid evolution was seen in the field of satellites worldwide[4]. A smaller version satellite named CubeSat was launched in 2003, which became popular due to its size and space capability, followed by many other CubeSat satellites in the consecutive year. Later, in 2014, PocketQube was proposed by Professor Bob Twiggs of Morehead State University, Kentucky, USA. Many PocketQube have been launched and are orbiting around the earth in Low Earth Orbit (LEO)[3].

The first artificial satellite, Sputnik 1, was launched by the Soviet Union on October 4, 1957. It was a 58 cm diameter sphere that weighed 83.6 kg and orbited the Earth every 96.2 minutes[7]. Sputnik 1 marked the beginning of the Space Age and sparked a global race for space exploration and satellite development[7].

Over the years, satellites have evolved in size, capabilities, and applications. From large communication and navigation satellites to small scientific research satellites, there are now thousands of satellites in orbit around the Earth, providing valuable data and services to people around the world[3].

PocketQubes are a recent addition to the satellite industry, and are designed to be even smaller and more affordable than traditional small satellites. They were first proposed in 2009 by a team of researchers at California Polytechnic State University, and are typically no larger than 5 cm x 5 cm x 5 cm, and weigh less than 1 kg[4][8].

The first PocketQube satellite, known as ”Sprites”, was developed by a team of researchers at Cornell University and launched in 2014[8]. The Sprites were tiny, measuring only 3.5 cm x 3.5 cm x 3.5 cm, and were designed to demonstrate the feasibility of using PocketQubes for scientific research and education[8].

Since then, the PocketQube platform has evolved significantly. Advances in technology have allowed for greater miniaturization, improved sensors and communication systems, and increased mission capabilities[8]. Today, PocketQubes can perform a wide range of missions, including Earth observation, communication, and scientific research[4].

In addition to the development of more advanced PocketQubes, there has also been significant progress in the development of PocketQube deployers. These deployers are essential for launching PocketQubes, and have become more sophisticated and capable over time.

As the technology continues to evolve, it is expected that PocketQubes will become increasingly capable and versatile. They are already being used for a wide range of missions, and are particularly popular among universities, small companies, and hobbyists who are interested in space research and exploration. With continued innovation and development, PocketQubes will likely continue to play an important role in the New Space ecosystem[3].

While the size and capabilities of satellites have evolved significantly since the launch of Sputnik 1, the importance of these spacecraft for global communication, navigation, and scientific research remains as strong as ever[7]. The advent of PocketQubes has further expanded the capabilities and accessibility of space technology, opening up new opportunities for research and exploration.

A study presented a design and analysis of a spring-loaded PocketQube deployer using finite element analysis[4]. A spring-loaded deployer that used two mechanisms to provide an axial force to the PocketQube during deployment was designed. The deployment process was simulated using finite element analysis software to verify the design's strength and stiffness. The results showed that the designed deployer was capable of deploying a PocketQube with a maximum mass of 200 grams[4][9].

M Papamatthaiou and E Kosmas provided a critical review of PocketQubes and their potential to revolutionize CubeSat constellations. The authors discussed the benefits of using PocketQubes in terms of cost, accessibility, and design flexibility[10]. They also highlighted the challenges associated with developing PocketQube deployers, including size constraints, mechanical complexity, and launch regulations[10].

Radu, Speretta, and Bouwmeester (2018) introduced the concept of PocketQubes and described their potential applications in space missions. The authors highlighted the advantages of using PocketQubes, including their low cost, ease of manufacturing, and ability to perform scientific missions. They also discussed the challenges associated with developing PocketQube deployers, including the need for compact and lightweight designs[11].

MO Khatsenko (2017) presented a deployable mechanism for PocketQube satellites. The authors designed a deployer that uses a shape memory alloy to actuate the deployment of the PocketQube[12] . The deployment process was tested using a prototype PocketQube, and the results showed that the deployer was capable of successfully deploying the PocketQube[12].

CHAPTER THREE: RELATED THEORY

3.1 Deployer Configuration

A typical 4P PocketQube deployer configuration may include the following components[6]:

1. A support structure that can house four PocketQubes, each measuring 1U, and to provide protection for the deployer and PocketQube parts during launch and deployment.
2. A launch vehicle adapter to secure the PocketQube to the launch vehicle.
3. A deployer mechanism, such as a spring or similar device, to release the PocketQube into orbit.
4. A power source, such as batteries or solar panels, to provide power to the deployer mechanism.
5. Communication equipment, such as a radio or antenna, to communicate with ground stations.
6. Sensors and instruments to monitor the PocketQube's environment and position in orbit.

3.2 Mechanisms Involved

3.2.1 Slider-spring Deployment Mechanism

PocketQube deployers use various mechanisms to release the PocketQube satellites into space, one of which is the slider spring deployment mechanism[13] . This mechanism involves a slider, a spring, and a stopper. The PocketQube satellite is mounted on the slider, and the stopper holds the slider in place while the spring is compressed between the slider and the stopper[14][5]. The stored energy in the compressed spring provides the force needed to deploy the satellite.

When the PocketQube deployer is in space and ready to release the satellite, the stopper is released, allowing the spring to push the slider and the satellite out of the deployer. The slider moves along a guide rail, and the satellite is then deployed into space.

The slider spring deployment mechanism is a simple and dependable deployment mechanism that is widely used in PocketQube deployers. Its straightforward design and manufacturing process make it a low-cost and low-risk deployment mechanism as it does not require any electrical or pyrotechnic components[14].

To further ensure reliability, the slider spring mechanism is often tested through simulations and physical tests[13]. This helps to identify any potential problems with the design and allows for adjustments to be made before the final product is produced.

3.2.2 Door Mechanism

The thermal knife door opening mechanism is the most common process used in PocketQubes. This mechanism utilizes a thermal knife, which is a thin wire made from a special alloy that rapidly heats up when an electric current is passed through it[5][13].

The thermal knife door opening mechanism involves securing the PocketQube satellite behind a door that is kept closed by a latch. The thermal knife is connected to the latch and is linked to an electric power source on the deployer[5].

To deploy the satellite, an electric current is passed through the thermal knife, causing it to heat up and melt the latch that is holding the door shut. Once the latch is melted, the door opens, and the satellite is released into space[14].

This mechanism is a low-risk and dependable way to deploy PocketQube satellites, and it requires minimal electrical power to operate. The thermal knife is a one-time use component that ensures safe and efficient deployment. The simplicity of its design also makes it easy to manufacture and incorporate into the deployer.

- Electronics for thermal knife
  The electronics used in the thermal knife mechanism of a PocketQube deployer are straightforward and relatively uncomplicated. The main component is an electrical power source, such as a battery or solar panel, which provides the electric current required to heat up the thermal knife[2].

  The thermal knife is constructed from a unique alloy that has specific characteristics, including a high melting point and electrical resistance, that make it suitable for the mechanism. When an electric current is passed through the thermal knife, it heats up rapidly, eventually melting the material.

  To activate the thermal knife, a circuit is established between the power source and the knife, which can be achieved through the use of a switch or a microcontroller using

MOSFET[2] . The microcontroller may also be employed to supervise the voltage and current flowing through the thermal knife to ensure it is functioning correctly.

In addition to the thermal knife, the mechanism may include other components like a latch or a door to secure the PocketQube satellite until the mechanism is triggered. Sensors such as temperature or pressure sensors can also be included to monitor the environment and ensure safe and efficient deployment[2].

3.3 Materials Selection

Proper material selection is a critical aspect of engineering design as it can impact the performance, reliability, durability, and safety of a product or system. The selection of the right material depends on various factors such as the intended use, environment, operating conditions, manufacturing processes, cost, and availability. Therefore, it is essential to evaluate different materials and compare their properties, characteristics, advantages, and limitations before making a final decision[15].

Table 3.1: Usable Materials
(Source: JEM Payload Accomodation Handbook, JAXA)

Aluminium Alloy	Titanium Alloy	Other Alloys
1000 series	Ti3Al-2.5V	200 series stainless
2011-T8	Ti5Al-2.5SN	300 series stainless
2024-T8	Ti6Al-4V	400 series stainless
2219-T6, -T8	Ti10Fe-2V-3Al	Inconel 600 (Annealing)
2618	Ti13V-11Cr-3Al	Inconel 625(Annealing)
3000 series	IMI 550	Inconel 718
5000 series		Inconel X-750
6000 series		
7049-T73		
7149-T73		
7050-T73		
7075-T73		

Among the possible material options mentioned, there are various categories of materials, including aluminum alloys, titanium alloys, stainless steels, and high-temperature alloys such as Inconel. Each material category has its unique properties, advantages, and limitations that should be considered based on the specific requirements of the application[6]. For example, aluminum alloys are lightweight, have excellent strength-to-weight ratios, and are corrosion-resistant, making them suitable for aerospace, automotive, and marine applications. Titanium alloys have high strength, excellent corrosion resistance, and biocompatibility, making them suitable for medical implants, aerospace, and defense applications. Stainless steels have high corrosion resistance, strength, and toughness, making them ideal for various industrial and consumer products, while high-temperature alloys such as Inconel have excellent mechanical properties at high temperatures and are used in gas turbines, jet engines, and nuclear reactors.

When selecting a material, the following factors should be considered:

1. Strength and durability requirements
   Materials should have the required strength and durability to withstand the expected loads and stresses in the application.

2. Environmental factors
   Materials should be resistant to the intended environment, including temperature, humidity, chemicals, and radiation.

3. Manufacturing processes
   Materials should be compatible with the chosen manufacturing processes, including casting, forging, machining, and welding.

4. Cost and availability
   Materials should be cost-effective and readily available in the required forms and sizes.

5. Other considerations
   Other factors such as weight, aesthetics, biocompatibility, and recycling potential may also be important depending on the application.

3.4 Random Vibration

Random vibration analysis is a technique for analyzing the response of a structure or system to random, non-periodic vibration inputs. The goal is to predict the probability distribution of the structural response due to random excitations[16].

The theory behind random vibration analysis is based on the power spectral density (PSD) of the random input signal. The PSD, denoted by S(f), is a function that describes the distribution of the input signal's power as a function of frequency f. The PSD can be estimated from measured data or derived from theoretical models[16].

To simulate the response of the structure or system to random excitations, Monte Carlo simulation is commonly used. This method involves generating a large number of time series of random excitations based on the PSD of the input signal. Each time series represents a realization of the random process and is denoted by x(t). The response of the structure or system is then calculated for each realization using the equations of motion or finite element analysis[17].

The statistical moments of the output, such as mean, variance, and probability density function (PDF), are then calculated based on the ensemble of responses[6]. For example, the mean response can be calculated as:

$$\mu = Ey[(t)] = \int_{y} (t) p(y) \, dy \tag{3.1}$$

where,
y(t) is the response of the structure or system
p(y) is the PDF of the response
and E[] denotes the expected value.

Random vibration analysis uses the power spectral density of the input signal and Monte Carlo simulation to predict the statistical properties of the response of a structure or system to random, non-periodic vibration inputs[16]. The analysis involves simulating a large number of realizations of the random process and calculating the statistical moments of the output.

3.5 Thermal Analysis

Thermal analysis of a PocketQube deployer involves studying the temperature distribution within the deployer and its components in different environmental conditions[6]. To do this, we use two important governing equations: the heat transfer equation and the conservation of energy equation.

The heat transfer equation is given as:

$$\rho C_p \frac{\partial T}{\partial t} = \nabla (k \nabla T) + Q \tag{3.2}$$

Where,
ρ is the density of the material
$C_p =$ is the specific heat capacity of the material

T is the temperature
t is time
k is the thermal conductivity of the material
Q is the heat source/sink

This equation describes how the temperature changes with respect to time due to heat transfer within the material and any heat sources/sinks present.

$$\int_{\nabla} (q+Q)dV = 0dy \tag{3.3}$$

Where,
q is the heat flux
Q is the heat source/sink
V is the volume

This equation states that the net heat flux and heat source/sink within a volume must balance out to zero, indicating that energy is conserved.

To carry out the thermal analysis of a PocketQube deployer, we must consider various factors such as the thermal conductivity of the materials used, the heat generated by the electronics, and the heat dissipated by the deployment mechanism[18]. We can use finite element analysis (FEA) to simulate the temperature distribution within the deployer and its components under different environmental conditions[6].

3.6 Bolt Calculation

Related equations:

$$Design\ Tensile\ Capacity\ of\ Bolt(F_t) = \frac{0.9 * f_{ub} * A_s}{\gamma} \tag{3.4}$$

$$Number\ of\ Bolts = \frac{Design\ Load}{Design\ Tensile\ Capacity\ of\ Bolt} \tag{3.5}$$

$Where,$

$f_{ub} = Ultimate\ Tensile\ Strength\ of\ Bolt$

$A_s = Effective\ Area\ of\ Bolt = \frac{\pi}{4}\left(d - 0.9382 * pitch\right)^2$

$\gamma = Factor\ of\ Safety$

CHAPTER FOUR: METHODOLOGY

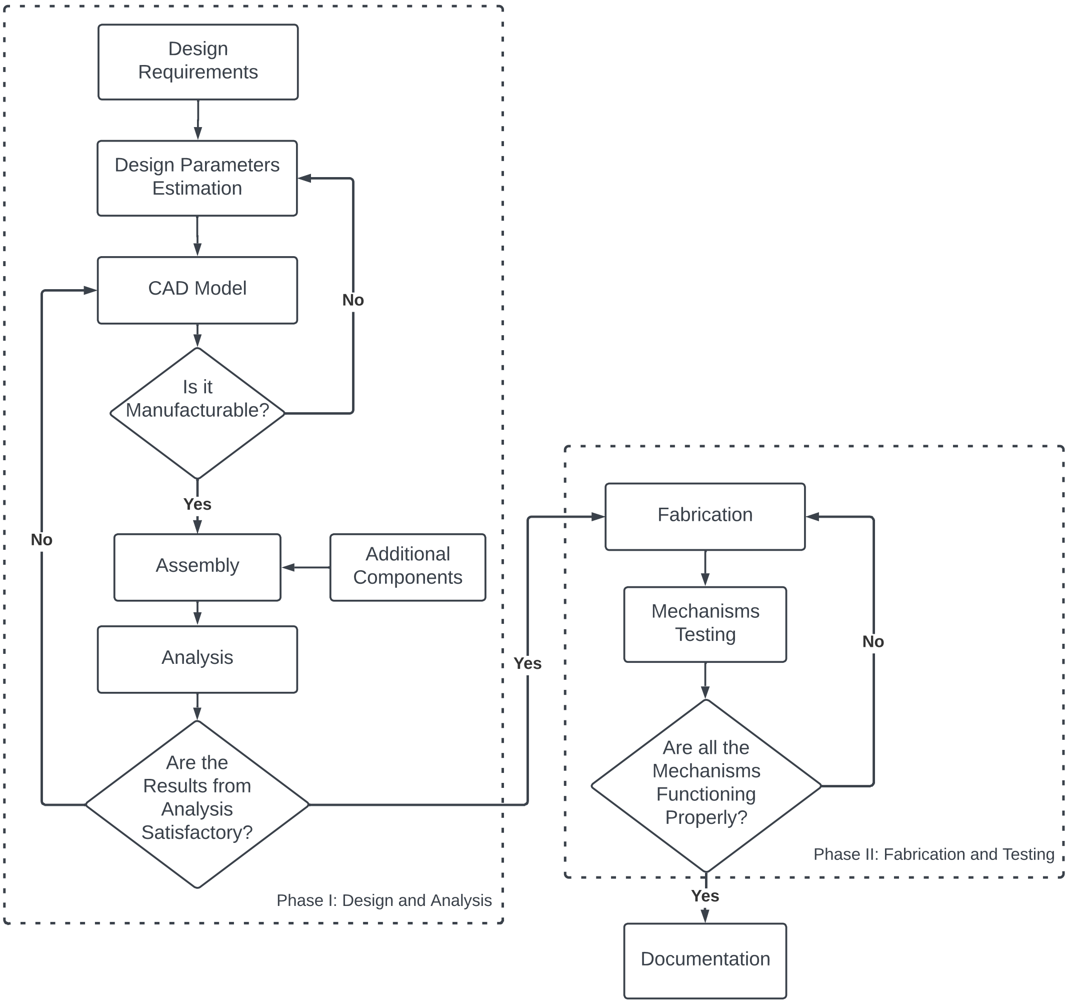


Figure 4.1: Methodology Flowchart

4.1 Design Requirements

4.1.1 Requirements according to JAXA

It is important to note that, although there are no standardized dimensional requirements for PocketQube deployers, other environmental requirements such as thermal, humidity, and vibration testing can be informed by established standards such as those set by the Japan Aerospace Exploration Agency (JAXA) for CubeSat deployers.

Therefore, while designing our PocketQube deployer, we consulted the environmental requirements provided by JAXA for CubeSat deployers in order to ensure our deployer met the necessary standards for launch and operation in space. These standards helped guide our design choices in regards to material selection, thermal management, and environmental testing.

- **Thermal Environment**

    1. HTV-X: +10   +32 [°C]

    2. Dragon: +18.3 +29.4 [°C]

    3. Cygnus: +10 +46.1 [°C]

    4. Inside the ISS: +16.7   +29.4 [° C]

    5. Outside the ISS : 15 +60 [°C] (When the satellite is in the J-SSOD)

- **Random Vibration**
  When performing a vibration test on the launch environment as part of the verification of the safety design shown in Section 4.2.2 of JEM Payload Accommodation Handbook - Vol. 8 - Small Satellite Deployment, the vibration environment shown in Table below shall be applied to each axis in a hard-mounted configuration.

Table 4.1: PSD Response of Each Launch Vehicle

HTV-X		Dragon		Cygnus	
Freq. (Hz)	PSD (g2/Hz)	Freq. (Hz)	PSD (g2/Hz)	Freq. (Hz)	PSD (g2/Hz)
20	0.005	20	0.02	20	0.004
50	0.02	200	0.02	30	0.004
120	0.031	2000	0.001	70	0.015
230	0.031			150	0.015
1000	0.0045			2000	0.0006
2000	0.0013				
Overall (gms)	4.05	Overall (gms)	3.2	Overall (gms)	2.44
Duration (sec)	60	Duration (sec)	60	Duration (sec)	60

[6]

4.1.2 Other Requirements

1. Dimensions according to JEM Payload Accommodation Handbook - Vol. 8 - Small Satellite Deployment Interface Control Document. The deployer should be of standard 4P size and must be easily integrated with the launch vehicle.
2. Fundamental frequency of the PQD should be greater than 120 Hz as per vibrational requirements.
3. All external fasteners and fasteners holding the main structure shall not be loose after vibration.
4. The temperature inside electronics casing should be within the working range of each component, ragning from -20 to 60 degree Celsius.
5. The velocity of PQs during deployment is in the range 0.6 m/s to 1.5 m/s.

4.2 Design Parameters Estimation

1. Size and Weight
   The deployer was designed to accommodate 4U PocketQube which required dimensions of 10x10x30 cm^3. The deployer weighed around 1 kg, which was within the standard requirements.

2. Deployment Mechanism
   Thermal knife setup consisting of nichrome wire and nylon string was used to open the door for initializing the deployment.Spring-loaded mechanism was used to push the PocketQubes for the deployment.

3. Compatibility with Launch Vehicle
   The deployer was designed to be compatible with launch vehicle in both size and mounting holes.

4. Environmental Conditions
   The deployer is exposed to harsh vibration and thermal environment in both launch vehicle and space. To be able to handle the vibration, the materials were selected such that the natural frequency of the deployer is above 120Hz.

   The deployer also experiences extreme temperatures ranging from -50 to 150 degree Celsius in space and the electronics need to survive these temperatures. For the insulation of electronics, Mylar sheet was used inside the electronics casing.

4.3 CAD Model

The entire deployer was divided into four sub-assemblies: outer structure, slider-spring mechanism, thermal knife door mechanism and electronics. Each sub-assemblies were designed separately and assembled.

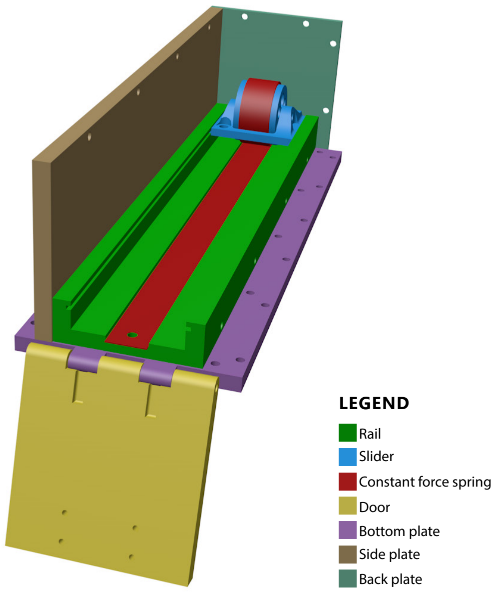


Figure 4.2: PQD Assembly

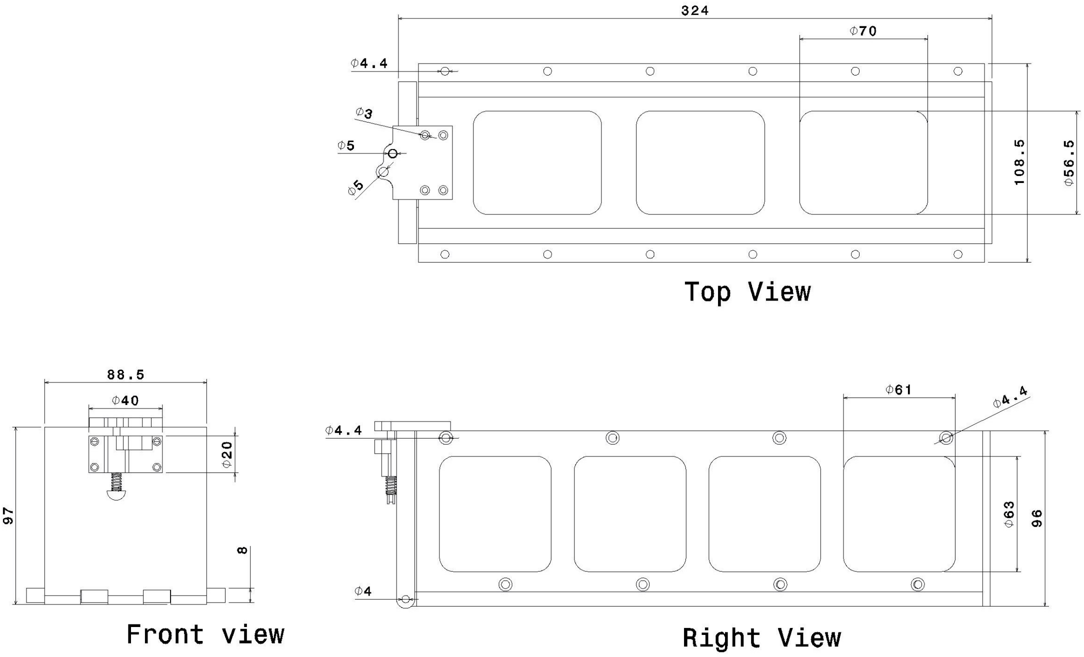


Figure 4.3: Drafting

4.3.1 Outer Structure

For the outer casing design, the focus was on creating a compact and lightweight structure while ensuring sufficient strength to withstand the loads experienced during launch. The casing was designed using CATIA V5 and consisted of multiple parts that were assembled to form the final product. The dimensions of the finished product were 300mm x 100mm x 100mm.

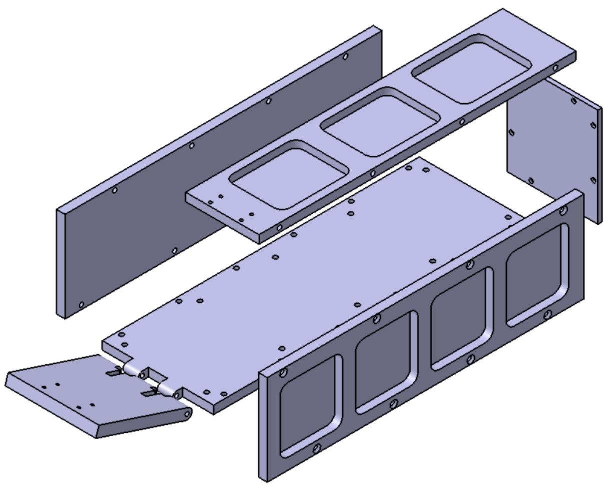


Figure 4.4: Outer Structure

4.3.2 Slider-Spring Mechanism

The slider spring mechanism was designed to be the mechanism that released the PocketQube satellite from the deployer. The mechanism consists of a spring and a slider that work together to apply the necessary force for deployment. The spring and slider were designed to be compact, lightweight, and reliable to ensure successful deployment.

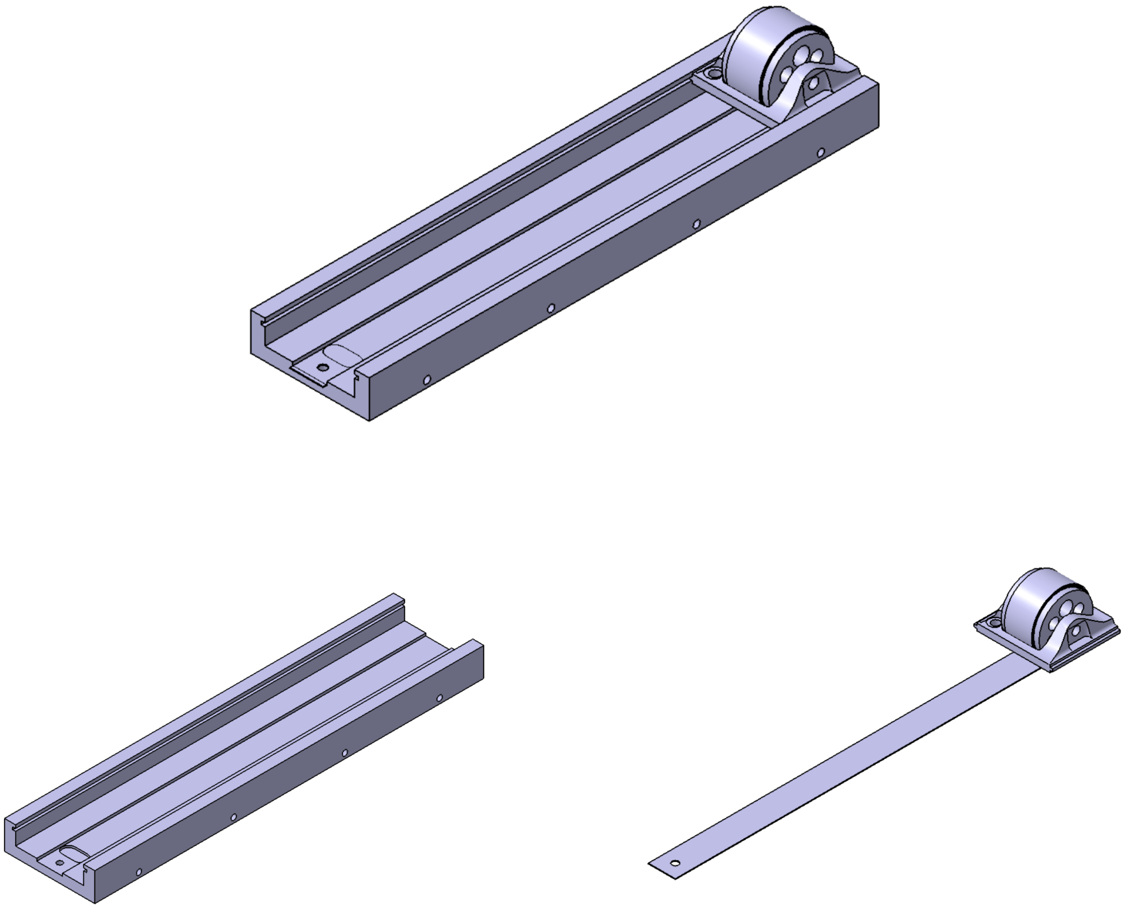


Figure 4.5: Slider-Spring Assembly

4.3.3 Thermal Knife Door Mechanism

The door mechanism was designed to hold the PocketQube satellite in place until deployment. The mechanism uses a thermal knife made of Nichrome wire to cut a Nylon string that holds the door in place, allowing the satellite to be released. The door mechanism was designed to be compact and lightweight, with easy-to-use controls to ensure reliable and efficient deployment.

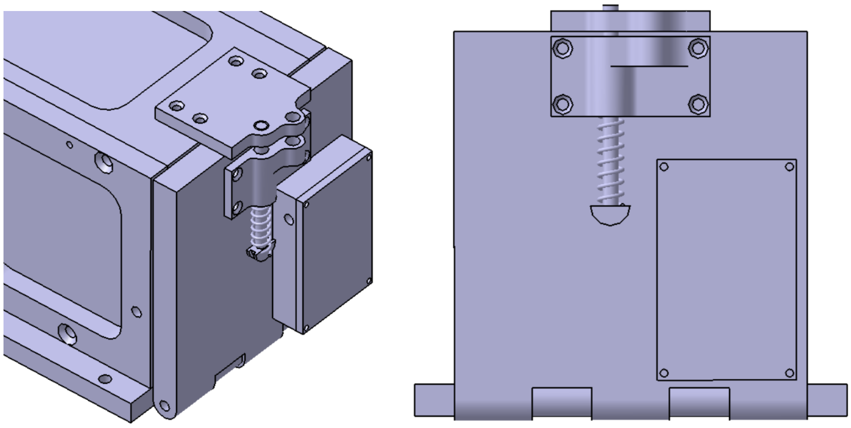


Figure 4.6: Door Assembly

4.3.4 Electronics and Casing

The electronics casing was designed to house the components necessary for controlling the deployer. This includes the Arduino Nano and the MOSFET , as well as any other necessary components. The electronics casing was designed to be thermally resistant as well as compact and lightweight, with easy access for maintenance and upgrades.

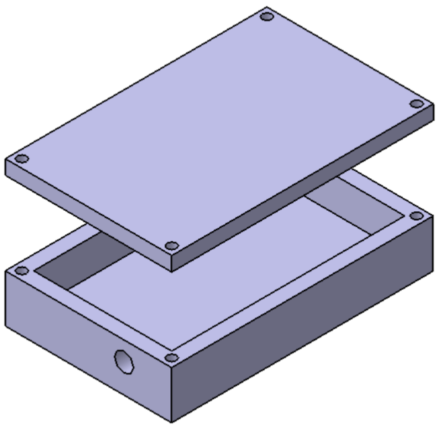


Figure 4.7: Electronics Casing

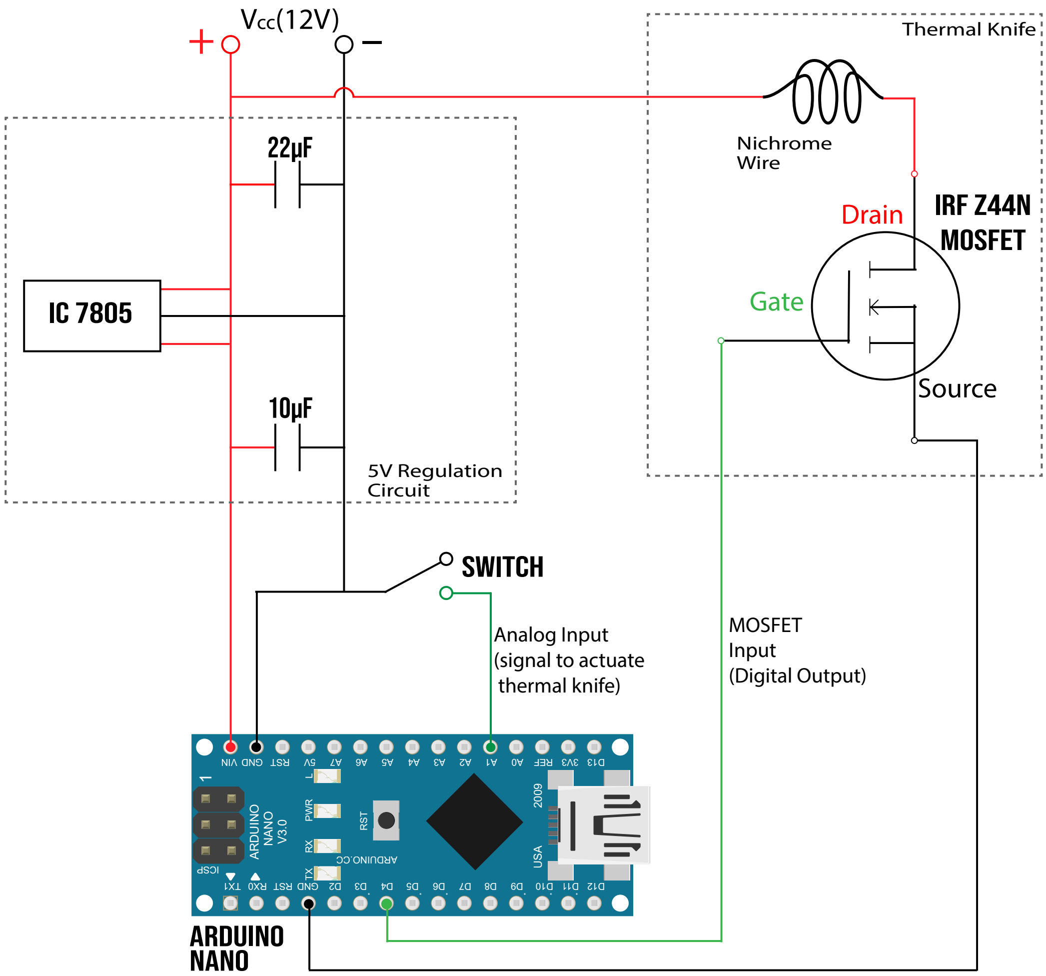


Figure 4.8: Circuit Diagram

4.4 Material Selection

The material selection process for the PocketQube deployer was a crucial step in ensuring the deployer's reliability and functionality. After considering various materials, we decided to use aluminum as the primary material for most of the fabrication.

Aluminum was chosen due to its combination of good strength and low weight, which are essential properties for the deployment process. The deployer must be able to withstand the stress of launching the satellite into orbit while being light enough to minimize the system's overall weight. The use of aluminum also provides several advantages over other possible materials. For example, aluminum has good thermal conductivity, which helps to regulate the temperature of the deployer during use. Additionally, aluminum is corrosion-resistant, which helps to ensure that the deployer remains functional even in harsh environments.

The door of the deployer was also made of aluminum due to its strength and durability, which ensures that the door remains secure and functional during the deployment process. The electronics compartment was also made of aluminum to protect the electronics from the harsh environment of space.

We planned to use 3D printed materials for the pusher as it allows for complex shapes and easy customization. Steel nut and bolt were chosen as fasteners due to their high strength and durability. The aluminum material was selected as it provided a strong and durable rail that could withstand the stress of deploying the satellite into orbit. Additionally, aluminum's lightweight properties helped to minimize the overall weight of the deployer, making it more efficient for launch.

The material selection process for the PocketQube deployer was critical in ensuring the deployer's reliability and functionality. Aluminum was chosen as the primary material for most of the fabrication due to its good strength and low weight. Aluminium was used for the rail of the deployer, and 3D printed materials were used for the pusher, while steel nut and bolt were chosen as fasteners.

4.5 Analysis

4.5.1 Vibration Analysis

- **Reasons for vibration testing**

  The reasons for vibration testing are:

  1. To establish confidence that the satellite can withstand the launch environment and still function afterwards.
  2. To verify compliance with various structural and mechanical requirements, some of which includes:
  3. The satellite payload and hardware can withstand and function well after exposure to highest load.
  4. No loosening of bolts and maintenance of structural integrity as per the criteria mentioned in the satellite testing standards.
  5. Satellite meets the specified constraints on natural frequencies.
  6. No loosening of electrical connectors.

- **Types of Vibration Testing**

  In general, there are three types of vibration testing methods to test any structure for its structural integrity, which are Radom Vibration Testing, Sine Vibration Testing, and Shock Testing.

  1. Random Vibration Testing
     In this type of testing, the satellite is subjected to excitation at all frequencies within a prescribed bandwidth, typically 20 to 2000 Hz. Energy at each frequency is controlled to a specific level. The amplitude of vibration is random with Gaussian distribution around the desired test level.
  2. Sine Vibration Testing
     This type of testing exposes the satellite to sinusoidal excitation at either a singular frequency or a range of frequencies. The sweep rate can be linear or logarithmic. This type of testing is good for analyzing resonance phenomena and modelling situations with dominant narrowband frequency components.
  3. Shock Testing
     This type of testing is utilized to mimic the effects of short-duration, high-amplitude occurrences like impacts, the detonation of pyrotechnic devices, shock waves from large explosions, etc.

  Among the three types of vibration testing methods, Random Vibration Testing provides best simulation of the actual environment the satellite gets exposed to.

- **Vibration Testing: Standards**

  Out of the many different Random Vibration Testing Standards that could be available in the market, two of the following have been referred to for the current design of Vibration Test Mechanism:

  1. ISO 19683:2017 Space systems - Design qualification and acceptance tests of small spacecraft and units.
  2. JX-ESPC-101133-B JEM Payload Accommodation Handbook Small Satellite Deployment Interface Control Document.

  The ISO 19683:2017 is not freely available, while JX-ESPC-101133-B by JAXA (Japan Aerospace Exploration Agency) is freely available, so JX-ESPC-101133-B has been referred extensively through the course of this design.

  Vibration testing is essential to evaluate product performance and durability under real-world conditions. A Vibration Testing Mechanism comprises several critical components that work together to generate, control, and measure vibration accurately. They are:

1. Vibration Actuator
   The vibration actuator is the component responsible for generating the vibration in a vibration testing mechanism. The type of actuator used depends on the application and frequency range required. There are various types of vibration actuators available, including electromagnetic, hydraulic, and piezoelectric actuators. The actuator is typically controlled by a vibration controller, which adjusts the output to achieve the desired vibration level.
2. Vibration Controller
   The vibration controller is a device that regulates the vibration waveform and frequency of the actuator in a vibration testing mechanism. It receives input signals from the accelerometer and adjusts the actuator's output to achieve the desired vibration level. The controller can also measure and record the vibration response of the test object and compare it to the set criteria. The controller is a critical component of the vibration testing mechanism, as it ensures that the vibration is within the desired frequency range and amplitude.
3. Vibration Amplifier
   The vibration amplifier is a device that amplifies the signal from the vibration controller and delivers it to the vibration actuator. The amplifier can adjust the signal's amplitude, phase, and frequency to match the actuator's characteristics and the test requirements. The amplifier is typically required to ensure that the actuator can generate the required level of vibration.
4. Shaker Table
   The shaker table is a platform that supports the test object and transmits the vibration from the actuator to the object in a vibration testing mechanism. The table can have different sizes and shapes, depending on the test object's dimensions and weight. The table's stiffness and resonance frequency should be carefully chosen to ensure accurate and reliable test results. The shaker table is a critical component of the vibration testing mechanism, ensuring that the vibration is transmitted to the test object accurately and consistently.
5. Accelerometer
   The accelerometer is a sensor that measures the vibration response of the test object in a vibration testing mechanism. It can be attached to the object's surface or embedded inside it, depending on the test requirements. The accelerometer's sensitivity, frequency range, and mounting method should be chosen according to the vibration level and the test object's material and structure. The accelerometer

is a critical component of the vibration testing mechanism, as it ensures that the vibration response of the test object is accurately measured and recorded.

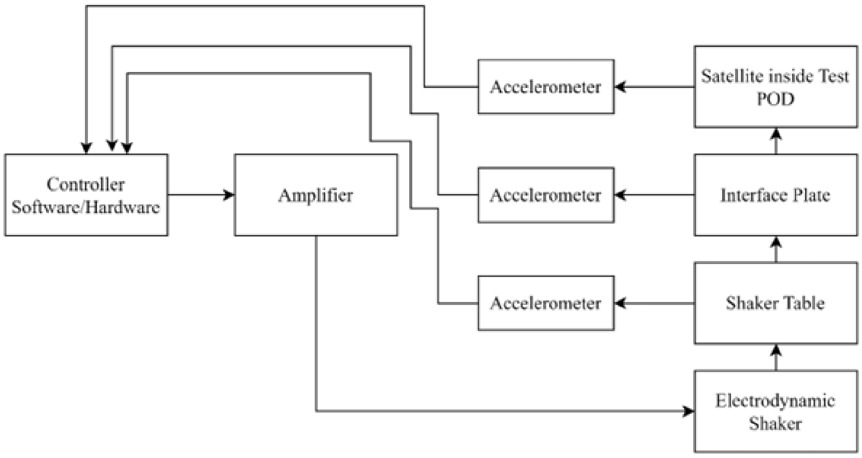


Figure 4.9: Vibration Testing Procedure

Although Vibration Testing Mechanisms are essential for evaluating product performance and durability, they might not be available or accessible in every situation. In such cases, Computational Analysis can be a reliable alternative. For computational analysis, ANSYS was used to perform Modal Analysis and Random Vibration Analysis. These analyses simulated and predicted the product's behavior and performance under various vibration conditions, providing valuable insights for product design and development.

Based on historical data, a rocket's highest estimated vibration frequency is 100 Hz, which varies depending on its acceleration. As a result, the deployer should be capable of withstanding a maximum vibration of 100Hz. The graph below shows the relationship between vibration frequency and acceleration during SpaceX's most recent Falcon 9 and Falcon Heavy launches[19].

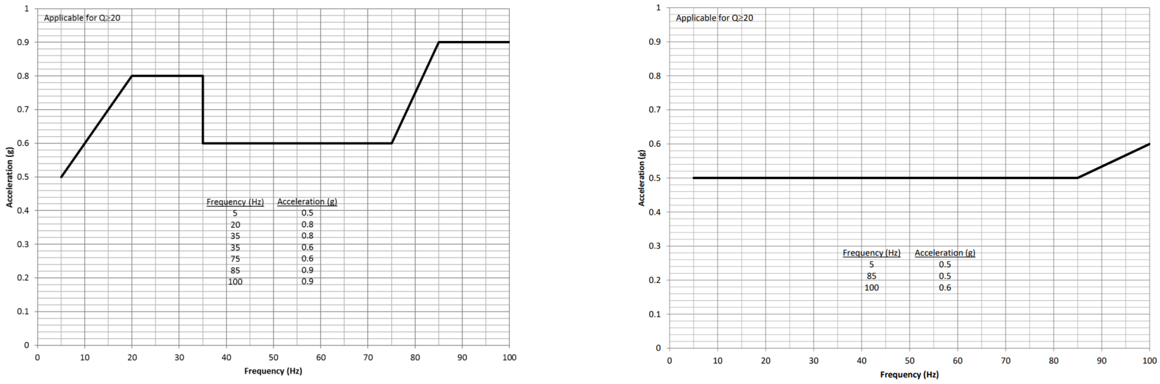


Figure 4.10: Maximum limit level axial and lateral equivalent sine environment for Falcon 9 and Falcon Heavy

(Source: SpaceX, Falcon user guide, 2021)

4.5.2 Thermal Analysis

Thermal analysis of PocketQube Deployer casing was done with the help of ANSYS in steady state thermal system. The theoretical equations that drive steady-state thermal analysis in ANSYS are the heat diffusion equation and the Fourier's law of heat conduction. These equations are fundamental in the field of heat transfer and are used to model the transfer of heat energy within a system. The heat diffusion equation describes how the temperature of a material changes over time due to heat transfer[20]. It is given by:

$$\rho C_p \frac{\partial T}{\partial t} = \nabla(k\nabla T) + Q \tag{4.1}$$

The Fourier's law of heat conduction, on the other hand, describes the rate of heat transfer through a material[20]. It is given by:

$$q = -k\nabla T \tag{4.2}$$

ANSYS was used to solve for the temperature distribution and heat transfer in the deployer, subject to specific boundary conditions and material properties.

A thermal test of a PocketQube deployer casing would involve evaluating the temperature changes and stability of the casing during deployment. This is to ensure that the casing can withstand the thermal environment of space and will not compromise the satellite payload inside. The test would typically simulate thermal conditions during launch and in-orbit and measure the temperature changes at various points on the casing surface, as the temperature varies from -50 to 150 degree Celsius in the Low Earth Orbit[18]. The results of the test would then be used to validate the thermal design and identify any potential issues that need to be addressed.

Different source of thermal inputs are available in the low earth orbit of the earth in the form of solar radiation flux, Albedo of Earth, infrared radiation and their distribution is shown below[18]:

Table 4.2: Thermal Input in LEO

Thermal Input	Thermal Power
Solar radiation flux	1375 W/m^2
Albedo of Earth	35%
Earth IR	237($\pm$21) W/m^2

The PocketQube Deployer in low earth orbit receives direct radiation from Sun which consists majorly of Ultraviolet radiation. The maximum value of this Solar Flux is 1414W/m2. But since this value varies with respect to the orbit inclination angle as well as the location of the Satellite in the orbit the mean value of the flux considered for computation is 1375W/m2.

Albedo of earth refers to the reflectivity of thermal input from the earth and is found to be approximately 35% of solar input which is equal to 481.25W/ m2.

Infrared radiation also acts as a source of Thermal input. The Earth absorbs the IR radiation and emits the same. The average value of this flux is 237W/m2.

4.6 Fabrication

In this project, fabrication of a working model of PocketQube deployer was done using locally available materials for mechanism demonstration purposes. The model consisted of parts like rail, slider-spring mechanism, outer casing, door mechanism, and assembly components. This report provides a detailed description of each of these parts and the materials used in their fabrication.

1. Outer Casing
   The outer casing of the PocketQube deployer serves as the protective covering for the

internal components. The casing was made using acrylic and wood. The wood and acrylic was cut to desired dimensions using a CNC Laser cutter.

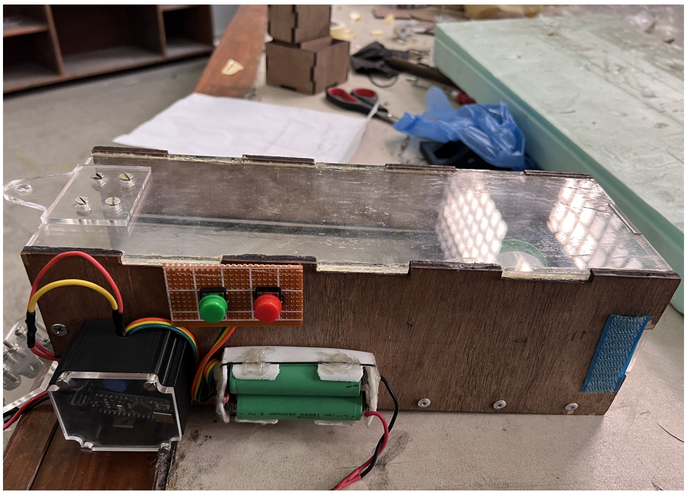


Figure 4.11: PQD Structure

2. Rail
The rail is an essential component of the PocketQube deployer, and it is used to guide the PocketQube into the desired position during deployment. The rail was made using locally available aluminum sections. The aluminum sections were cut to the desired length and assembled using rivets and nut bolts. The rail was then mounted onto the outer casing using rivets.

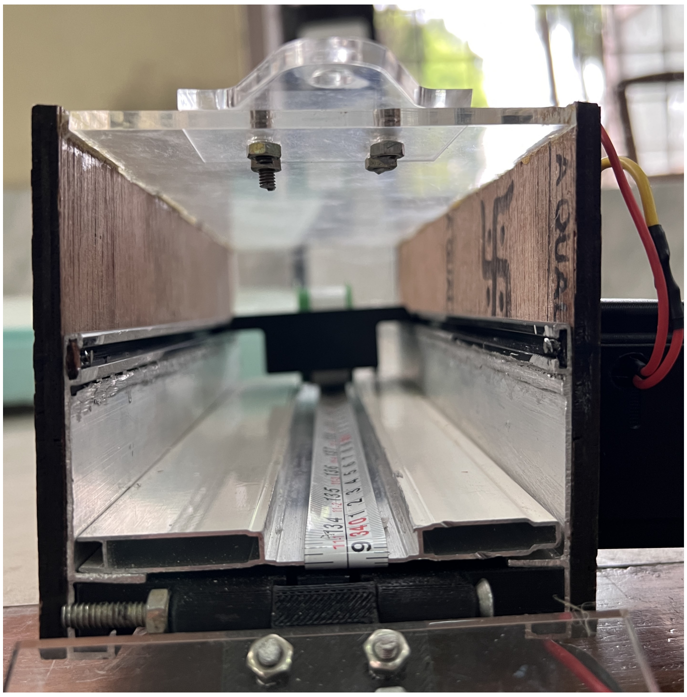


Figure 4.12: Rail

3. Slider-spring Mechanism
   The slider-spring mechanism is another critical component of the PocketQube deployer, and it is responsible for releasing the PocketQube from the rail during deployment. The slider was 3D printed using PLA, which was designed to fit the rail precisely. The spring used in the mechanism was sourced from a powerful measuring tape, which was cut to the desired length and fitted onto the slider. The slider and spring were then assembled and mounted onto the rail.

Figure 4.13: Slider-spring Mechanism

4. Door Mechanism
   Acrylic sheet was used to make the door. The hinges to attach door to the casing was made using 3D printed PLA. Mechanism for opening the door was made using thermal knife consisting of nichrome wire and nylon string.

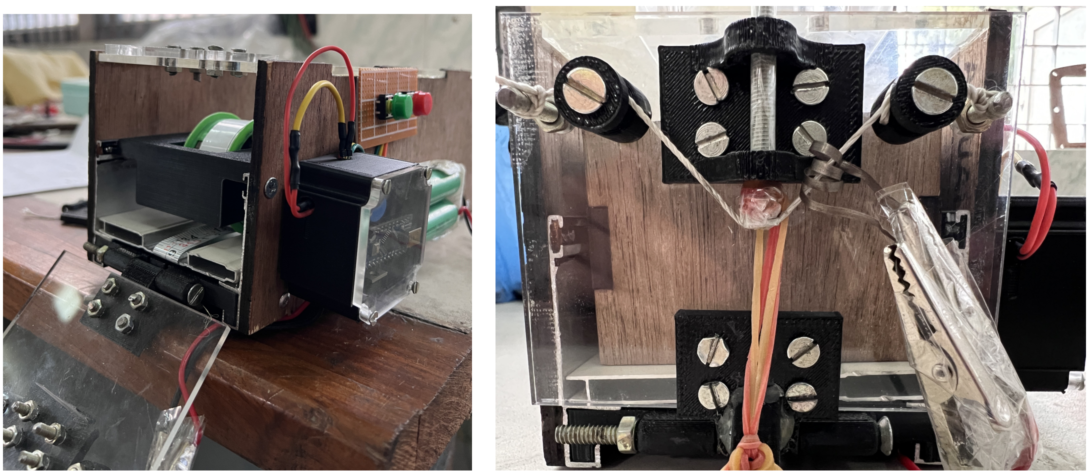


Figure 4.14: Door Assembly and Thermal Knife

5. Electronics Casing
   Electronics casing must be able to insulate the electronics from extreme temperatures. The casing was 3D printed using PLA and its cover was made using acrylic.

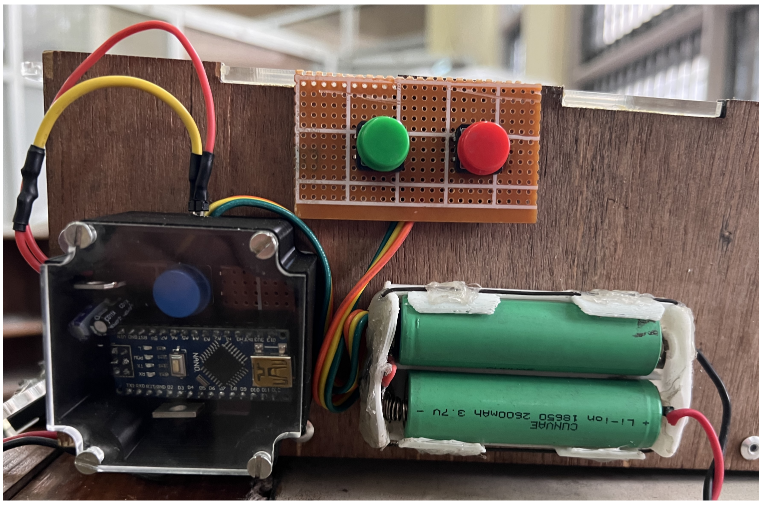


Figure 4.15: Electronics Casing and Assembly

CHAPTER FIVE: RESULTS AND DISCUSSION

The PocketQube deployer successfully demonstrated its ability to deploy PocketQube satellites. The deployer was equipped with a switch, which simulated the deployment signal received by the deployer from launch vehicle. When the switch was pressed, the thermal knife mechanism was actuated, heating the nichrome wire and cutting the nylon thread, initiating the deployment process.

The deployment process was successfully carried out, indicating that the deployer is reliable and functional.

5.1 Deployment Test

The fabricated prototype was put into test in both unloaded and loaded (with 4P PQs) conditions to obtain the velocity during the deployment. The obtained results are:

For unloaded condition,
time taken for deployment =0.45 sec
Distance travelled=0.3m
Velocity during deployment = 0.67m/s

For loaded condition,
time taken for deployment = 0.75 sec
Distance travelled = 0.3m
Velocity during deployment = 0.4m/s

Based on the testing results, it was found that the PocketQube deployer was able to achieve the desired velocity range of 0.6 - 1 m/s only in the unloaded condition, where the velocity was measured to be 0.67 m/s. However, for the loaded condition, the measured velocity was 0.4 m/s, which was lower than the desired range.

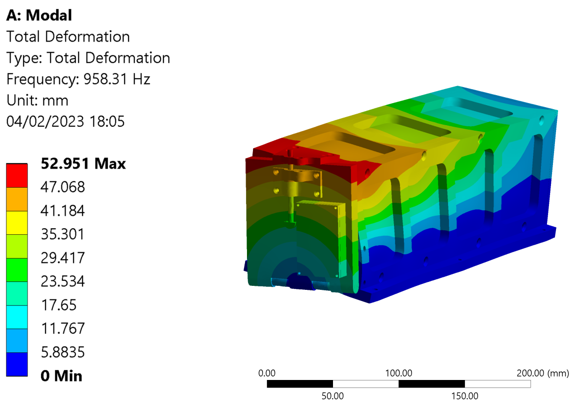
This discrepancy in velocity between the unloaded and loaded conditions can be attributed to the spring used in the deployer mechanism. It was found that the locally available spring used in the testing was not strong enough to achieve the desired velocity in the loaded condition. However, it is expected that the desired velocity range can be achieved with a more powerful spring

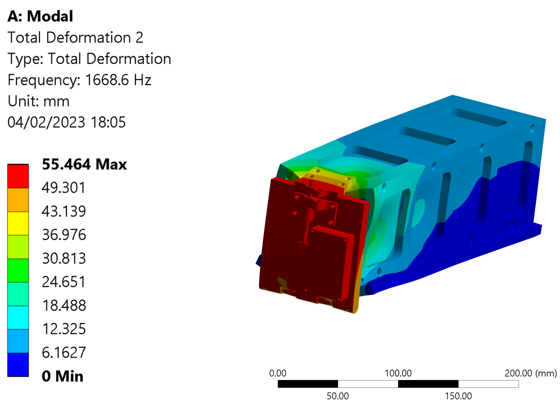
5.2 Analysis Results

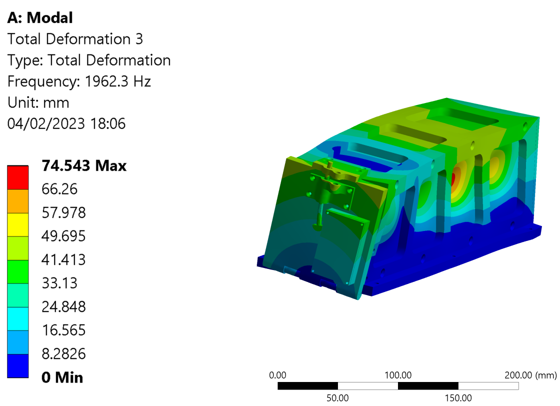
5.2.1 Vibration Analysis

1. Modal Analysis

   To perform this analysis, modal analysis was conducted using ANSYS Workbench. The modal analysis calculated the six natural frequencies of the structure, which provided important information about its dynamic behavior. These natural frequencies were then used in the random vibration analysis, where the response of the structure was simulated under realistic launch conditions.







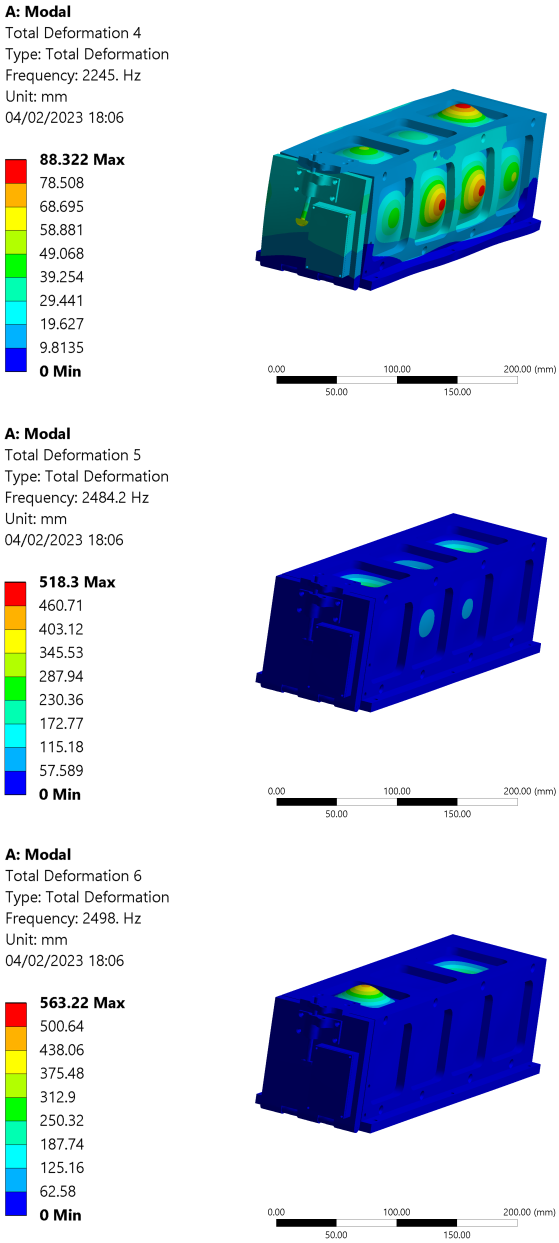


Figure 5.1: Six Modes of Vibration

In the modal analysis 6 modes of vibration of PocketQube deployer are 958 Hz, 1668 Hz 1962 Hz 2245Hz 2484 Hz and 2498 Hz. All the six modes of vibration of the PocketQube deployer are above 120Hz which is the requirement of vibration of PocketQube deployer according to JAXA.

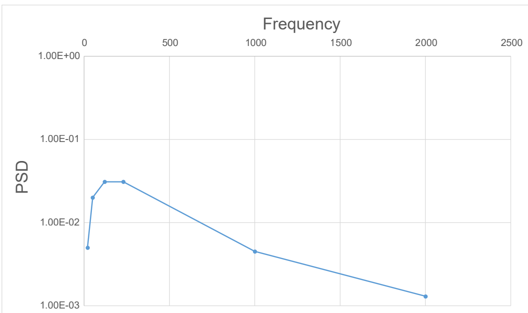
Since deployer experiences different type of external loads, structure should be able to handle variety of vibrations, so a random vibrational analysis of structure is done using PSD (Power Spectral Density) which gives value about the amount of vibrational energy content in the structure during vibration. The lower the frequency, the greater the vibrational energy content in the structure and vice versa.

2. Random Vibrational Analysis

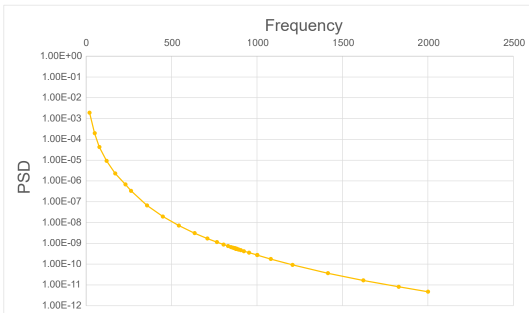
   The random vibration analysis was used to calculate the Von Mises stress, deformation, and PSD (Power Spectral Density) response in the structure. The PSD response was evaluated using the PSD versus g-acceleration value, which provided insight into the distribution of the vibrational energy in the structure. The results of this analysis helped to understand the dynamic behavior of the PocketQube deployer and identify any potential weaknesses in the design that could be improved for better performance and reliability.

   PSD graph is a useful for analyzing signals in various applications, such as noise analysis, vibration analysis, and audio signal processing. It can help to identify the presence of unwanted frequencies, such as noise or interference, and can be used to design filters to remove these frequencies from the signal.In a PSD graph, the x-axis represents the frequency range of the signal, and the y-axis represents the power density (or amplitude squared) at each frequency. The shape of the PSD graph provided insights into the frequency components present in a signal and how they contribute to the total energy.

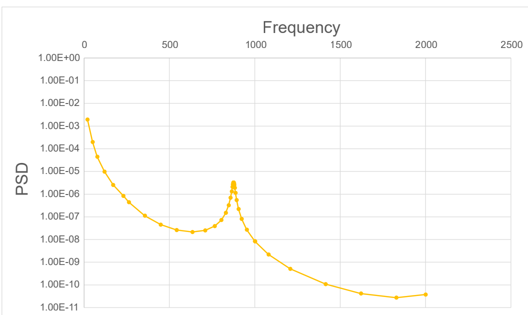
   The PSD graph was used to represent the distribution of power (or energy) present in a signal as a function of frequency. It provided information about the spectral content of a signal and was used to analyze signals in the frequency domain.



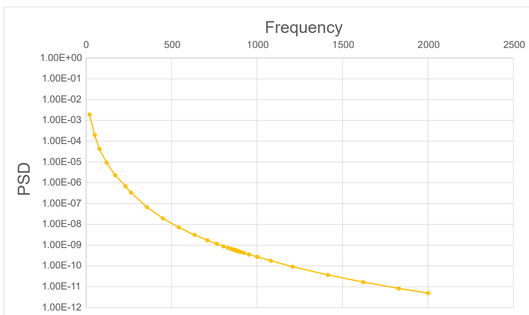
(a) Input



(b) Output(X-direction)

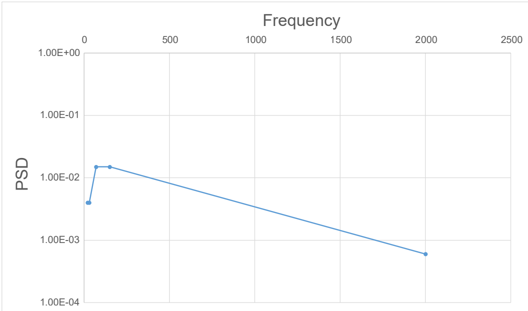


(c) Output(Y-direction)

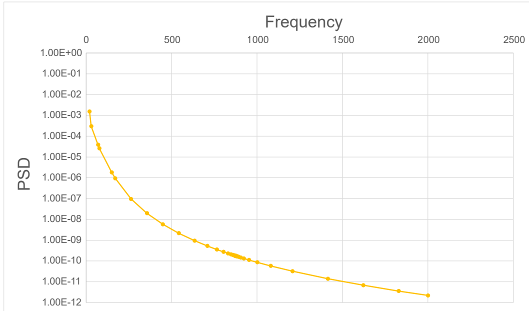


(d) Output(Z-direction)

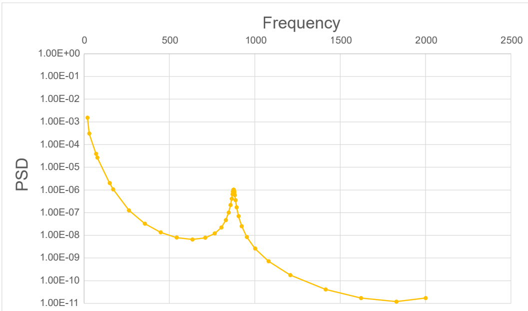
Figure 5.2: PSD Response of HTV-X



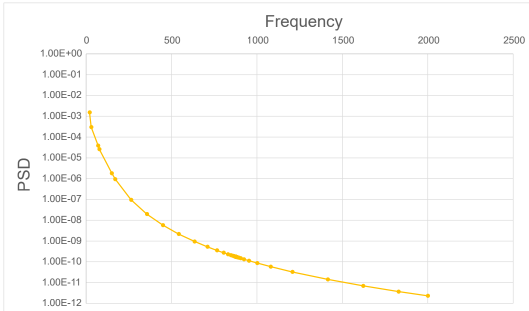
(a) Input



(b) Output(X-direction)

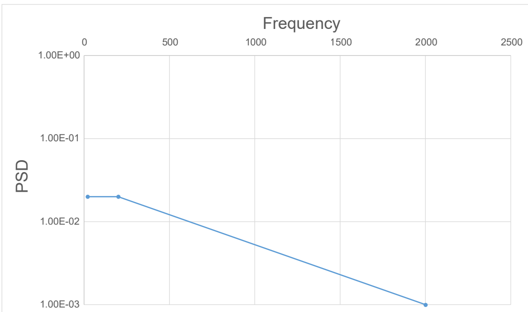


(c) Output(Y-direction)

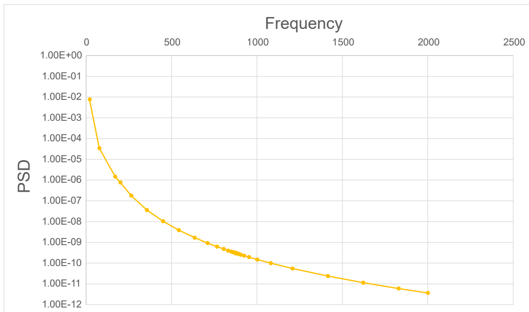


(d) Output(Z-direction)

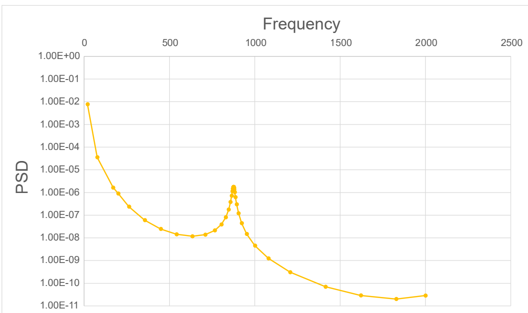
Figure 5.3: PSD Response of Cygnus



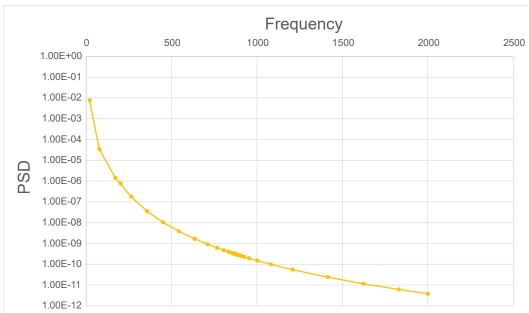
(a) Input



(b) Output(X-direction)



(c) Output(Y-direction)



(d) Output(Z-direction)

Figure 5.4: PSD Response of Dragon

Modal analysis and random vibration analysis have been conducted on the PQD with a given PSD value. The results of the analysis indicate that the PQD is able to withstand the random vibration test and all the tests were successful. Modal analysis has helped to identify the natural frequencies and corresponding mode shapes of the deployer, which is important for predicting the behavior of the structure under different loading conditions. Random vibration analysis has provided insights into the structural response of the deployer under realistic vibration environments. These analyses are essential for ensuring the structural integrity and reliability of the PQD, and they have demonstrated that the deployer is capable of meeting the necessary performance requirements.

5.2.2 Thermal Analysis

(a) Steady State Analysis at High Temperature

When the PocketQube Deployer is facing direct sunlight, all the three source of thermal input acts on the Deployer casing. These thermal input acts as boundary condition for the steady state thermal analysis and are evaluated for the six sides of PocketQube Deployer.

Table 5.1: Boundary conditions at high temperature

Part	Thermal Source	Magnitude(W/m^2)
Two faces exposed to sun	All three	2093.25
Top face	IR	237
Bottom face	Albedo of Earth + IR	718.25
Two faces not exposed to sun	Albedo of Earth + IR	718.25

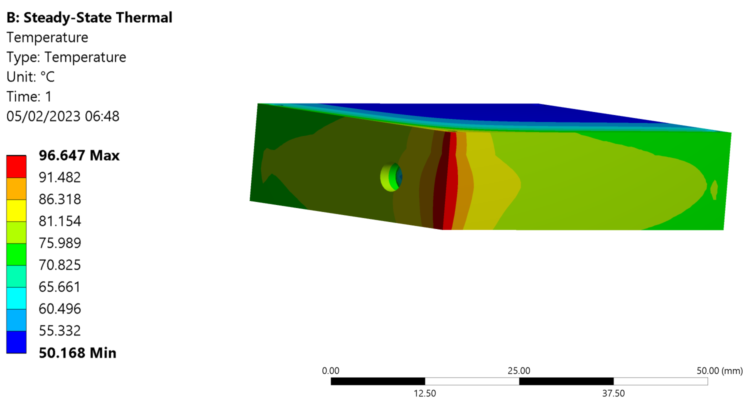


Figure 5.5: High temperature distribution in outer surface

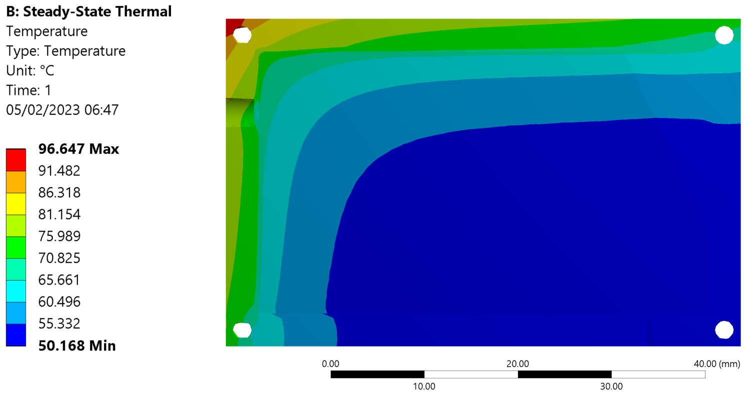


Figure 5.6: High temperature distribution in inner surface

(b) Steady State Analysis at Low Temperature

When the deployer is not facing direct sunlight, source of thermal input acting on the deployer casing are Albedo of Earth and IR whereas solar radiation flux do not acts as thermal input in this case. These thermal input acts as boundary condition for the steady state thermal analysis and are evaluated for all the six sides of deployer.

Table 5.2: Boundary conditions at low temperature

Part	Thermal Source	Magnitude(W/m^2)
Top face	IR	237
All remaining faces	Albedo of earth + IR	718.25

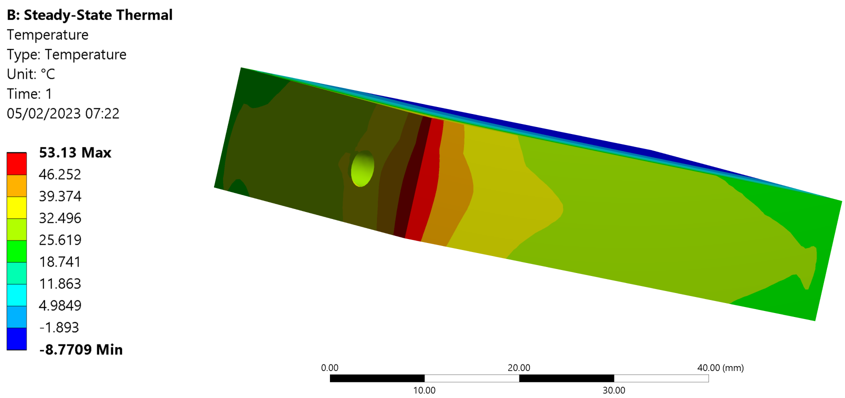


Figure 5.7: Low temperature distribution in outer surface

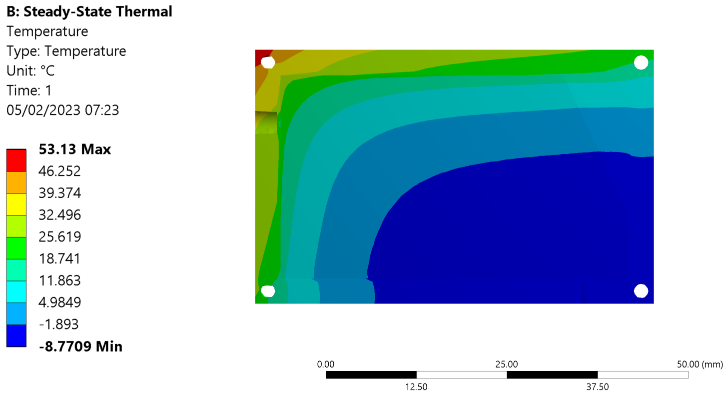


Figure 5.8: Low temperature distribution in inner surface

Based on the thermal analysis of the electronic casing for the PQD, it was found that the temperature on the inner surface of the casing was within the working temperature range of all electronic components. The extreme values of temperature provided were -50 and 150 degrees, but the extreme values recorded inside the casing were -15 and 70 degrees. Therefore, it can be concluded that the electronic casing is able to maintain a safe operating temperature range for the electronic components within it.

5.3 Bolt Calculation

The results obtained from random vibrational analysis was used to calculate the required grade of bolt.

Max stress $\approx$ 10 MPa (Von-Mises Stress From ANSYS)

Design load = Maximum stress x Curved surface area of hole

Curved surface area of hole = $2.5x10^{-4}$

Design Load = 2.5 kN

No. of Bolts = $\dfrac{Design\ load}{Design\ tensile\ capacity\ of\ bolt}$

For 1 bolt,

Design tensile capacity of bolt (F_t) = Design load

So,

Design tensile capacity of bolt (F_t) = 2.5 kN

$$F_t = \frac{0.9 * f_{ub} * A_s}{\gamma}$$

$$A_s = \frac{\pi}{4}(d - 0.9382 * pitch)^2$$

Pitch = 0.5mm, d = 4mm, γ = 1.25

$A_s = 9.787\ mm^2$

Now,

Ultimate tensile stress $f_{ub} \approx$ 355 MPa

Table 5.3: Bolt classification

	Bolt Class						
Description	4.6	4.8	5.6	5.8	6.6	8.8	10.9
Yield Strength(MPa)	240	320	300	400	480	640	900
Ultimate Tensile Strength(MPa)	400	400	500	500	600	800	1000

The obtained ultimate tensile stress value was within 400 MPa, so bolt of grade 4.6 is sufficient.

5.4 Results Validation

The design, analysis and fabrication of the PQD has fulfilled the following requirements:

1. The design requirements were successfully fulfilled, and the structure was able to withstand vibration and all expected loads.
2. The natural frequency of the structure was found to be more than 120Hz, meeting the requirement.
3. The deployment velocity was found to be 0.4 m/s in loaded condition.
4. The results of the vibration analysis indicate that the PQD is able to withstand the random vibration test for given PSD values.
5. The temperature range inside the electronic casing was found to be -15 to 70 degree Celsius, which is within the working temperature range of all electronic components.
6. The thermal knife mechanism was successfully tested and found to work as intended.
7. The rail spring mechanism was successfully tested and found to work properly.
8. The door mechanism was successfully tested and found to be functional.

Overall, these results demonstrate the successful design and testing of all the mechanisms, meeting all design requirements and specifications.

5.5 Problems Faced

1. Lack of Reference Documents
   The limited availability of relevant documents and technical information, which made it difficult to gain a comprehensive understanding of the design and construction of PocketQube deployers.

2. Unavailability of Proper Fabrication Tools
   The lack of access to the specialized tools required for fabrication, which made it difficult to produce a functional prototype of the deployer.

3. Unavailability of Required Materials
   The limited availability of the materials required for the construction of the deployer, which impacted the feasibility and cost-effectiveness of the project.

4. Budget Constraints
   The limitations of the project budget, which restricted the resources available for fabrication and testing.

5. Technical Challenges
   The technical challenges associated with designing, analyzing, and fabricating a deployer, including the complexity of the mechanism and the precision required for successful deployment.

CHAPTER SIX: CONCLUSION AND FUTURE ENHANCEMENT

6.1 Conclusion

The project aimed to design and analyze a pocketqube deployer, and while the final product was fabricated using locally available materials such as plywood, acrylic, and 3D printed parts for demonstration purposes, the results were promising.

The design and analysis process involved a thorough assessment of the requirements and constraints of the project, as well as the selection of appropriate materials and fabrication methods to ensure a functional and reliable product.

The deployment mechanism was successfully tested and demonstrated, showing that the design and analysis phase had been effective in producing a working product. However, further testing and optimization may be required to ensure the reliability and durability of the product over the long term.

Overall, the project successfully demonstrated the feasibility of using locally available materials to produce a functional model of pocketqube deployer for testing all the mechanisms, and provided a foundation for future development and optimization.

6.2 Future Enhancement

1. Vibrational testing of the PocketQube Deployer can be done using an electrodynamic shaker on a shaker table. The deployer should be subjected to a number of vibrational frequencies experienced during launch and deployment to ensure it can handle these frequencies without damage to any structure.
2. Thermal testing of the PocketQube Deployer can be done in a thermal vacuum chamber to simulate the vacuum and temperature conditions of space, including extreme low and high temperatures.The deployer should be able to handle these thermal conditions without damage or performance degradation.
3. A small communication system can be set up in the deployer to track the condition of the deployer from its launch to its deployment in the launch vehicle.
4. Alternative materials can be explored to find more lightweight and durable options for the fabrication of the deployer.

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APPENDIX

A Drafting

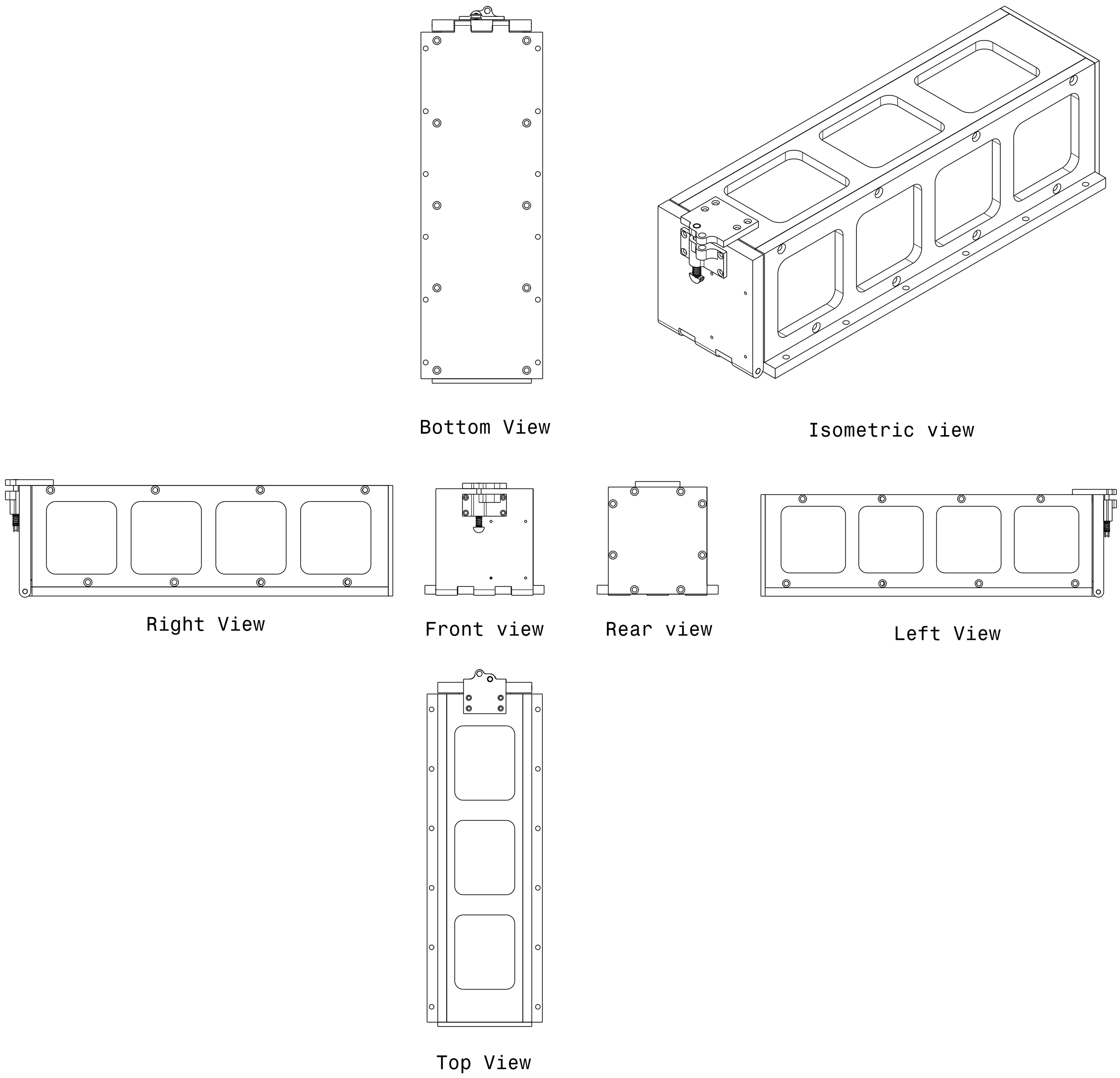

Figure A.1: Assembly Drafting

A.1 Slider-Rail

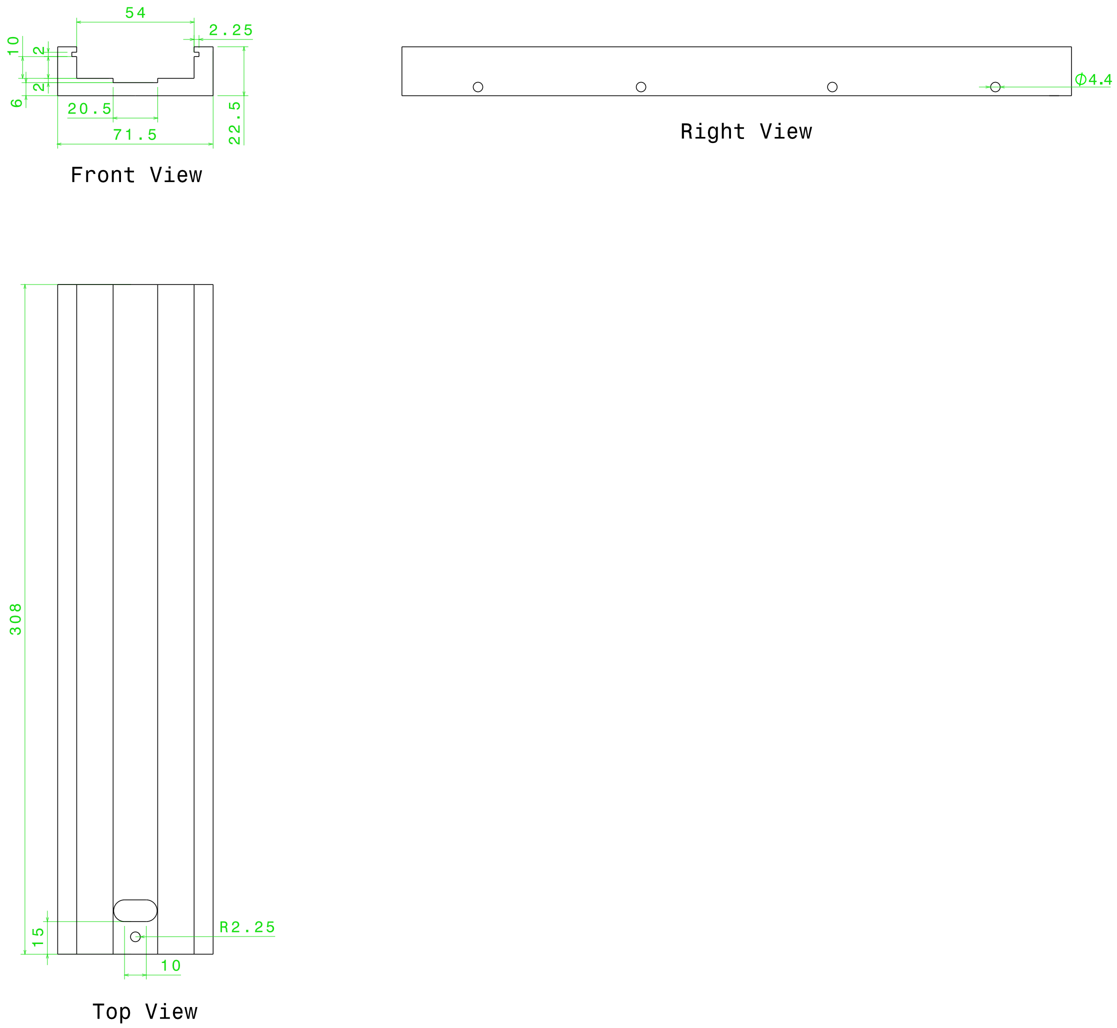

Figure A.2: Rail

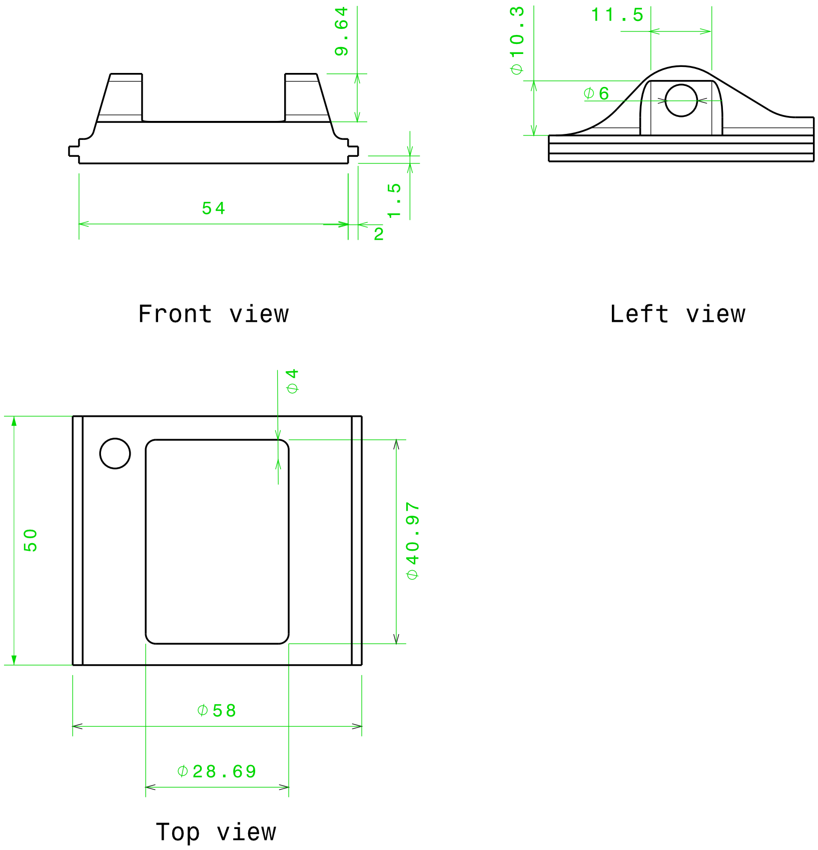

Figure A.3: Slider

A.2 Outer Casing Structures

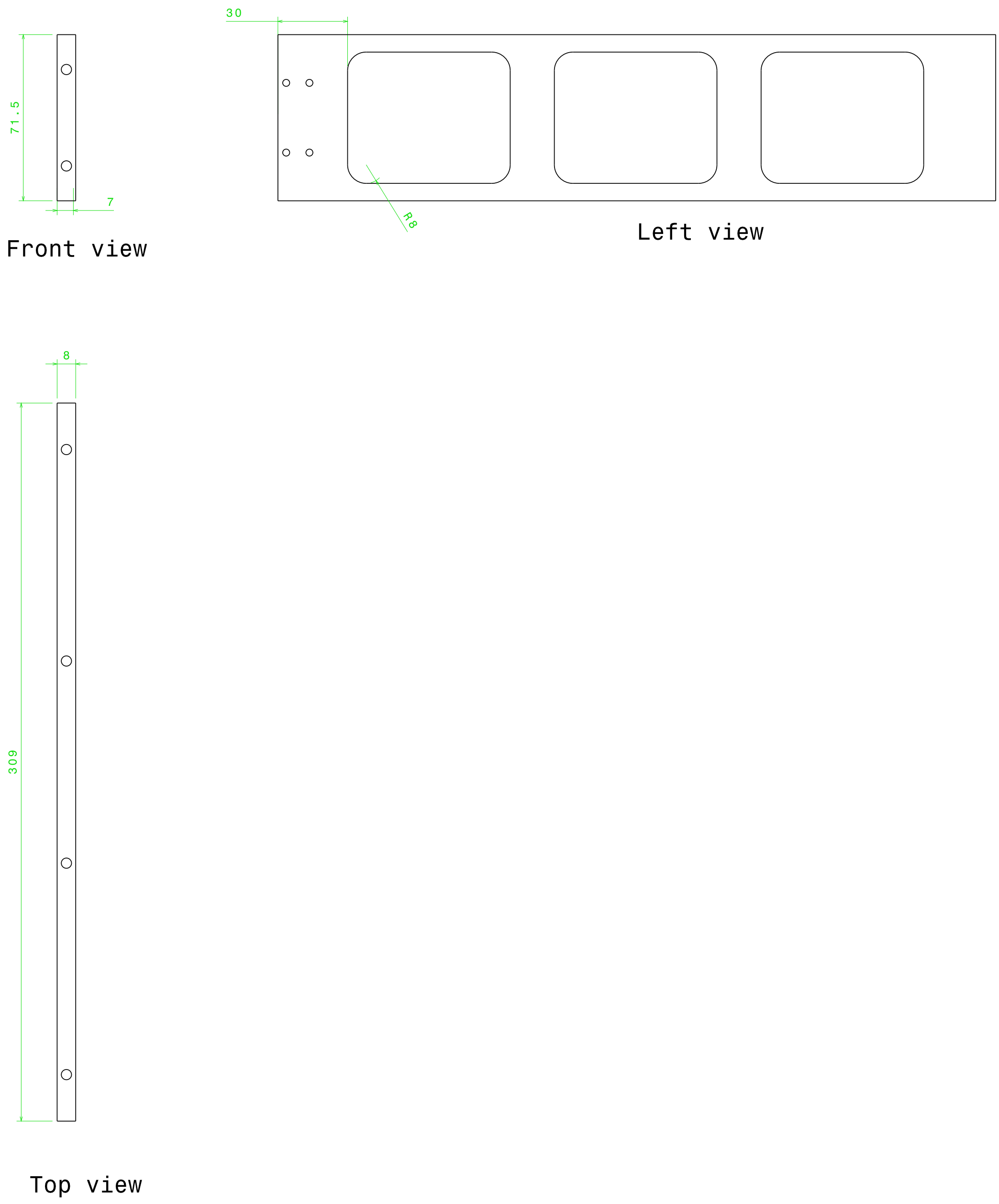

Figure A.4: Top Plate

Figure A.5: Bottom Plate

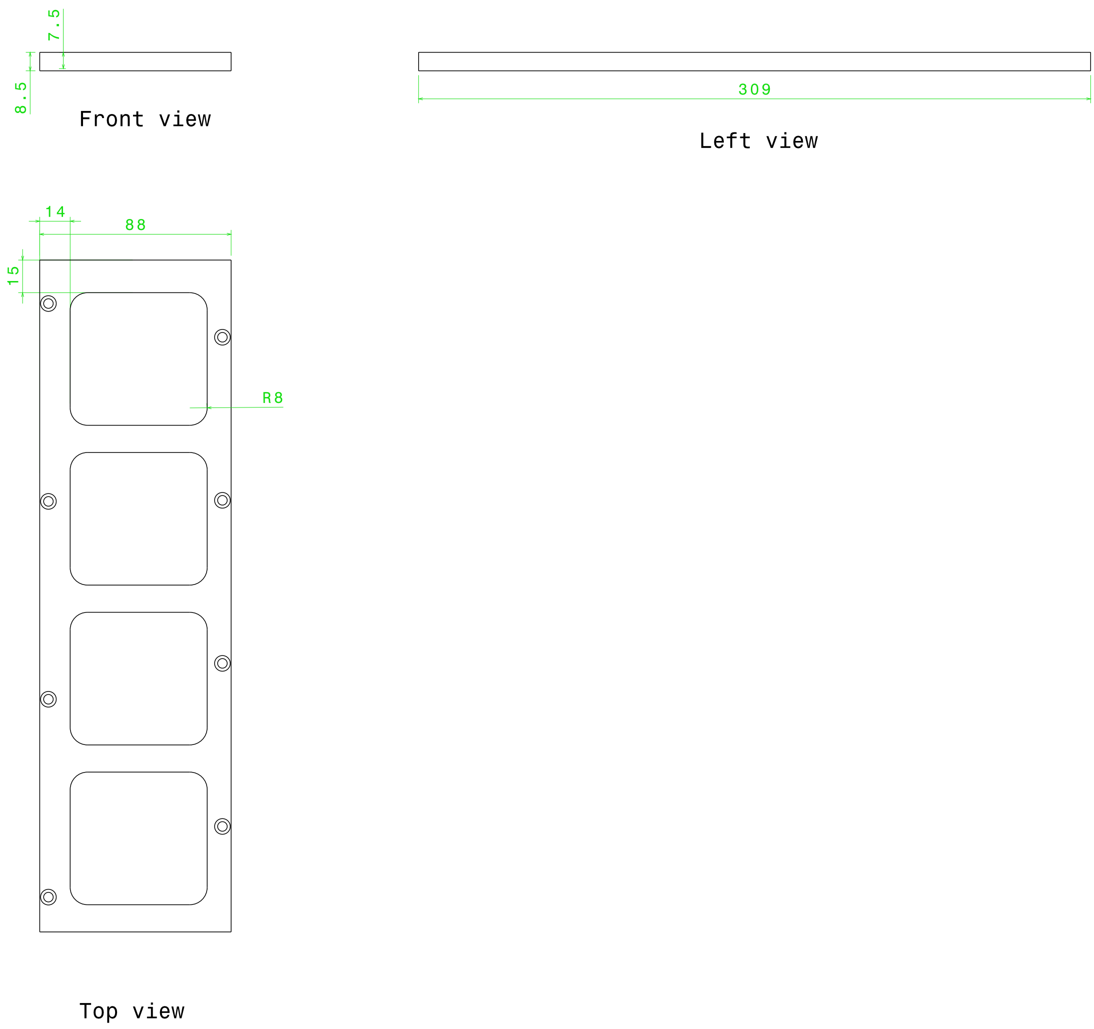

Figure A.6: Side Plate

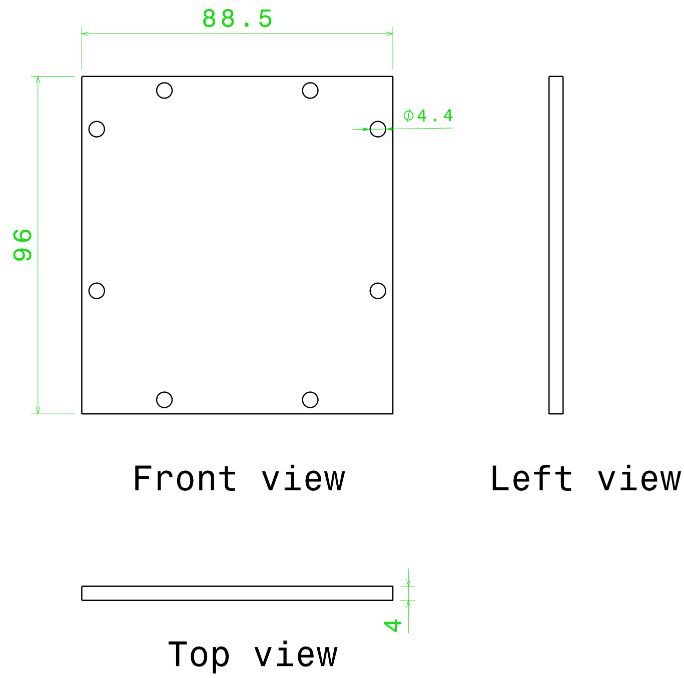

Figure A.7: Back Plate

A.3 Electronics Casing

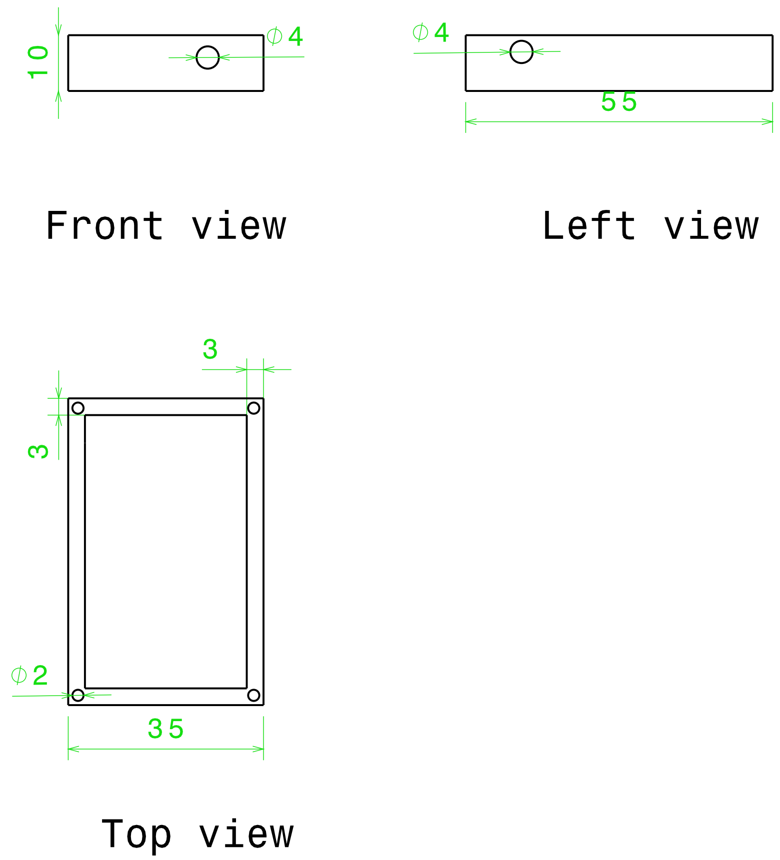

Figure A.8: Electronics Casing

B Arduino Code for giving deployment signal to the MOSFET

```
int LED=4;
int SW1=A1;
int SW2=A2;
void setup()
{
    pinMode(LED, OUTPUT);
    pinMode(SW1, INPUT);
    pinMode(SW2, INPUT);
    digitalWrite(SW1, HIGH);
    digitalWrite(SW2, HIGH);
}
void loop()
{
    int sw1=digitalRead(SW1);
    int sw2=digitalRead(SW2);
    if(sw1==LOW)
        {
        digitalWrite(LED, HIGH);
        delay(9000);
        }
    else
        {
        digitalWrite(LED, LOW);
        }
    if(sw2==LOW)
        {
    digitalWrite(LED, LOW);
}
}
```