



**TRIBHUVAN UNIVERSITY  
INSTITUTE OF ENGINEERING  
PULCHOWK CAMPUS**

**DESIGN AND FABRICATION OF ELASTIC-DRIVEN UNMANNED AERIAL  
VEHICLE(UAV) LAUNCHER**

**BY:**

**Avinash B.K (076BME003)**

**Poonam Limbu (076BME009)**

**Manush Giri (076BME020)**

**Sudarshan Poudel (076BME043)**

**A PROJECT REPORT**

**SUBMITTED TO THE DEPARTMENT OF MECHANICAL AND  
AEROSPACE ENGINEERING IN PARTIAL FULFILLMENT OF THE  
REQUIREMENT FOR THE DEGREE OF BACHELOR IN MECHANICAL  
ENGINEERING**

**DEPARTMENT OF MECHANICAL AND AEROSPACE ENGINEERING  
LALITPUR, NEPAL**

**APRIL 2024**



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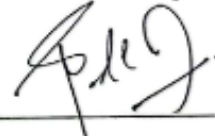
# LETTER OF APPROVAL

**TRIBHUVAN UNIVERSITY  
INSTITUTE OF ENGINEERING, PULCHOWK CAMPUS  
DEPARTMENT OF MECHANICAL AND AEROSPACE ENGINEERING**

The undersigned certify that they have read, and recommended to the Institute of Engineering for acceptance, a project report entitled "DESIGN AND FABRICATION OF ELASTIC DRIVEN UNMANNED AERIAL VEHICLE (UAV) LAUNCHER" submitted by Avinash B.K., Poonam Limbu, Manush Giri, Sudarshan Poudel in partial fulfillment of the requirements for the degree of Bachelor of Mechanical Engineering.



Supervisor, Sanjaya Neupane  
Assistant Professor  
Department of Mechanical and Aerospace Engineering  
IOE, Pulchowk Campus



External Examiner, Er. Sanjiv Paudel  
Managing Director  
Machine Hub Nepal



Committee Chairperson, Dr. Sudip Bhattarai  
Assistant Professor  
Head, Department of Mechanical and Aerospace Engineering  
IOE, Pulchowk Campus

Date: 2024/04/10

## **ABSTRACT**

Unmanned Aerial Vehicles (UAVs) have proven indispensable in various applications, from surveillance to environmental monitoring. UAV deployment efficiency is critical for fast reaction and better mission capabilities. This project offers an Elastic Driven UAV Launcher, which is intended to provide a reliable and fast launch mechanism for UAVs in a variety of settings. To push UAVs into the air, the launcher uses an Elastic-based technology, eliminating the need for standard propulsion techniques such as gas or electric motors. This breakthrough promises to minimize launch complexity, and operating costs. The system's architecture has an elastic mechanism capable of effectively storing and releasing energy. The launcher may be adapted to different UAV sizes with weights up to 10kg, ensuring compatibility with a wide range of UAV types. Different launch tests for a load of 2.6kg and a 10-degree launching angle resulted in a launch speed of 6.25m/s and an error of 65.8% using 3 elastic bands, whereas a launch speed of 3.23 m/s and an error of 46.8% using 2 elastic bands respectively. The results of the fabrication and experimental testing demonstrate the launcher's performance in terms of launch velocity precision, and repeatability. Finally, the Elastic-Driven UAV Launcher represents a possible path forward for UAV deployment technologies, stressing efficiency, adaptability, and sustainability. Further research and development might improve the concept and broaden its usefulness across a range of UAV tasks, aiding in the growth of airborne deployment systems.

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## **LIST OF ABBREVIATIONS**

**UAV** Unmanned Aerial Vehicle

## LIST OF SYMBOLS

$\alpha$  Alpha Angle

$\mu$  Rolling Frictional Coefficient

$M_c$  Mass of Carriage

$M_u$  Mass of UAV

$M$  Combined mass of carriage and UAV ( $M_c + M_u$ )

$N$  Normal Reaction

$L$  Length of the track

$V_f$  Exit velocity of the UAV

$H$  Vertical height from ground to tip of Launcher

$K_{eq}$  Equivalent Stiffness of the Elastic band

$X$  Extension of the Elastic band

$d$  Horizontal distance between legs

$W_{ext}$  External Work done

$\Delta K$  Change in Kinetic Energy

$\Delta U$  Change in Potential Energy

## CHAPTER 1: INTRODUCTION

### 1.1 Background

Catapult launch systems have been around for a long time, even before the advent of aircraft. The idea of propelling an aerodynamic object by giving it kinetic energy dates back to the ancient hunting bow[1]. The Wright Brothers used a weight and pulley system to launch the first powered, heavier-than-air flight in 1903[2]. Nowadays, aircraft carriers typically use steam catapults and, more recently, electromagnetic catapults to launch aircraft. Small unmanned aircraft usually weigh under 200 pounds.[3]. The reasons to catapult launch a UAV are various and may include:

- The aircraft's limited range necessitates its deployment close to the area of interest, where suitable infrastructure may not be available. runway.
- A proper runway might not be a luxury available to the developer.
- The aircraft's design might prevent it from having the necessary gear for a conventional takeoff.

An aircraft catapult launch system aims to achieve two objectives: providing the aircraft with sufficient kinetic energy and doing so without damaging its structural integrity[4]. This paper examines three primary types of launchers: weight and pulley launchers, spring launchers, and pneumatic launchers[5]. Weight and pulley systems are noted for their simplicity, usually do not need a dissipation system, and are appropriate for very small aircraft. Spring launchers are also lightweight and simple but are similarly limited to very small aircraft[6]. Pneumatic launchers can accelerate heavier aircraft to high speeds while maintaining a lighter system weight compared to weight and pulley systems, and they apply gentler loads than spring-based systems. Understanding how these launch systems interact with the aircraft is essential for designing a compact and robust launch system.[7] Despite significant advances in electromagnetic launch systems, they may be too costly or require too many custom parts for smaller UAV operators.[8]



Figure 1.1: The launch of a de Havilland Queen Bee target drone.[9]

Historically, unmanned aerial vehicle launches have relied on either a heavy, trailer-mounted catapult system or a pre-built runway surface, both of which are impractical for remote operations. While runway systems and trailer-mounted catapults perform their intended functions well, they are ill-equipped to launch unmanned, remotely piloted aircraft in distant locations because they do not offer a lightweight, portable mechanism that can be transported and operated by one person. Various types of UAV launchers are employed based on the UAV's size, weight, and mission requirements. Rubber-driven catapults, utilizing elastic elements, are common for small planes. Pneumatic launchers, driven by compressed air, find application in launching UAVs of small to medium size. Steam-driven launchers are reserved for larger flying objects, often used on aircraft carriers. Additionally, rocket propulsion is employed for tactical objects, especially in military applications. Notably, research on electrically powered launchers has gained popularity, addressing challenges related to energy accumulation and motion control. Despite the variety of launchers available, the demand for lightweight, portable launch mechanisms that can be operated by individuals is evident. The focus on operator safety, energy efficiency, and the adaptability of launchers to different UAV sizes has led to the

exploration of elastic band-driven UAV launchers.[10]

The accumulation of energy stands out as a primary technical challenge in UAV launchers. While existing solutions rely on potential energy storage (e.g., capacitors, batteries, pressure tanks, elastic elements), the exploration of kinetic energy storage through rotating flywheels has gained attention. The development of launchers powered by kinetic energy, particularly using rotating flywheels and electromagnetic clutches, presents new possibilities for efficient and reliable UAV launches.

The concept of an Elastic rope launcher involves utilizing elastic ropes as energy storage devices for launching UAVs with controlled acceleration. The exploration of elastic rope drive UAV launchers represents a step towards addressing the evolving needs of UAV operations, ensuring precise, autonomous, and safe takeoffs in various environments. The exploration of elastic rope drive UAV launchers represents a step towards addressing the evolving needs of UAV operations, ensuring precise, autonomous, and safe takeoffs in various environments.

Traditionally launching unmanned aerial vehicles is achieved by operating from a heavy, trailer-mounted catapult system or pre-constructed runway surface that is not practical for remote surfaces. When considering the utilization of a runway surface, it's essential to acknowledge that such a surface typically isn't accessible for remote operations.

## **1.2 Problem Statement**

The UAV launcher market is dominated by expensive options like pneumatic systems, posing a financial hurdle for many potential users. This project aims to overcome this challenge by developing a cost-effective alternative, making UAV technology more accessible.

The design and simplicity of this project are open to allow for easy modifications and enhancements, facilitating the integration of future advancements without the need for complete system replacements.

Additionally, maintenance and repair of existing UAV launchers can be time-consuming and disruptive due to complex designs. This project emphasizes ease of maintenance and replacement, featuring a disassemble-friendly design and readily replaceable parts to minimize downtime and operational disruptions.

Sourcing materials for UAV launcher fabrication can also be a challenge, often requiring costly imports. In contrast, this project utilizes materials within Nepal, promoting sustainability and supporting local industries.

Moreover, the absence of easily accessible UAV launchers limits opportunities for engineering students to engage in research and experimentation. This project aims to fill this gap, providing a practical solution that empowers students to explore UAV-related studies and projects more readily.

### **1.3 Objectives**

#### **1.3.1 Main Objectives**

Design and Fabricate an Elastic-driven Unmanned Aerial Vehicle(UAV) Launcher.

#### **1.3.2 Specific Objectives**

- i. To develop a UAV launcher with the capability to launch UAVs of variable weight efficiently.
- ii. To implement a precision mechanical adjustment mechanism to vary launch velocities, accommodating diverse UAV speed requirements.
- iii. To integrate a flexible launch angle adjustment mechanism for adaptability to different operational scenarios.
- iv. To conduct thorough performance testing.

### **1.4 Scope**

The UAV Launching System Market presents a spectrum of opportunities driven by the burgeoning demand for unmanned aerial capabilities across both defense and civilian sectors. In the defense domain, the market benefits from the increasing adoption of UAVs for intelligence, surveillance, and reconnaissance purposes, as well as for combat missions. Furthermore, the expanding use of UAVs in civilian applications, such as agriculture, infrastructure inspection, and disaster management, propels the market's growth. As technology advancements continue, there are opportunities for innovation in

launching system designs, emphasizing portability, rapid deployment, and compatibility with evolving UAV technologies. The segmentation of the UAV Launching System Market is nuanced, considering factors such as launch mechanism types, payload capacity, and compatibility with different UAV models. This segmentation allows for targeted solutions that cater to the diverse needs of end-users, ranging from military agencies and law enforcement to commercial enterprises and research institutions, thereby contributing to the market's resilience and adaptability in a dynamic landscape.

## **1.5 System Requirements**

### **1.5.1 Lathe Machine**

A lathe machine is a power-driven, versatile machine tool used to create cylindrical workpieces. There are various types of lathes, including bench lathes, standard engine lathes, toolroom lathes, manufacturing lathes, and special purpose lathes..

In our project, we've taken on the task of fabricating a UAV launcher from scratch, which means fabricating each individual part ourselves. The parts we need aren't easily found on the market in the precise sizes and forms we need. So, We've depended largely on a lathe. We have used bench lathe for our project. This versatile tool has been indispensable for us as we've used it for tasks such as reducing the diameters of shafts, turning pieces to precise dimensions, facing surfaces to ensure smoothness, and drilling holes with accuracy.

### **1.5.2 Drilling Machine**

A drilling machine is a versatile tool designed for creating holes in a variety of materials, ranging from wood and metal to plastic and composites. These machines come in various types, including bench drills, pillar drills, and radial drills, each offering unique features and capabilities suited for different applications.

In our project, where we had to assemble a multitude of parts, the drill machine became our go-to tool. Almost every piece required drilling, whether it was metal plates, wooden components, or other materials. The drill machine's versatility allowed us to create holes of varying sizes to match the specific needs of each part. Essentially, the drill machine was critical to our project, allowing us to integrate each component into

the final product.

### **1.5.3 Grinding Machine**

A grinding machine, often shortened to grinder, is a power tool (or machine tool) used for grinding. There are various types of grinders, each serving specific functions. Some common ones include the belt grinder, bench grinder, jig grinder, and angle grinder. An angle grinder, also known as a side grinder or disc grinder, is a handheld power tool used for grinding (abrasive cutting) and polishing.

In our work, we often utilized the angle grinder due to its accessibility and user-friendliness. Our tasks involved cutting numerous metal plates and treads into smaller pieces and specific shapes. Essentially, we used the grinder more as a cutting tool. Additionally, we used it to smooth out both metal and wooden surfaces, enhancing the overall finish of our workpieces.

### **1.5.4 Welding Machines**

Welding is a fabrication process that joins materials, usually metals or thermoplastics, primarily by using high temperatures to melt the parts together and allow them to cool, causing fusion. Metal welding is distinct from lower temperature bonding techniques such as brazing and soldering, which do not melt the base metal (parent metal) and instead require flowing a filler metal to solidify their bonds.

Welding emerged as a crucial technique throughout the entirety of our project. We did arc welding for our project. Many of the products available in the market were not suited to our dimensions, requiring extensive cutting and modification of parts. Welding became essential for joining these modified components, as our project demanded robustness and strength, particularly since metal comprised a significant portion of the materials used.

### **1.5.5 Solidworks and Workstation**

SolidWorks is a solid modeler and utilizes a parametric feature-based approach to create 3D CAD models and assemblies. Parameters refer to constraints whose values determine the shape or geometry of the model or assembly. Parameters refer to constraints whose values determine the shape or geometry of the model or assembly.

Our design process was driven by SolidWorks. With it, we meticulously designed and assembled each component, ensuring precision and integration. Its collaborative features streamlined communication, enhancing team coordination. Overall, SolidWorks was instrumental in transforming our ideas into finely crafted solutions.

#### **1.5.6 Miscellaneous Tools**

Apart from above mentioned systems, we relied heavily on various tools for our project. These included a vernier caliper for accurate measurements, a vice and clamp for securing materials, a hammer for shaping metal, Spanner , and a metal chipper for removing excess material. Safety was key, so we used a face shield to protect against sparks. A square scale helped maintain precision. These tools, along with others like filer and measuring tapes e.t.c were crucial for our project's success.

## CHAPTER 2: LITERATURE REVIEW

### 2.1 Related Theory

#### 2.1.1 Conservation of Energy

The law of conservation of energy asserts that the total energy of an isolated system remains unchanged over time; it is conserved. This principle indicates that there is a specific quantity, called energy, which remains constant despite the various transformations nature undergoes. This is a highly abstract concept, rooted in mathematics, suggesting that there is a numerical value that remains unchanged regardless of what occurs. It is not a description of a physical mechanism or a tangible entity; rather, it is a peculiar fact that when we calculate this number before and after observing natural phenomena, it remains the same.

Formula,

$$K_1 + U_1 = K_2 + U_2$$

where,

$K_1$  is initial kinetic energy,  $U_1$  is initial potential energy

$K_2$  is final kinetic energy,  $U_2$  is final potential energy

When a system is influenced by an external force, energy can be transferred into or out of the system. An external force can perform work against internal forces, altering the system's potential energy, or it can act as a net force, changing the system's kinetic energy. The work  $W_{ext}$  done by the external force on a conservative system can be expressed as follows:

$$W_{ext} = \Delta K + \Delta U \text{ where, // } W_{ext} \text{ is External Work applied,}$$

$\Delta K$  is change in Kinetic Energy,

$\Delta U$  is change in potential energy.

#### 2.1.2 Newton's Second law

According to Newton's Second Law of motion, "At any instant of time, the net force on a body is equal to the body's acceleration multiplied by its mass or, equivalently, the

rate at which the body's momentum is changing with time.”

Mathematically,

$$F = m \cdot a$$

### **2.1.3 State of Equilibrium**

An object is in equilibrium when Newton's first law holds true. This condition occurs in a reference coordinate system when all external forces and moments acting on the object are balanced. In other words, the sum of all external forces and moments on the object is zero. According to Newton's first law, under these equilibrium conditions, an object at rest will remain at rest, and an object in motion will continue moving at a constant velocity.

### **2.1.4 Law of Friction**

Friction is the force resisting the relative motion of solid surfaces, fluid layers, and material elements sliding against each other. In static friction, the frictional force resists force that is applied to an object, and the object remains at rest until the force of static friction is overcome. In kinetic friction, the frictional force resists the motion of an object.

According to law of friction, friction is proportional to the normal force exerted between the surfaces. Coefficient of friction is the ratio of the frictional force resisting the motion of two surfaces in contact to the normal force pressing the two surfaces together. It is usually symbolized by the Greek letter ( $\mu$ ).

Mathematically,  $\mu = \frac{F}{N}$ ,

where, F is the frictional force and N is the normal force.

## **2.2 Past Studies**

Previous benchmark analyses have shown that UAV bungee catapults have advantages compared to their competitors (pneumatic, hydraulic, kinetic energy, Rocket Assisted Takeoff - RATO catapults) concerning the simplicity of their construction, low purchase cost and maintenance cost. The main disadvantages of UAV bungee catapults are a limited capability to launch greater mass with a required launch speed, and a significant gradient of acceleration change on the launching rail ("jerk" action). In a widespread

conception of UAV bungee catapults [12], elastic cords are not only a power source, but also a part of the driving system of the catapult, since they pull the launch trolley directly[11].

One approach to catapult launching involves a setup with a carriage and a locking mechanism to secure an aircraft. The carriage receives a significant acceleration by channeling a launching force from a launching device. A locking mechanism holds the carriage in place at a launch position. Additionally, the catapult includes a takeoff damper that produces a damping force opposing the launching force. This takeoff damper serves to limit the acceleration of the carriage during the initial moments of launch.[13].

An apparatus for launching an aircraft having a multiplicity of interconnected elongated tracks of rigid material forming a track system and wherein each elongated track has a predetermined elongated track cross-sectional design, a winch system connected to the track system wherein the winch system has a variable mechanical advantage, one or more elongated elastic members wherein one end of each of the one or more elongated elastic members is adjustably connected to the track system, and a carrier slidably mounted to the track system wherein the carrier is connected to the winch system and to the other end of each of the one or more elongated elastic members.[15]

Small and medium-sized fixed-wing UAVs have a lower cost compared to large UAVs. Small and medium-sized tactical UAVs have become increasingly prominent, according to the development of intelligence and miniaturization of sensors and weapons, and the new tactics application including teams, swarm, and loyalty wingmen, which is based on artificial intelligence and network communications. Short-range reliable take-off technology is a major problem for small and medium-sized fixed-wing UAVs to achieve all-terrain applications on vehicle-borne and ship-borne. Elastic-rope launcher is available for small and medium-sized fixed-wing UAVs, with the advantages of brief structure, convenient operation, and strong adaptability to the environment.[14]

Assisting in the starting procedure of Unmanned Aerial Vehicles (UAVs) is one of many very important areas of modern aviation research. Supported start-up saves fuel or electrical energy, increases operator safety and level of autonomy, extends the application area, and, in some applications, even enables the operator to shape the motion characteristics of the initial phase of a UAV's flight. Currently used solutions, depending on an aircraft's class, are based on the utilization of rubber, pneumatic or electromagnetic

launchers. Using the transmission systems of the drive and the controlled clutch and an electromagnetic brake, it is possible to precisely control the speed and acceleration of the launched object.[16]

## CHAPTER 3: METHODOLOGY

### 3.1 Flow Chart

The outline of how our project proceeds is shown below:

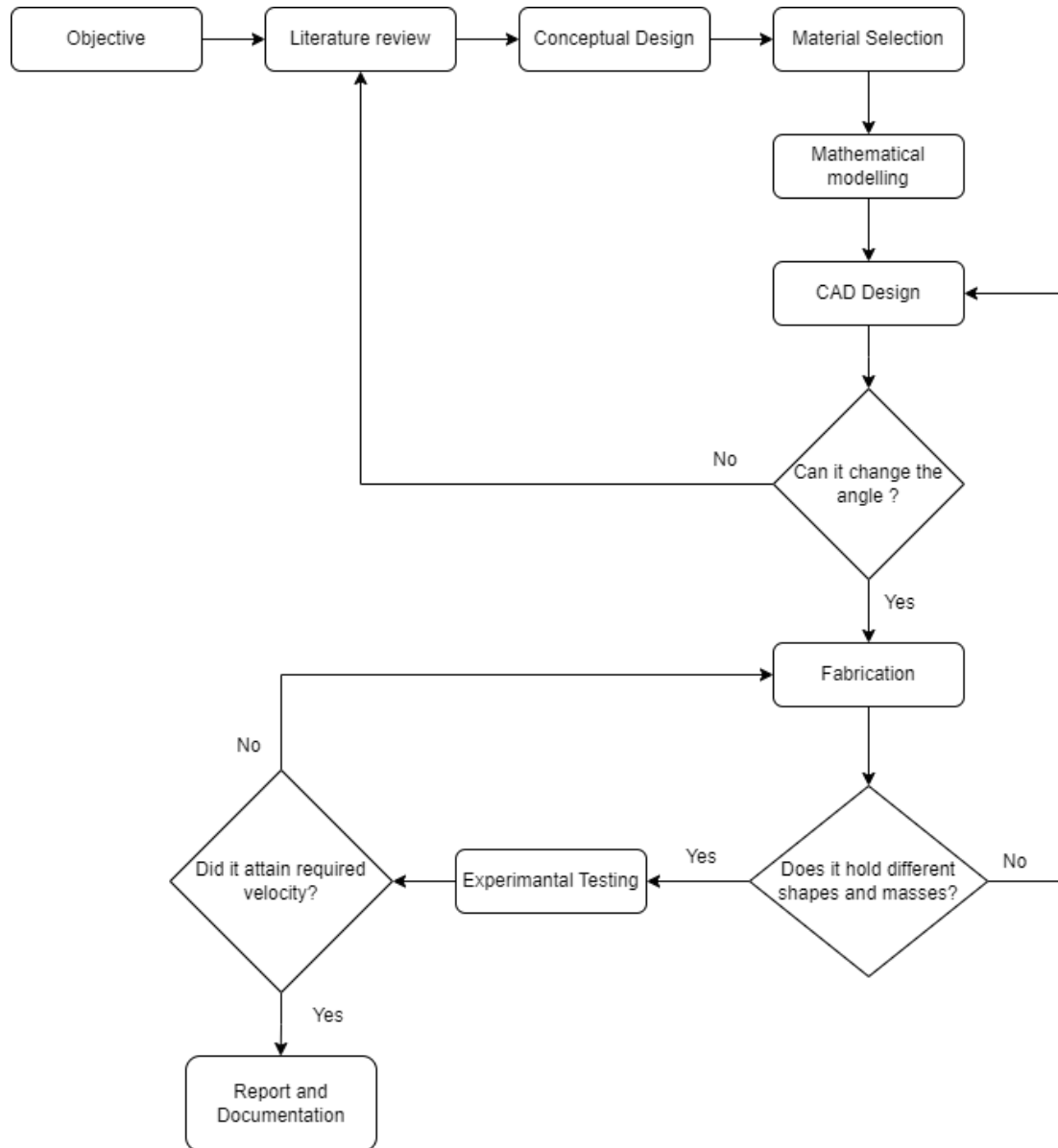


Figure 3.1: Flow Chart representing Project Outline

### 3.2 Conceptual Design

The overall conceptual design of the working mechanism of UAV launcher consists of the following three steps:

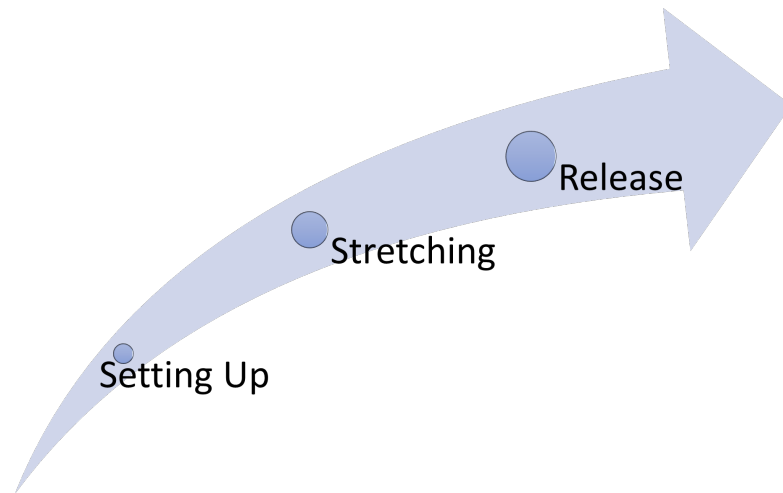


Figure 3.2: Conceptual Flow Diagram

#### 3.2.1 Setting up

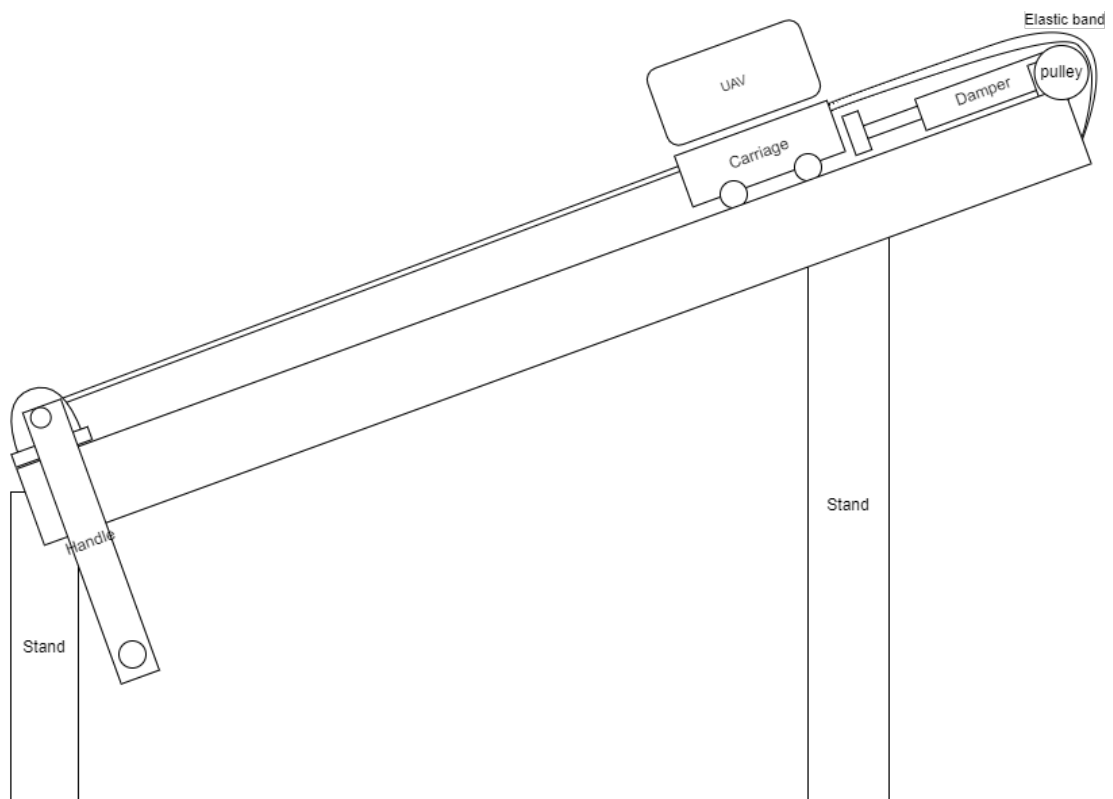


Figure 3.3: Setting Up

The setting up of the launcher for efficient launching is very necessary and needs to be done carefully. Setting up the Launcher is the longest part of its working mechanism. The setting up of the launcher consists of different activities such as:

1. Determination and setting angle of launch,
2. Calculation of required velocity for the UAV to take off,
3. Determination of the number of elastic bands required,
4. Determination of required extension of elastic band,
5. Clamping of UAV in the carriage.

### 3.2.2 Stretching

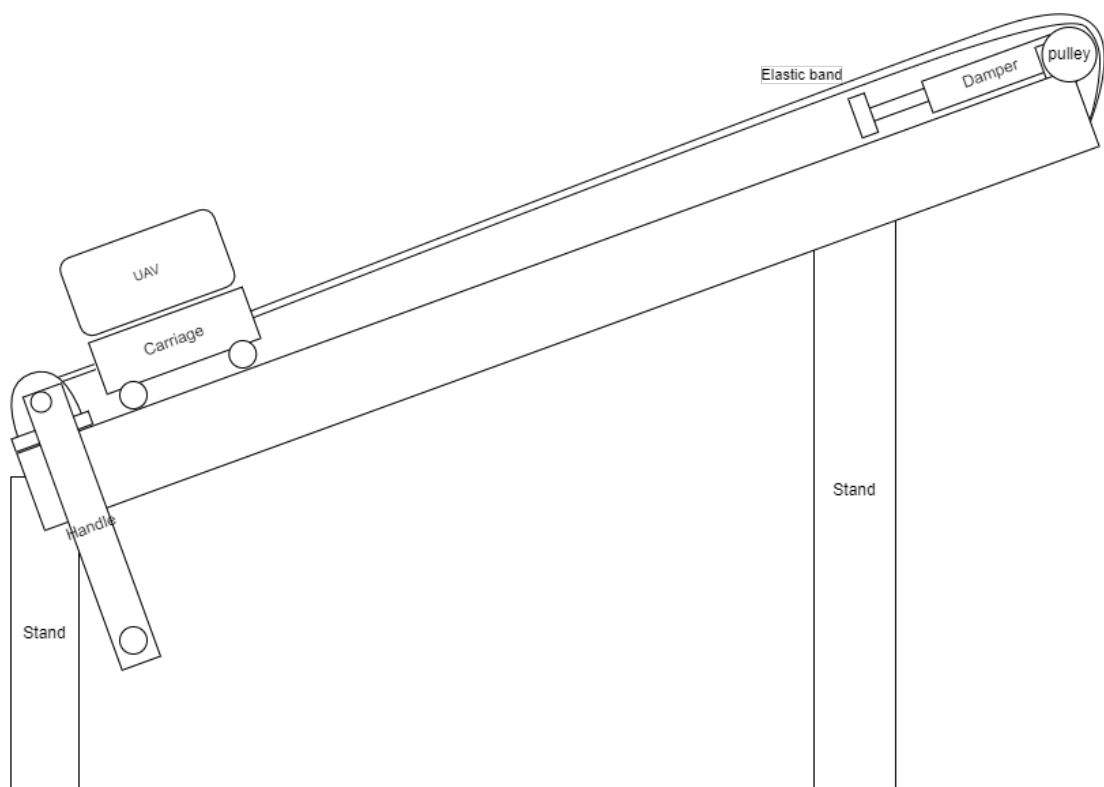


Figure 3.4: Stretching

Stretching includes the required extension of the elastic band through the winch mechanism. The extension of the elastic band is first calculated considering all the required constraints for the UAV for the takeoff.

### 3.2.3 Releasing

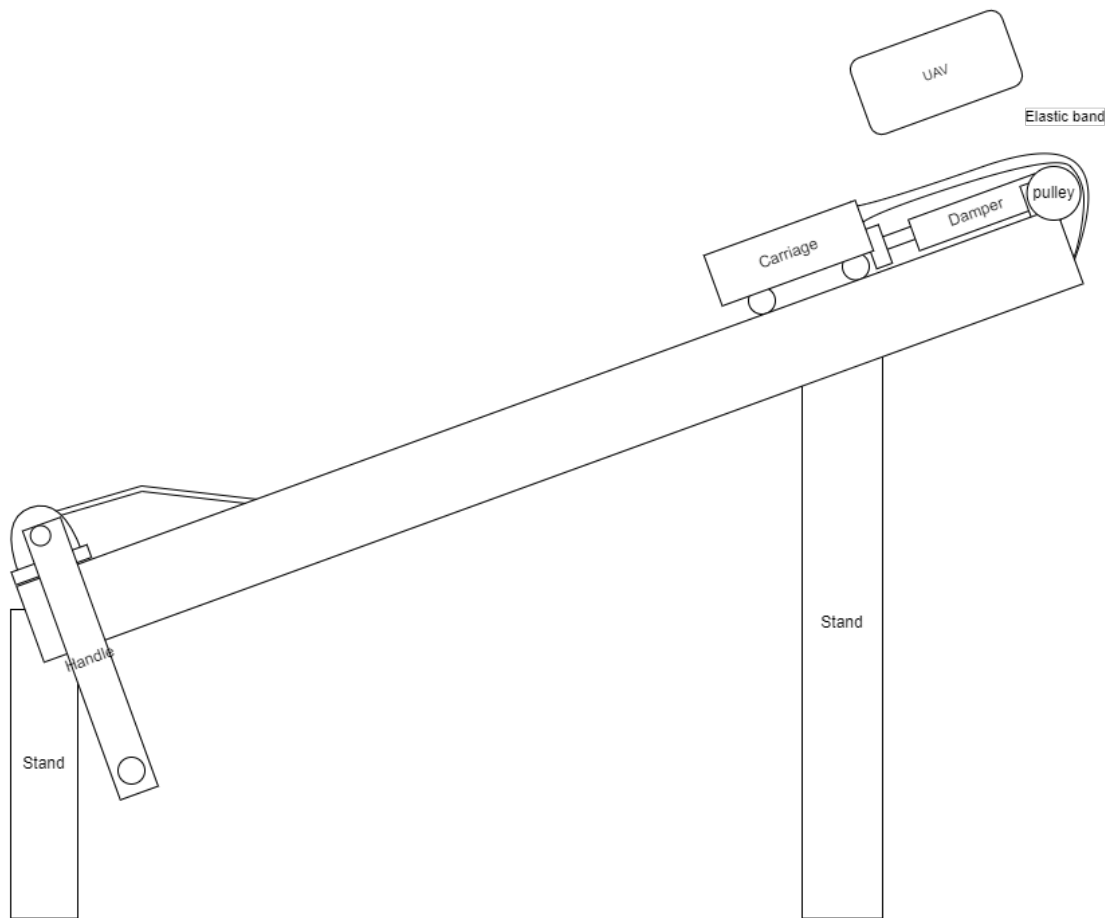


Figure 3.5: Releasing

As the carriage holding the UAV is stretched, the clip is removed from the carriage to release it and move it through the wood track and attain its required velocity for takeoff. When the carriage is released, it strikes the damping mechanism, causing a sudden jerk that helps the UAV break free from the carriage and start flying.

### 3.2.4 Mechanism Diagram

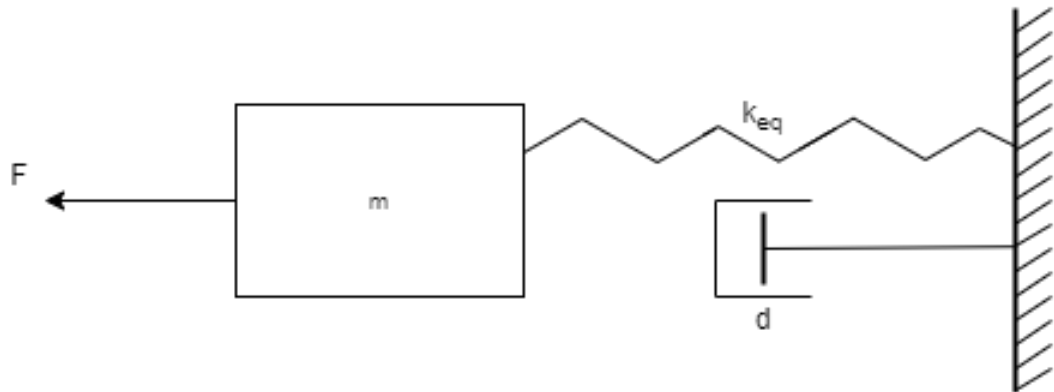


Figure 3.6: Mechanism Diagram

### 3.3 Material Selection

We begin our project by conducting a thorough evaluation of available materials in the market.

1. Recognizing the need for strength, we choose metal plates to ensure the structural integrity of our project.
2. Considering the necessity for an extension that can provide enough potential energy, we settle on elastic ropes, which also allow adjustment as needed.
3. For the effectiveness of the winch mechanism, we choose metal ropes renowned for their high tensile strength, ensuring reliable performance under pressure.
4. Prioritizing smoothness for the carriage track, we choose wood, which offers the desired surface texture for effortless carriage motion. Although aluminum plates initially seem viable, we ultimately rule them out due to irregularities that arise during fabrication.

### 3.4 Mathematical Modeling

Assumptions made:

1. The whole UAV launcher is considered as the kinetics of a system of rigid bodies.
2. The mass of elastic bands is neglected.

3. Rolling Friction coefficient is considered 0.0012.[17]

4. Drag force if neglected.

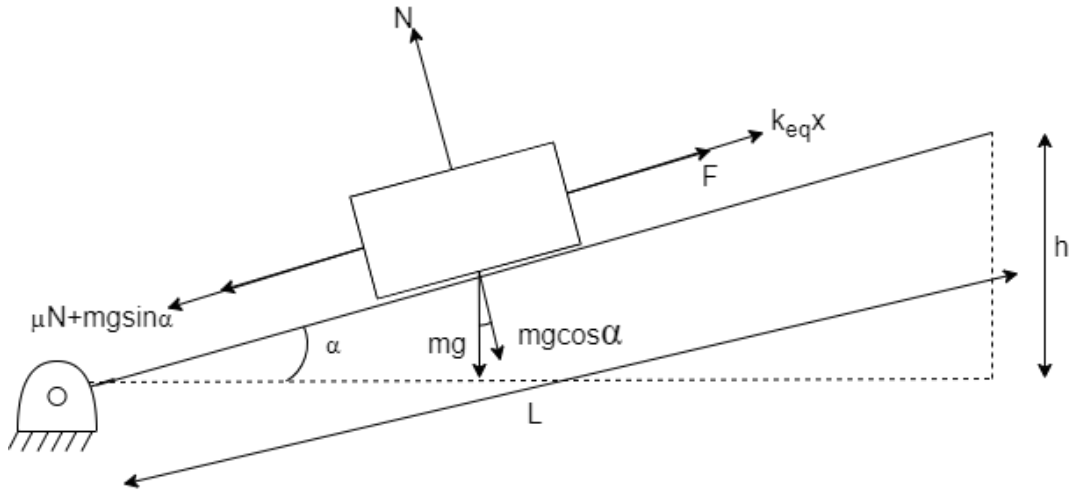


Figure 3.7: Free Body Diagram

where,

$M_c$  = Mass of Carriage = 6.11 kg

$M_u$  = Mass of UAV

$M$  = Combined mass of carriage and UAV ( $M_c + M_u$ )(kg)

$N$  = Normal Reaction (N)

$L$  = Length of the track (m) = 1 m

$\alpha$  = Angle of Launch

$\mu$  = Rolling frictional coefficient between bearing and track

$v_t$  = Exit velocity of the UAV (m/s)

$H$  = Vertical height from the ground to tip of Launcher (m)

$k_{eq}$  = Equivalent stiffness of the Elastic band (N/m)

$x$  = Extension of Elastic band (m)

The figure depicts the various forces action on the UAV and track system at the time of the release where the whole system is assumed to be in equilibrium resulting in the following equations:

$$\mu \cdot N = mg \cdot \cos(\alpha) \dots \dots \dots (3.1)$$

Now,

$$F = M \cdot a = k_{eq} \cdot x - \mu \cdot N - mg \cdot \sin(\alpha) \dots \dots (3.2)$$

From equation (3.1) and equation (3.2),

$$F = M \cdot a = k_{eq} \cdot x - \mu \cdot (mg \cdot \cos(\alpha)) - mg \cdot \sin(\alpha) \dots \dots (3.3)$$

From the conservation of energy equation,

Total energy required to launch the UAV at velocity ( $V_t$ ) is given by,

$$F \cdot L = \frac{1}{2} \cdot (M \cdot v_t^2) + mg \cdot H$$

$$F \cdot L = \frac{1}{2} \cdot (M \cdot v_t^2) + mg \cdot L \cdot \sin(\alpha)$$

$$F = \frac{1}{2L} \cdot (M \cdot v_t^2) + mg \cdot \sin(\alpha) \dots \dots \dots (3.4)$$

From equation (3.3) and equation (3.4), we get

$$\frac{1}{2L} \cdot (M \cdot v_t^2) + mg \cdot \sin(\alpha) = k_{eq} \cdot x - \mu \cdot (mg \cdot \cos(\alpha)) - mg \cdot \sin(\alpha)$$

$$x = \frac{\frac{1}{2L} \cdot (M \cdot v_t^2) + 2mg \cdot \sin(\alpha) + \mu \cdot (mg \cdot \cos(\alpha))}{k_{eq}} \dots \dots \dots (3.5)$$

Which is the required governing equation for the UAV launcher system. For the given values of L, M,  $\alpha$ ,  $v_t$ , and  $k_{eq}$ , we can find the extension of chords required to launch the UAV at the required velocity ( $v_t$ ).

### 3.5 Design Methodology

After doing a thorough literature review and examination of other UAV launchers, our team set out to create a solution that would be both effective and simple to use. Inspired by the mechanics of elastic ropes and propelled by hand pulling, we set out to create an elastic-driven UAV launcher.

We also had the opportunity to see the UAV launchers at the National Innovation Center and gain some valuable insights. However, as with any project, we encountered challenges along the way. Due to the limited availability of materials in the market and the high costs associated with acquiring them, we encountered financial and technical constraints that impacted the design of our UAV launcher. After numerous iterations, considering all the factors, we ultimately designed a 3D model Using SolidWork. The 3D model prepared is shown in Figure 3.2

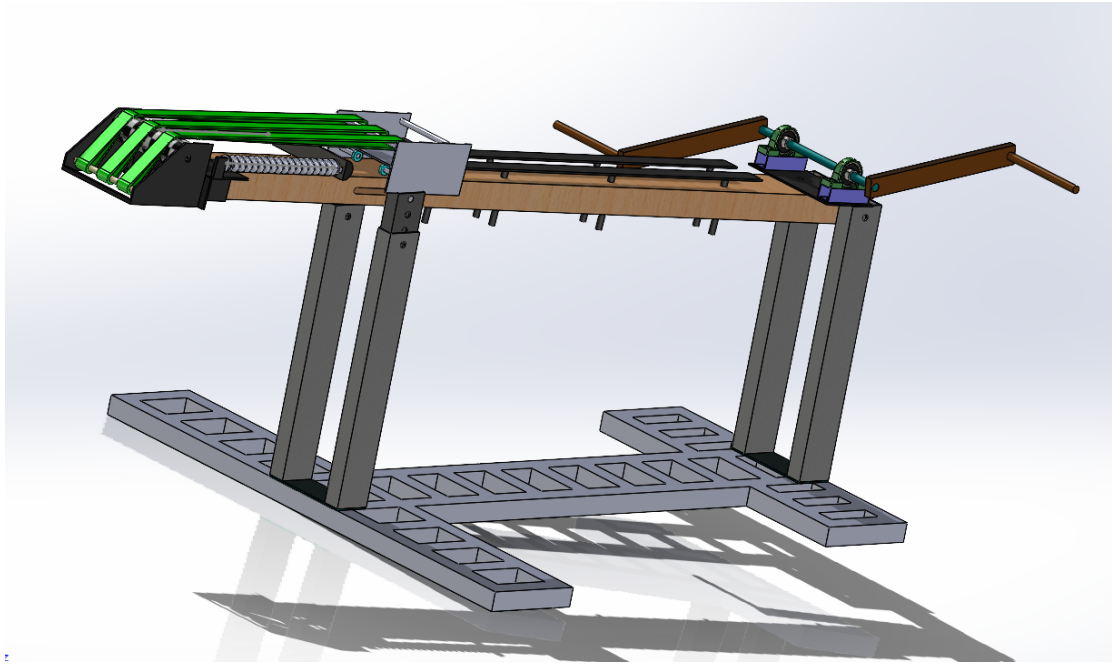


Figure 3.8: CAD Model of UAV Launcher

### 3.5.1 Base Assembly

We designed a strong base to support the entire structure, which consists of four legs and an I-shaped frame base.

#### 1. Legs

Each leg is made of strong rectangular hollow bars and is positioned below the track. A total of 6 hollow bars are used for the construction of legs. The front legs, situated on the takeoff side, consist of four bars, with two inner bars sliding inside the outer pair. This configuration enables adjustments in leg height to achieve the desired launch angle. A clamp mechanism is developed to firmly hold and modify the length of the bars, assuring reliability and stability throughout use.

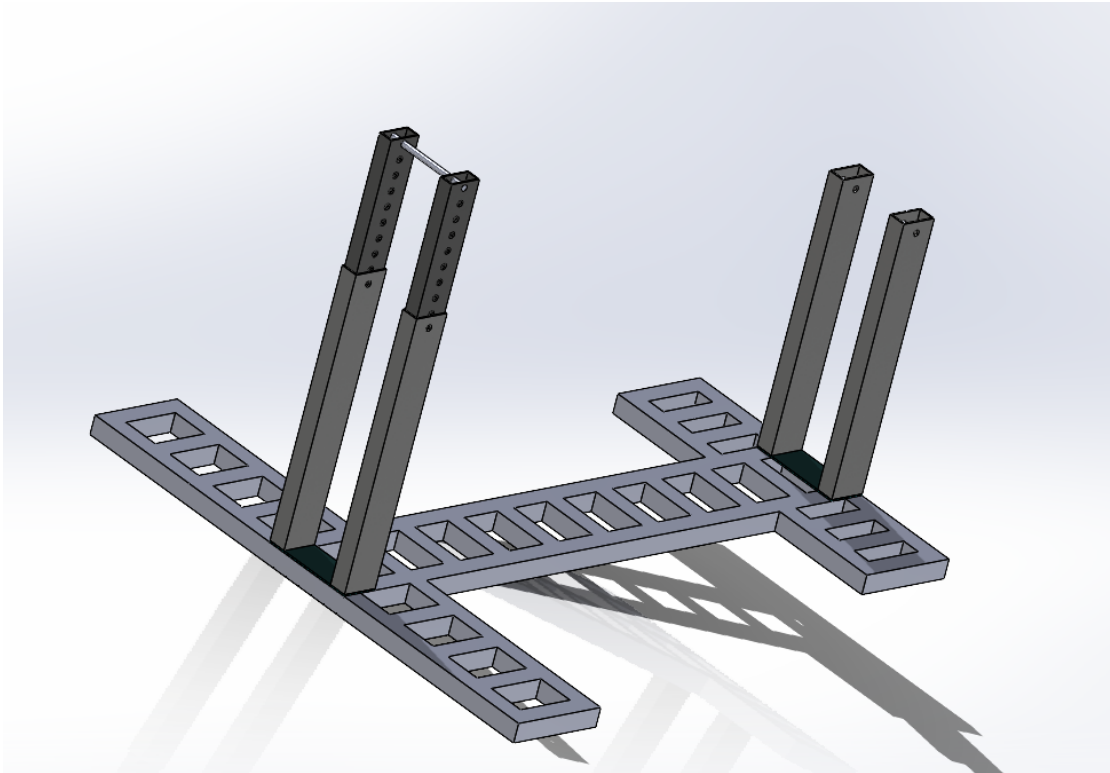


Figure 3.9: CAD Model of Base

## 2. I-shaped Frame Base

The ground base is in an I-shaped form and is constructed with rectangular frames for robust support. Notably, the front frame is longer than the back portion, strategically engineered to withstand the higher forces encountered during launch. This deliberate asymmetry enhances the overall stability of the system.

To enhance mobility, caster wheels are fixed to the bottom of the I-shaped frame, allowing for easy transportation of the entire system from one location to another. During launcher operation or launch, the intense forces involved can induce forward movement and structural instability. To counteract this, two L-shaped rectangular frames are strategically positioned at the rear end of the I-sectional frame. These frames are designed to rotate freely about an axis, essentially providing hinge support.

### 3.5.2 Track

Determining the size and right path of the UAV launcher track required extensive research and careful calculations. Through careful attention to detail and mathematical

calculations, we were able to decide on a track that would work to satisfy our requirements. Taking into account the various components that sit on the track, as well as leaving room for future adjustments, we settled on constructing a track 223 cm long. However, the actual working track is only 100 cm which is shorter than the total length but still is more than sufficient for our needs. The remaining length is for key components such as the damper mechanism, winch assembly, and elastic band assembly, guaranteeing that our launcher runs smoothly and effectively.

Initially, we constructed a steel frame using U and L sections. However, we later decided to remove it due to difficulties in welding and its inability to provide a smooth running surface caused by irregularities. As a result, we decided to use wood for our running track.

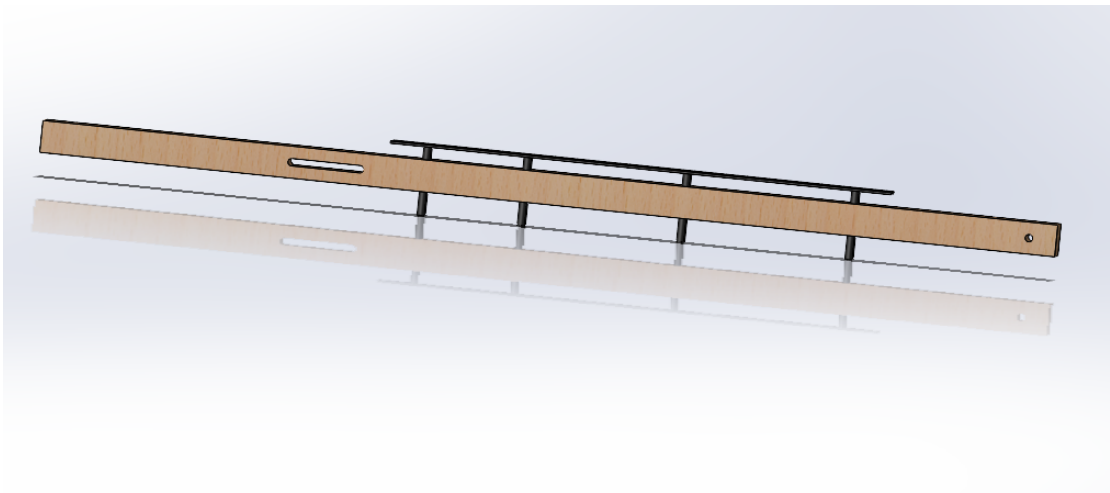


Figure 3.10: CAD Model of Track

The track has two strategically placed metal plates added to its structure. These plates, situated along the actual working track, serve a crucial role in ensuring the stability of the carriage. They are positioned exactly such that the carriage travels past them without coming into contact with them.

A slot is created at the side of the track to satisfy the requirement for different launch angles. When adjusting the height of the legs, the shaft gets space to move in the slot. We aim to provide flexibility within a range of 5 to 20 degrees. We found the appropriate slot length using mathematical calculations, ensuring smooth and precise modifications to reach the correct launch angle.

### 3.5.3 Winch Assembly

To pull the carriage, significant force must be applied. Pulling this amount of force is not possible for an individual, so a winching mechanism is employed to utilize mechanical advantage.

#### Design of Winch

We investigated different solutions like gear systems, motors, and electric winches. However, due to their complexity, we found them unsuitable for our needs. Eventually, we decided to create a manual winch from scratch.

We designed a winch with two cranks for movement. A shaft is placed between two pillow block bearings. Cranks are positioned on both sides of the shaft at equal distances. These cranks are placed 180 degrees apart from each other. Additionally, a hole is placed in the middle of the wire for the metal rope.

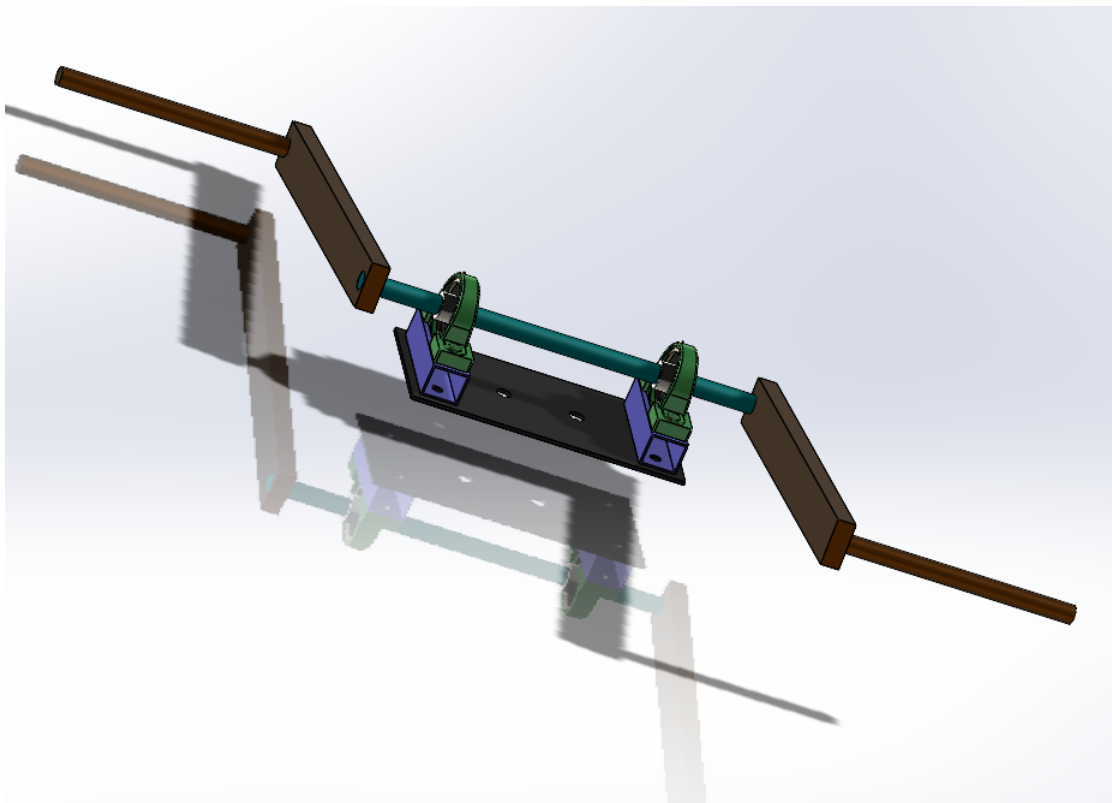


Figure 3.11: CAD Model of Winch Assembly

### **3.5.4 Lock and Release Mechanism**

The lock and release mechanism served a crucial dual purpose: to securely hold the carriage in place during operation and to release it once the elastic rope had been extended to the required distance.

#### **Design of Lock and Release mechanism**

This system comprised three essential components:

- Firstly, it needed a mechanism to firmly grasp the shaft of the carriage, ensuring it remained securely in position.
- Secondly, there had to be a designated point for attaching the metal rope, which would then pass through the shaft of the pulley and wind up during the pulling action.
- Lastly, the system required a reliable and user-friendly release mechanism to ensure smooth and effortless operation.

Initially, we attempted to implement a lock and key system. The lock was crafted using threads and nuts, requiring the key to be pulled out to release the mechanism. However, we encountered challenges as the mechanism proved overly complex to operate, with the key being notably difficult to pull out. So eventually, we used a spring-loaded clamp as our lock and release mechanism, addressing the initial difficulty in release. When selecting a clamp, factors such as the curvature of the clamp teeth and the diameter of the shaft to be secured are taken into account.

### **3.5.5 Carriage**

The primary role of the carriage is to securely hold the UAV and smoothly slide within the frame of the UAV launcher. In addition to this primary function, several other important factors were taken into account during the design phase.

- Carriage should be able to accept UAVs of various shapes and sizes, giving a universal solution for a wide range of launching needs.

- The carriage needs to have features for different components, including elastic ropes and metal wire rope, which should be arranged so that they are supported by opposite sides.
- Crucially, the design must take into account the dynamic forces applied during UAV flight, needing strong construction that can sustain vertical forces without disengaging from the framework.

### Design of Carriage

The carriage is made up of multiple components, each of which is designed to match our specific requirements while also assuring ease of construction.

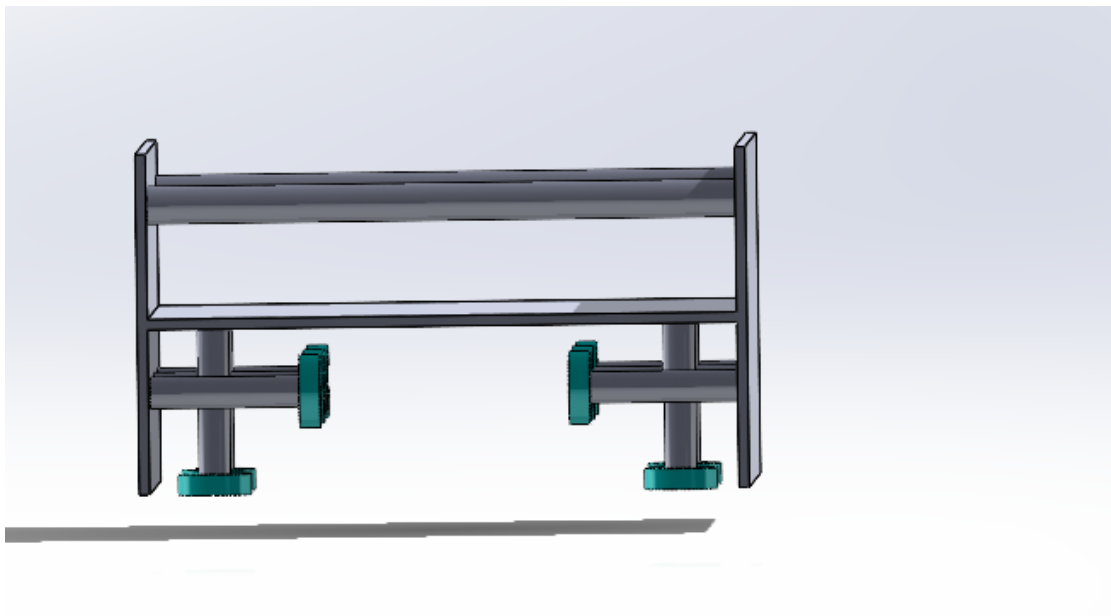


Figure 3.12: CAD Model of Carriage

#### 1. Upper Section

The upper component of the system serves for securely holding UAV. It comprises specialized plates. Notably, its design incorporates adjustability in size, enabling accommodation of varying UAV dimensions.

#### 2. Middle Section

In the middle section, two L-sectional plates are employed to create compartments for accommodating four shafts. Specifically, two of these shafts serve the purpose of securing the upper section, which holds the UAV. Another front shaft

is designated for housing an elastic rope, while the last shaft is positioned to facilitate attachment with a clamp.

### 3. Lower Section

We chose a lower carriage design that is sturdy and glides smoothly within the frame. To achieve this, we installed eight bearings strategically on the lower part. The bearing arrangement is well-organized to allow the carriage to glide smoothly. Each of these bearings is positioned perpendicular to the others. The UAV and the entire carriage are supported by four bearings on the horizontal shaft, with the remaining four bearings guiding the carriage and guaranteeing smooth operation.

A deliberate gap was introduced between the carriage plate and the bearings. This makes it easy to pass through the metal plates of the frame and acts as a safeguard against disengagement. With the metal plates of the frame acting as stoppers for vertical movement, the carriage is securely held in place during operation.

#### **3.5.6 Damping Mechanism**

The damping system's primary function was to bring the carriage to a stop safely. Since the carriage came in at high speeds with a high force, the damping system had to absorb and disperse that energy effectively. This not only prevented any sudden stops but also protected the equipment from damage, making sure everything lasted longer and worked smoothly.

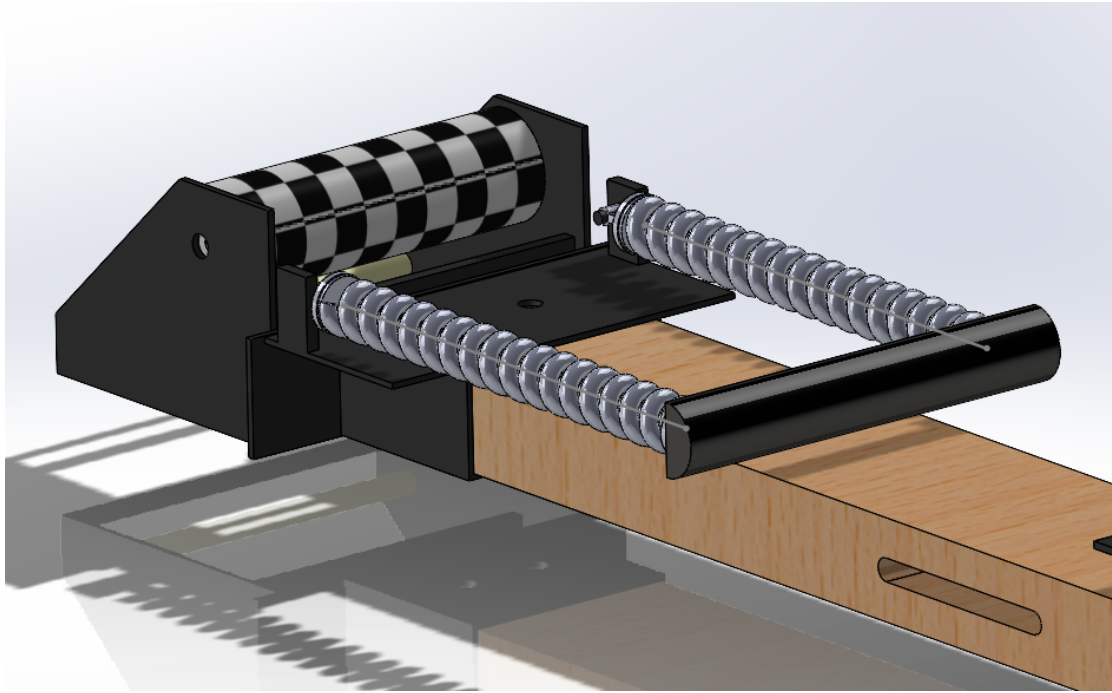


Figure 3.13: CAD Model of Damping Mechanism

After thoroughly reviewing various damping options, we settled on bike shock absorbers as dampers for their compatibility with our project needs and ease of installation. Average damping force of damper is 2150 N [18]. This decision was the result of careful consideration, ensuring that our damping solution perfectly aligned with our objectives.

We utilized two bike shock absorbers (rear) as dampers. To enhance the damping system and ensure a smooth striking surface for the carriage, we incorporated both metal plates and sponge foam. In operation, the carriage impacts the sponge foam, and the force is subsequently transmitted to the tips of the dampers. The metal plates served the dual purpose of supporting the dampers and securing the sponge foam in place.

### **3.5.7 Elastic Band Assembly**

We focused on two components when designing the elastic band assembly: first, selecting the appropriate elastic band, and second, designing the mechanism to keep it securely in place.

## Selection of Elastic Band

Since the market offered elastic bands of fixed dimensions, our only flexibility lay in choosing the quantity and arrangement of bands required for our project. So, we brought an elastic band and conducted stiffness calculations on our own. Based on our findings, we made the decision regarding the appropriate number of bands needed for our project. We decided to use three elastic bands and place them parallelly.

## Design of Elastic Band holding system

The primary purpose of this component is to hold the elastic bands during extension. During the design phase, several key functions had to be taken into account:

1. It must possess sufficient strength to withstand the extension force exerted by the elastic bands without yielding or deforming.
2. The design should ensure smooth and proper movement of the elastic bands, allowing them to stretch and retract without impediment or restriction.

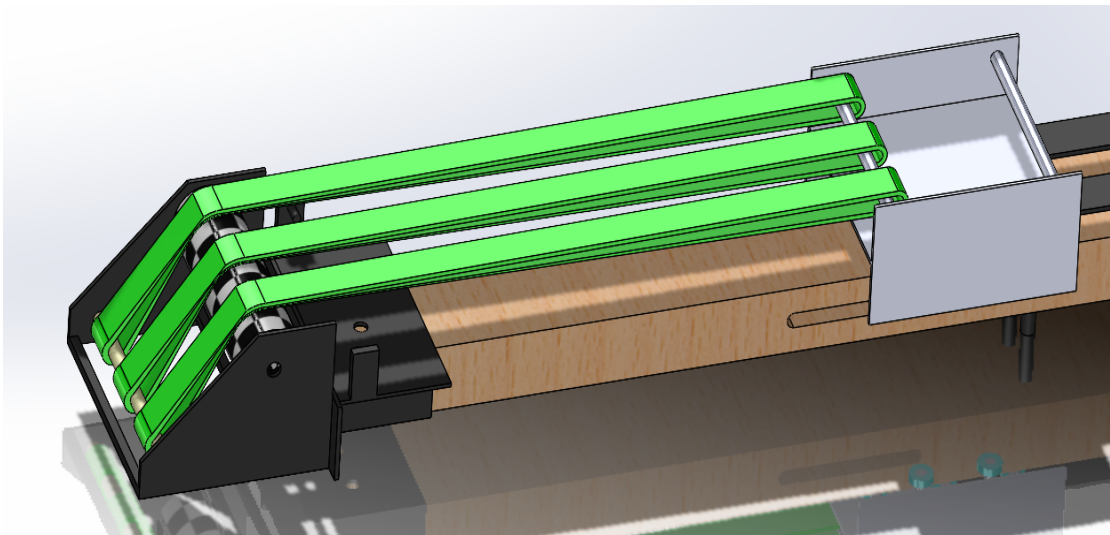


Figure 3.14: CAD Design of Elastic Band holding System

We started by designing a base for the system. We designed a cap-structured base that fits onto the top of the UAV launcher, ensuring a strong connection to the track. To hold the elastic band, we added triangular sections to the sides of the cap. These plates support a pulley at the top and a shaft at the bottom, allowing the elastic band to move

smoothly. Pulley is placed for the smooth movement of elastic bands

### 3.5.8 Angle Changing Mechanism

Different angles of launch are essential for UAVs due to the diverse requirements of their missions. Whether it's covering varying distances, navigating different terrains, or achieving optimal flight trajectories, selecting the right launch angle is crucial. Therefore, an angle-changing mechanism in UAV launchers is indispensable, as it allows operators to dynamically adjust launch angles, ensuring the UAV's performance is optimized for the task at hand.

The primary goal of our project is to change the mechanism's angle, gently going from a 5-degree incline to a 20-degree incline. We've implemented a straightforward yet efficient mechanism. It involves utilizing front legs alongside a slotted track system. There are four rectangular hollow bars, where the inner two are placed inside the outer pair. This design allows for a versatile adjustment of angles through the manipulation of the inner legs' height. Complementing this functionality, a carefully crafted clamp mechanism is positioned to firmly secure the inner hollow bar, enhancing stability.

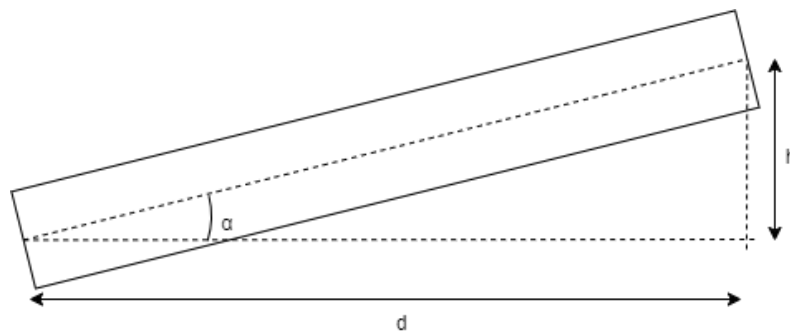


Figure 3.15: Geometric Diagram

From the geometry above, upon applying trigonometric principles, we get the relationship,

$$\tan(\alpha) = \frac{p}{b} = \frac{\text{Extra Height of leg}(h_i)}{\text{Horizontal distance between Legs}(d)} \dots\dots\dots(3.6)$$

where,

$i = 1$  for  $1^\circ$ ,  $i = 2$  for  $2^\circ$ , and so on up to  $i = n$  for  $n^\circ$

### Determination of Slot Length

Determination of Slot length is crucial for the mechanism's functionality, particularly when the base remains fixed. We depend on geometric calculations for this purpose, focusing solely on lengths between the vertical legs.

To determine the slot length, we compute the difference between the lengths of the inclined track for the maximum and minimum angles.

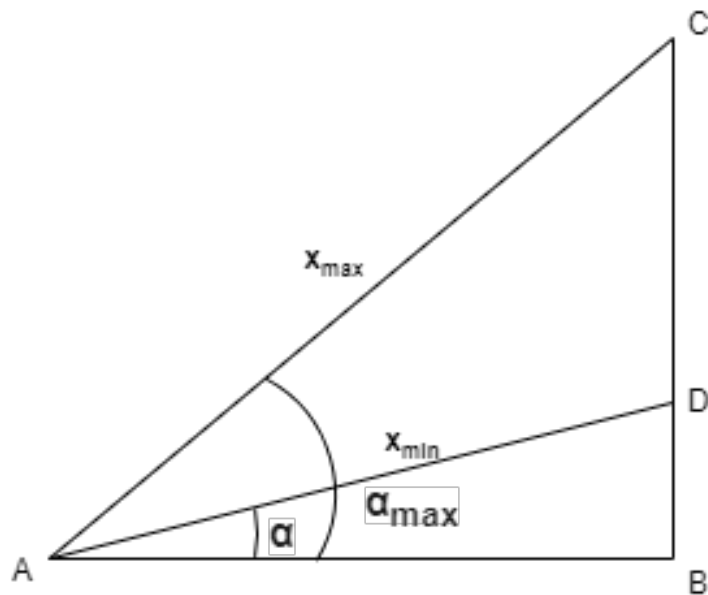


Figure 3.16: Slot angle determination

Mathematically, this can be expressed as:

$$\text{Slot length} = \text{Length of track for max. angle} - \text{Length of track for min. angle}$$

## CHAPTER 4: RESULTS AND DISCUSSION

### 4.1 Fabricated Components

#### 4.1.1 Base Assembly

Base assembly consists of the following parts:



Figure 4.1: Fabricated Base

#### 1. Legs

Rectangular section hollow bar was brought and cut in total 6 pieces. For the clamp mechanism, we drilled holes into the front legs. Then, bolts are inserted from the outside, securely holding the inward hollow legs in place.

For increased stability and support, the legs were welded onto metal plates, which were then securely welded to the I-shaped frame. This double-welding method ensures a robust connection, capable of withstanding the weight and forces exerted during operation.

A horizontal rectangular bar was welded between the two sets of legs to ensure

proper structural integrity and support.

## 2. Base

We bought a long rectangular frame. We then went ahead and precisely modified the frame, cutting it to fit the measurements specified in our design.

To attach the caster wheels to the frame, drill holes were meticulously made in the I-shaped structure. Threads were then carefully cut into these holes, providing a secure anchor point for the wheels. This meticulous process ensures that the caster wheels are firmly attached, guaranteeing smooth and effortless movement of the entire system.

We cut the rectangular hollow bars and assembled them to create an L-shaped body through welding. For the hinge connection to the base, we cut two metal pieces for each leg. Then, we drilled concentric holes through both the L-shaped structure and the metal plates. Finally, we secured them together using threads and nuts.

### **4.1.2 Track**

We brought a rectangular piece of wood and carefully cut and smoothed it down to make it just right for our design.

We made the slot by drilling into the wood sideways, creating a 9 cm long opening. Then, we smoothed out the surface, using a file to make sure it was nice and even.

Two metal plates were brought. We cleaned the surface with a grinder. Each plate was carefully drilled making four holes in it. To successfully prevent the carriage from dislodging, the first two holes are placed strategically closer together at a distance of 22 cm at the takeoff side, and the remaining holes are put at a distance of 35 and 37 cm. Welding the metal plates with threads was quite a challenge. Keeping those threads perfectly perpendicular during welding was no easy feat. But, after putting in a lot of hard work and determination, we managed to pull it off successfully.



Figure 4.2: Fabricated Track

### 4.1.3 Winch Assembly

We used a metal plate as the base for the winch assembly, which we drilled and secured to the track. To adjust the height, we positioned two hollow square bars beneath the two pillow blocks. Using a lathe machine, we machined the shaft to fit our specific requirements. Additionally, we acquired a bar and machined it down to create two cranks.

Next, we drilled holes on both sides of each crank for assembly with the shaft. One hole was for connecting to the shaft, while the next one was for attaching the handle. To ensure there is no slippage, we adopted a key system by drilling and cutting threads. For extra support, we welded the handle again with the crank.

Furthermore, we drilled a small hole in the middle of the shaft to accommodate the metal rope.



Figure 4.3: Fabricated Winch Assembly

#### 4.1.4 Lock and Release Mechanism

We brought a spring-loaded clamp and did some testing. However, we encountered slippage because the clamp's curvature was slightly smaller than the diameter of the shaft we aimed to securely hold. To tackle this problem, we implemented a strategic solution by welding a rectangular section onto the front part of the clamp. This modification not only addressed the curvature disparity but also enhanced the overall grip and stability of the clamp on the shaft.

To accommodate the metal wire rope, we took a small thread and drilled a hole through it. Then, we placed the wire through that hole and secured it in place with nuts. This simple yet effective solution ensured a sturdy grip for the wire, allowing us to utilize

the clamp more efficiently.



Figure 4.4: Fabricated Clamp

#### 4.1.5 Carriage

For the upper part, we used metal plates. These plates were carefully cut and bent to achieve the necessary gripping shape, tailored to the specific dimensions and contours required. At the bottom of these plates, we drilled holes strategically to facilitate attachment with the shafts of the middle section, ensuring secure holding of the shafts in place.

We've transformed sheet metal plates into two L-section plates for the middle section of our project. In these plates, we drilled four holes each for the shafts. We cut two threaded rods to hold the upper part firmly. Using a lathe machine, we carefully

smoothed out both the front and back shafts. The front shaft was made smooth to ensure the elastic band could slide on without any roughness. As for the back shaft, it needed to be smooth for the clamp to grip effectively. We assembled the shaft to the L Section with nuts.



Figure 4.5: Fabricated Carriage

We again used two more L-section plates for the lower part. Shafts for holding the bearings were machined on a lathe at the robotics club. The shaft was then interference fit with the bearings. Shafts with bearings were carefully welded to the carriage's L-section metal frame.

#### **4.1.6 Damping Mechanism**

We carefully made two U-section plates from a metal sheet, ensuring they were robust enough to securely hold the dampers in place, and welded them to the base of the elastic band assembly. Using nut bolts, we firmly attached the dampers' ends to these plates,

ensuring a stable connection.



Figure 4.6: Fabricated Damping Mechanism

Additionally, to reinforce the setup, we machined two smaller metal plates into L-sections. These specialized L-section plates were designed to enhance the stability of the damping system, providing reliable support for the dampers along the track. These plates were nut-fitted to the damper and the track.

#### **4.1.7 Elastic Band Holding System**

We constructed a cap-like structure from metal sheets by cutting and welding together plates of the required size. Rectangular parts were welded onto this cap-like structure, providing additional reinforcement. Two holes were drilled into the plates to accommodate the shaft for holding the elastic band and the shaft for the pulley. Additionally, a horizontal shaft was installed to enhance the overall strength of the assembly.

For the pulley, we used a nylon rod. Using a lathe and drilling machine, we created a

through-hole in the rod and then proceeded to turn and smooth out its surface, ensuring optimal functionality.



Figure 4.7: Fabricated Elastic Band Holding System

## 4.2 Calculation of Stiffness of Elastic Band

We experimented to get the elastic constant ( $k$ ) of a one-meter-long elastic rope. The procedure involved applying various weights to the rope and meticulously recording both its initial and final lengths after each weight increment. The collected data forms a comprehensive dataset that facilitates the analysis of the elastic behavior of the rope, allowing for the calculation of its elastic constant under diverse loading conditions.



Figure 4.8: Calculation of Stiffness of Elastic band

Table 4.1: Data Observed for Stiffness of Elastic Band

Mass (kg)	Weight (N)	Initial length (m)	Final Length (m)	Extension (m)
2.07	20.307	1.065	1.09	0.025
4.61	45.224	1.067	1.13	0.063
7.25	71.123	1.069	1.205	0.136
9.87	96.825	1.075	1.28	0.205
12.59	123.507	1.077	1.374	0.297
15.22	149.308	1.083	1.473	0.39
18.1	177.561	1.087	1.575	0.488
20.7	203.067	1.09	1.64	0.55

We plotted the graph of Weight vs Extension using Excel.

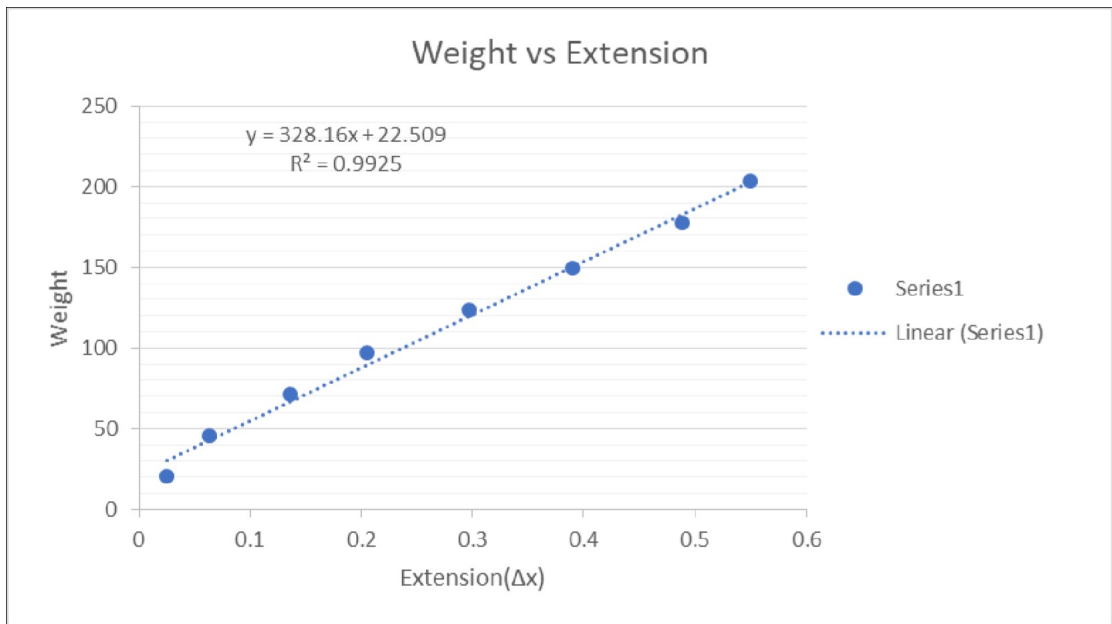


Figure 4.9: Graph of Weight vs Extension

From the above graph, we found that the stiffness of the elastic rope was found to be 164.08 N/m (half of the slope of the weight-extension curve).

### 4.3 Calculation for different angle of launch

Using the relation from equation (3.6), we have calculated the following data for angles ranging from 5 degrees to 20 degrees:

Table 4.2: Data for different angle of launch

S.N	Angle of Launch ( $\alpha$ )	Extra height of Leg ( $h_i$ ) (cm)
1	5°	12.7
2	10°	25.7
3	15°	38.9
4	20°	52.9

From the above table, we can use the height values for specific angles of launch.

### 4.3.1 Calculation of Slot length

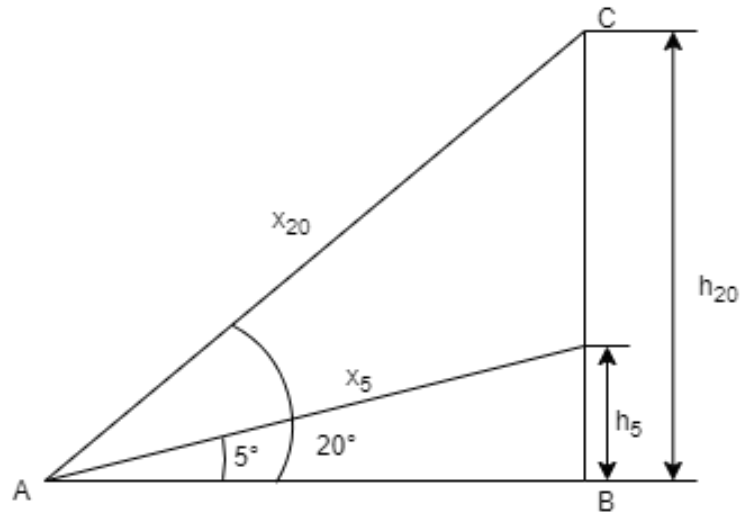


Figure 4.10: Slot Length Calculation

where,

$h_5$  = Extra Height of Leg for 5 degree

$h_{20}$  = Extra Height of Leg for 20 degree

$x_5$  = Inclined distance between legs at 5 degree

$x_{20}$  = Inclined distance between legs at 20 degree

$d$  = Horizontal distance between legs

From the table (4.2),  $h_5 = 12.7$  cm and  $h_{20} = 52.9$  cm and from design, we have,  
 $d = 145.5$  cm (Constant)

Now, from the above geometry,

$$\sin(\alpha) = \frac{p}{h}$$

For  $\alpha = 5^\circ$ ,

$$\sin(5^\circ) = \frac{h_5}{x_5} = \frac{12.7}{x_5}$$

Therefore,  $x_5 = 145.7$  cm

For,  $\alpha = 20^\circ$ ,

$$\sin(20^\circ) = \frac{h_{20}}{x_{20}} = \frac{52.9}{x_{20}}$$

Therefore,  $x_{20} = 154.7$  cm

Therefore, Slot Length =  $x_{20} - x_5 = 154.7 - 145.7 = 9$  cm

Based on this calculation, a slot of length 9 cm is constructed in the track.

#### 4.4 Theoretical Calculation

From equation (3.5), we found the governing equation of UAV launcher as shown below,

$$x = \frac{\frac{1}{2L} \cdot (M \cdot v_f^2) + 2mg \cdot \sin(\alpha) + \mu \cdot (mg \cdot \cos(\alpha))}{k_{eq}}$$

Using the above governing equation, we calculated data for varying masses, velocities, and angles keeping 2 and 3 elastic bands in parallel.

Table 4.3: Extension of elastic with varying velocity with 2 elastic bands in parallel

S.N	Mu(kg)	Mc(kg)	M(kg)	vt(m/s)	$\alpha$	keq(N/m)	kx	sina	cosa	$\mu$	x(m)
1	2	6.11	8.11	5	8	656.32	89.8228	0.13917	0.99027	0.0012	0.13686
2	2	6.11	8.11	6	8	656.32	119.56	0.13917	0.99027	0.0012	0.18217
3	2	6.11	8.11	7	8	656.32	154.703	0.13917	0.99027	0.0012	0.23571
4	2	6.11	8.11	8	8	656.32	195.253	0.13917	0.99027	0.0012	0.2975
5	2	6.11	8.11	9	8	656.32	241.21	0.13917	0.99027	0.0012	0.36752
6	2	6.11	8.11	10	8	656.32	292.573	0.13917	0.99027	0.0012	0.44578
7	2	6.11	8.11	11	8	656.32	349.343	0.13917	0.99027	0.0012	0.53228
8	2	6.11	8.11	12	8	656.32	411.52	0.13917	0.99027	0.0012	0.62701

Table 4.4: Extension of elastic with varying velocity with 3 elastic bands in parallel

S.N	Mu(kg)	Mc(kg)	M(kg)	vt(m/s)	$\alpha$	keq(N/m)	kx	sina	cosa	$\mu$	x(m)
1	2	6.11	8.11	5	8	984.48	89.8228	0.13917	0.99027	0.0012	0.09124
2	2	6.11	8.11	6	8	984.48	119.56	0.13917	0.99027	0.0012	0.12144
3	2	6.11	8.11	7	8	984.48	154.703	0.13917	0.99027	0.0012	0.15714
4	2	6.11	8.11	8	8	984.48	195.253	0.13917	0.99027	0.0012	0.19833
5	2	6.11	8.11	9	8	984.48	241.21	0.13917	0.99027	0.0012	0.24501
6	2	6.11	8.11	10	8	984.48	292.573	0.13917	0.99027	0.0012	0.29719
7	2	6.11	8.11	11	8	984.48	349.343	0.13917	0.99027	0.0012	0.35485
8	2	6.11	8.11	12	8	984.48	411.52	0.13917	0.99027	0.0012	0.41801

Table 4.5: Extension of elastic with varying mass with 2 elastic bands in parallel

S.N	Mu(kg)	Mc(kg)	M(kg)	vt(m/s)	$\alpha$	keq(N/m)	kx	sina	cosa	$\mu$	x(m)
1	3	6.11	9.11	10	8	656.32	480.4817	0.139173	0.990268	0.0012	0.732085
2	4	6.11	10.11	10	8	656.32	364.724	0.139173	0.990268	0.0012	0.555711
3	5	6.11	11.11	10	8	656.32	400.7995	0.139173	0.990268	0.0012	0.610677
4	6	6.11	12.11	10	8	656.32	436.8751	0.139173	0.990268	0.0012	0.665643
5	7	6.11	13.11	10	8	656.32	472.9507	0.139173	0.990268	0.0012	0.72061
6	8	6.11	14.11	10	8	656.32	509.0263	0.139173	0.990268	0.0012	0.775576
7	9	6.11	15.11	10	8	656.32	545.1018	0.139173	0.990268	0.0012	0.830543
8	10	6.11	16.11	10	8	656.32	581.1774	0.139173	0.990268	0.0012	0.885509

Table 4.6: Extension of elastic with varying mass with 3 elastic bands in parallel

S.N	Mu(kg)	Mc(kg)	M(kg)	vt(m/s)	$\alpha$	keq(N/m)	kx	sina	cosa	$\mu$	x(m)
1	3	6.11	9.11	10	8	984.48	328.6484	0.139173	0.990268	0.0012	0.333829
2	4	6.11	10.11	10	8	984.48	364.724	0.139173	0.990268	0.0012	0.370474
3	5	6.11	11.11	10	8	984.48	400.7995	0.139173	0.990268	0.0012	0.407118
4	6	6.11	12.11	10	8	984.48	436.8751	0.139173	0.990268	0.0012	0.443762
5	7	6.11	13.11	10	8	984.48	472.9507	0.139173	0.990268	0.0012	0.480407
6	8	6.11	14.11	10	8	984.48	509.0263	0.139173	0.990268	0.0012	0.517051
7	9	6.11	15.11	10	8	984.48	545.1018	0.139173	0.990268	0.0012	0.553695
8	10	6.11	16.11	10	8	984.48	581.1774	0.139173	0.990268	0.0012	0.590339

Table 4.7: Extension of elastic with varying angles with 2 elastic bands in parallel

S.N	Mu(kg)	Mc(kg)	M(kg)	vt(m/s)	$\alpha$	keq(N/m)	kx	sina	cosa	$\mu$	x(m)
1	2	6.11	8.11	10	5	656.32	284.2965	0.087156	0.996195	0.0012	0.433168
2	2	6.11	8.11	10	6	656.32	287.0607	0.104528	0.994522	0.0012	0.437379
3	2	6.11	8.11	10	7	656.32	289.8197	0.121869	0.992546	0.0012	0.441583
4	2	6.11	8.11	10	8	656.32	292.5728	0.139173	0.990268	0.0012	0.445778
5	2	6.11	8.11	10	9	656.32	295.3192	0.156434	0.987688	0.0012	0.449962
6	2	6.11	8.11	10	10	656.32	298.0579	0.173648	0.984808	0.0012	0.454135
7	2	6.11	8.11	10	11	656.32	300.7882	0.190809	0.981627	0.0012	0.458295
8	2	6.11	8.11	10	12	656.32	303.5093	0.207912	0.978148	0.0012	0.462441

Table 4.8: Extension of elastic with varying angles with 3 elastic bands in parallel

S.N	Mu(kg)	Mc(kg)	M(kg)	vt(m/s)	$\alpha$	keq(N/m)	kx	sina	cosa	$\mu$	x(m)
1	2	6.11	8.11	10	5	984.48	284.297	0.08716	0.99619	0.0012	0.28878
2	2	6.11	8.11	10	6	984.48	287.061	0.10453	0.99452	0.0012	0.29159
3	2	6.11	8.11	10	7	984.48	289.82	0.12187	0.99255	0.0012	0.29439
4	2	6.11	8.11	10	8	984.48	292.573	0.13917	0.99027	0.0012	0.29719
5	2	6.11	8.11	10	9	984.48	295.319	0.15643	0.98769	0.0012	0.29997
6	2	6.11	8.11	10	10	984.48	298.058	0.17365	0.98481	0.0012	0.30276
7	2	6.11	8.11	10	11	984.48	300.788	0.19081	0.98163	0.0012	0.30553
8	2	6.11	8.11	10	12	984.48	303.509	0.20791	0.97815	0.0012	0.30829

## 4.5 Experimental Data

### 4.5.1 Calculation of speed of the load after release

The approximate speed of the load is calculated by measuring the distance traveled by the load after impact on the damper in 0.1 seconds. The approximate length is calculated manually taking reference to the length of the track. The video was taken by Redmi Note 8 pro with a 30fps frame rate. The software used to take pictures between 0.1 seconds was Canva.

#### CASE I



Figure 4.11: Case I

Mass of Carriage ( $M_c$ ) = 10.45kg

Mass of load ( $M_u$ ) = 2.6kg

Angle of Launch ( $\alpha$ ) =  $10^\circ$

Number of Elastic bands = 2

Length of extension ( $x$ ) = 0.96m

Approximate distance traveled by the load after 0.1 seconds ( $L$ ) = 0.32308 m

Approximate speed of the load ( $v_t$ ) =  $\frac{0.32308}{0.1} = 3.2308\text{m/s}$

From the theoretical data,  
the theoretical velocity for the exact condition is = 9.4572322 m/s

$$\text{So, Error} = \frac{9.4572322 - 3.2308}{9.4572322} = 0.658377 = 65.8377\%$$

## CASE II



Figure 4.12: Case II

Mass of Carriage ( $M_c$ ) = 10.45kg

Mass of load ( $M_u$ ) = 2.6kg

Angle of Launch ( $\alpha$ ) =  $10^\circ$

Number of Elastic bands = 3

Length of extension (x) = 0.96m

Approximate distance traveled by the load after 0.1 seconds (L) = 0.625

Approximate speed of the load ( $v_t$ ) =  $\frac{0.625}{0.1} = 6.25\text{m/s}$

From the theoretical data,

the theoretical velocity for the exact condition is = 11.74759 m/s

So, Error =  $\frac{11.7457 - 6.25}{11.74759} = 0.46789 = 46.789\%$

## 4.6 Problems Faced

1. Difficulties were encountered in obtaining materials from the market.
2. It was found that some of the materials needed were very expensive, thereby imposing a financial limit on our attempts.

3. The lack of hands-on experience was made obvious, resulting in challenges in the fabrication process and necessitating extra effort for problem-solving.
4. Our design options had to be restricted to make them compatible with the available materials and the limitations of our budget.

#### 4.7 Budget Analysis

S.N.	Mechanism/Components	Cost
1	Base and Stand	Rs 5,000
2	Pulley	Rs 2,000
3	Track (Wood)	Rs 3,000
4	Carriage (Metal plates)	Rs 4,450
5	Nuts, Washers, and Thread rods	Rs 3,250
6	Pillow Block and Ball bearings	Rs 2,500
7	Elastic Bands (*3)	Rs 4,500
8	Cutting Blades and Welding rods	Rs 5,500
9	Adhesives (Fevicol, Dendrite)	Rs 2,500
10	Failure cost (SS Frame)	Rs 18,000
	<b>Total cost</b>	<b>Rs 50,700</b>

Figure 4.13: Budget Analysis

## **CHAPTER 5: CONCLUSION AND FUTURE ENHANCEMENTS**

### **5.1 Limitations**

1. The carriage designs resulted in increased weight, limiting the load capacity of the UAV.
2. Time constraints and limited access to the UAV made it difficult to make extensive changes to the UAV holder. This project focuses solely on providing initial force and velocity.
3. The project could only use three elastic bands due to time constraints during testing. While the force increases with additional bands within this limit, the project does not explore the relationship between bands and force beyond this scope.
4. Structural analysis of the components is not carried out.
5. Proper holding mechanism for UAV is still to be thought of. Lack of efficient holding and release mechanism for UAV in carriage causes too much power loss.
6. Due to lack of time, we could not laminate all the metal parts which led to the rusting of the launcher.

### **5.2 Conclusion**

In conclusion, the successful fabrication of the elastic-driven UAV launcher marks a significant milestone in UAV deployment technology. Our comprehensive research and testing have demonstrated the launcher's capability to efficiently and reliably launch UAVs across a range of operational parameters.

The ability to subtend angles from 5 degrees to 20 degrees for the angle of launch showcases the versatility of our design, allowing for adaptable launch trajectories tailored to specific mission requirements. Furthermore, our experimental results highlight the launcher's performance in achieving significant launch velocities, with velocities of

3.2308m/s and 6.25m/s attained using 2 and 3 elastic bands, respectively. These velocities were achieved with error of 65.8377% and 46.789%, showcasing the problem in holding and releasing UAVs in carriage yet having minimum energy consumption.

Moreover, our testing confirms the launcher's capability to launch UAVs of variable masses, providing flexibility in mission planning and payload deployment. The addition of small wheels to enhance portability further enhances the practicality and usability of our design, allowing for easy transport and deployment in diverse operational environments.

These results validate the effectiveness and reliability of our elastic-driven launcher in enhancing mission readiness and operational efficiency across a range of applications.

### **5.3 Scope for Future Enhancements**

Building on these encouraging findings, there are various options for future improvements to better optimize the performance and capabilities of the elastic-driven UAV launcher:

1. **Automated Launching Mechanism:** Investigate the use of automated launching methods to simplify launch operations and improve accuracy and consistency.
2. **Optimization of Launch Parameters by Enhanced Testing:** Implement thorough testing techniques to improve launch parameters such as launch angle, elastic tension, and payload arrangement.
3. **Integration of Remote Monitoring and Control:** Investigate the integration of remote monitoring and control capabilities to allow operators to remotely monitor launcher status, alter launch settings, and troubleshoot difficulties.
4. **Implementation of Safety and Compliance Standards:** Ensure that UAV launch systems meet industry standards and regulations, such as safety guidelines, operating protocols, and performance criteria.
5. **Better mobility of Launcher:** The tires used in the beginning were of desktop chairs which could not hold the massive weight of a UAV. So it is better to use tires of go-kart with long shafts and pillow block bearings.

6. For safety reasons, the maximum elongation of the elastic band should be calculated and its elastic limit should be noted through practical experiments where we use one elastic band and elongate it until it breaks down or tears down.
7. Prevention of rusting: Most parts of our launcher is made up of metal. So they have to be laminated to prevent rusting.
8. Design of holding and releasing of UAVs: The design of holding and releasing of UAVs should be constructed in such a way that the lock that holds the UAV in the carriage should only open when the carriage hits the damper.

By pursuing these avenues for future enhancements, we can further elevate the performance, versatility, and reliability of the elastic-driven UAV launcher, unlocking new possibilities for UAV deployment in a wide range of operational scenarios while enhancing operational efficiency and safety.

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# APPENDIX A

Components' Drawing

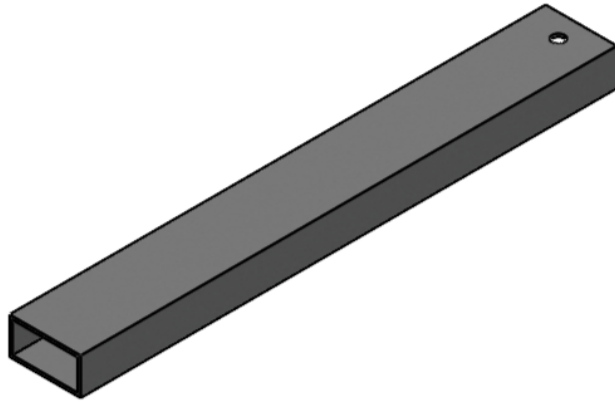
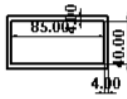
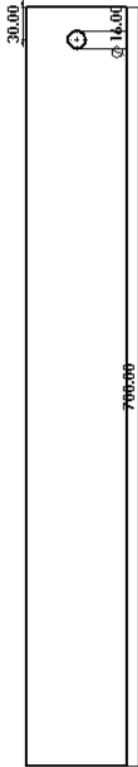


Figure A.1: Rectangle Outer Stand

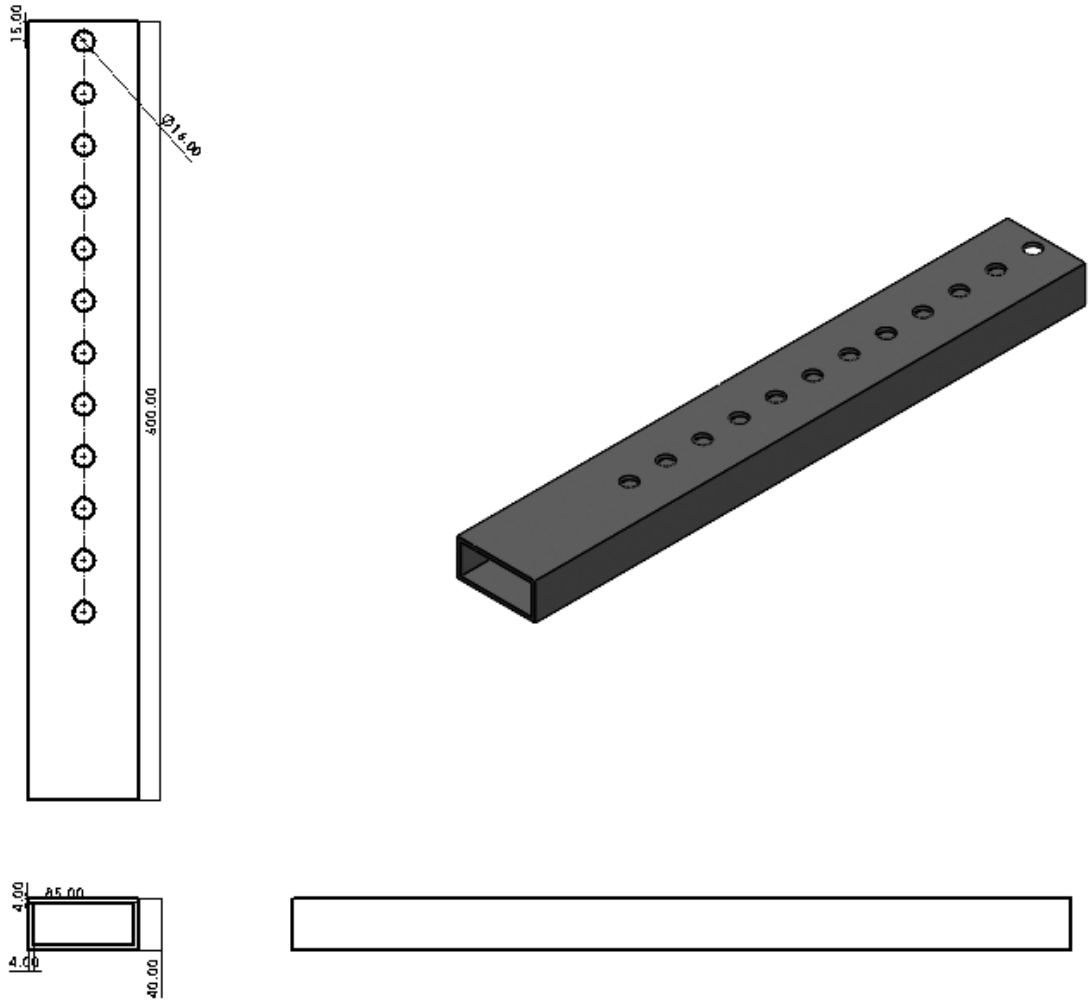


Figure A.2: Internal Rectangle Variable Angle Stand

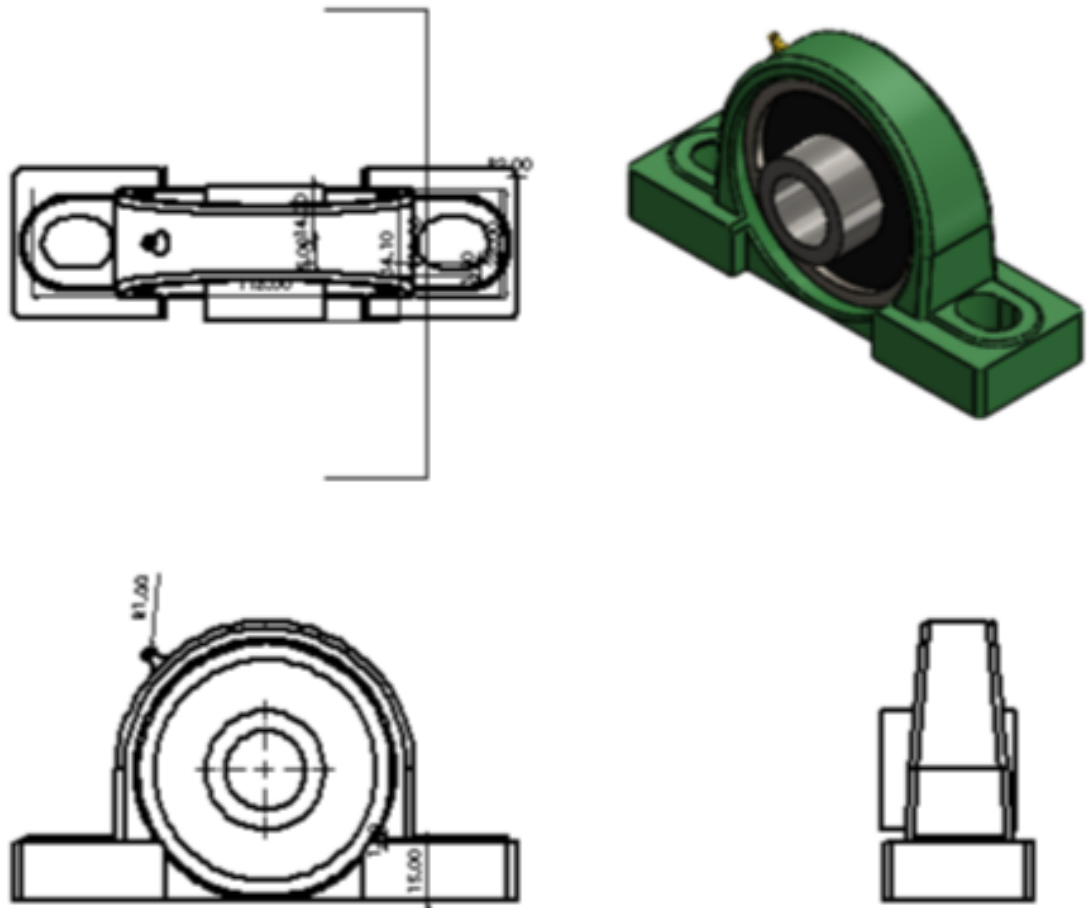


Figure A.3: Bearing Unit FKP204

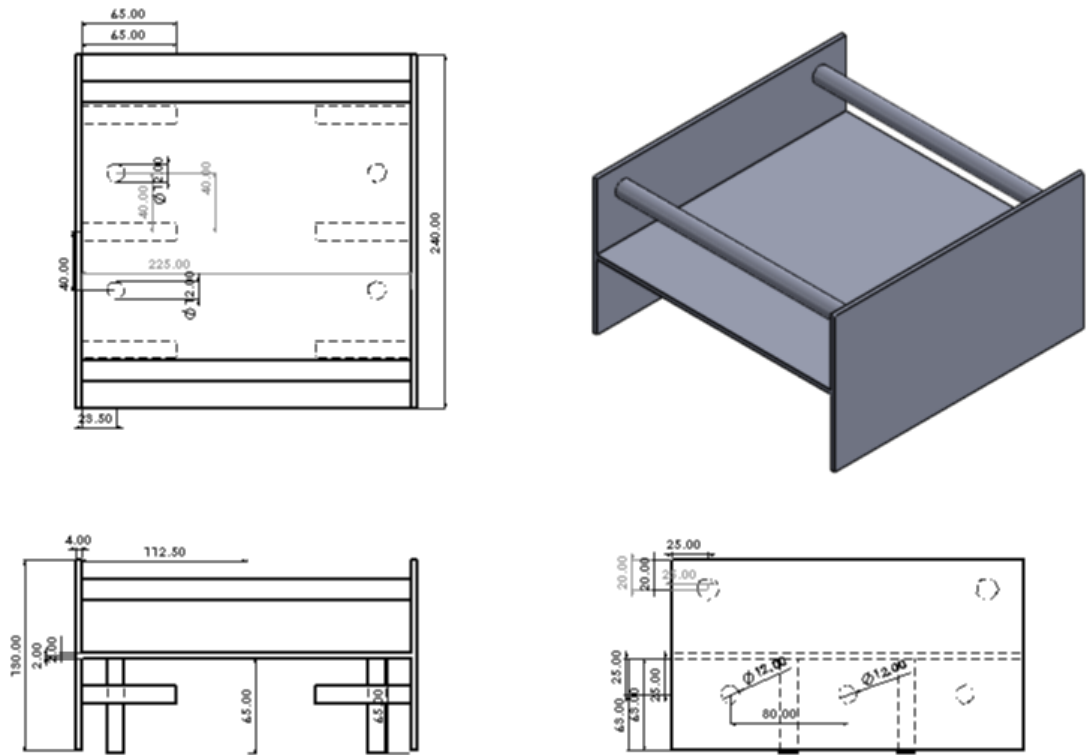


Figure A.4: Carriage

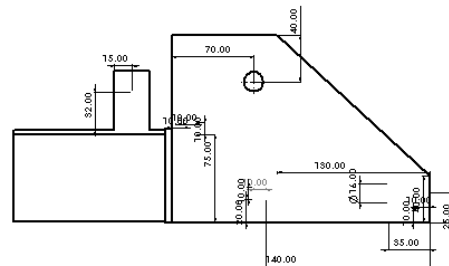
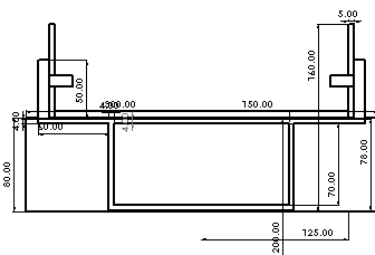
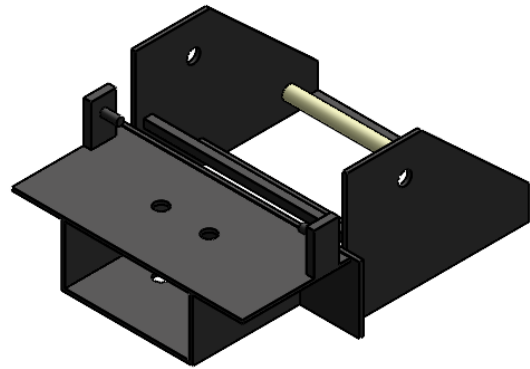
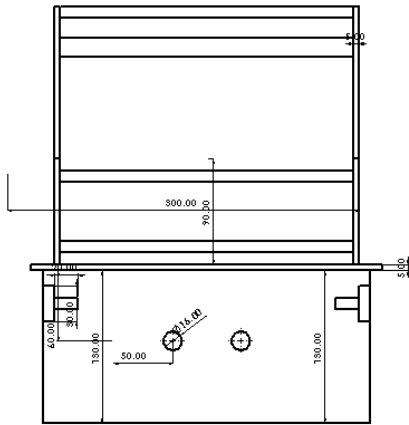


Figure A.5: Elastic Band Holding System

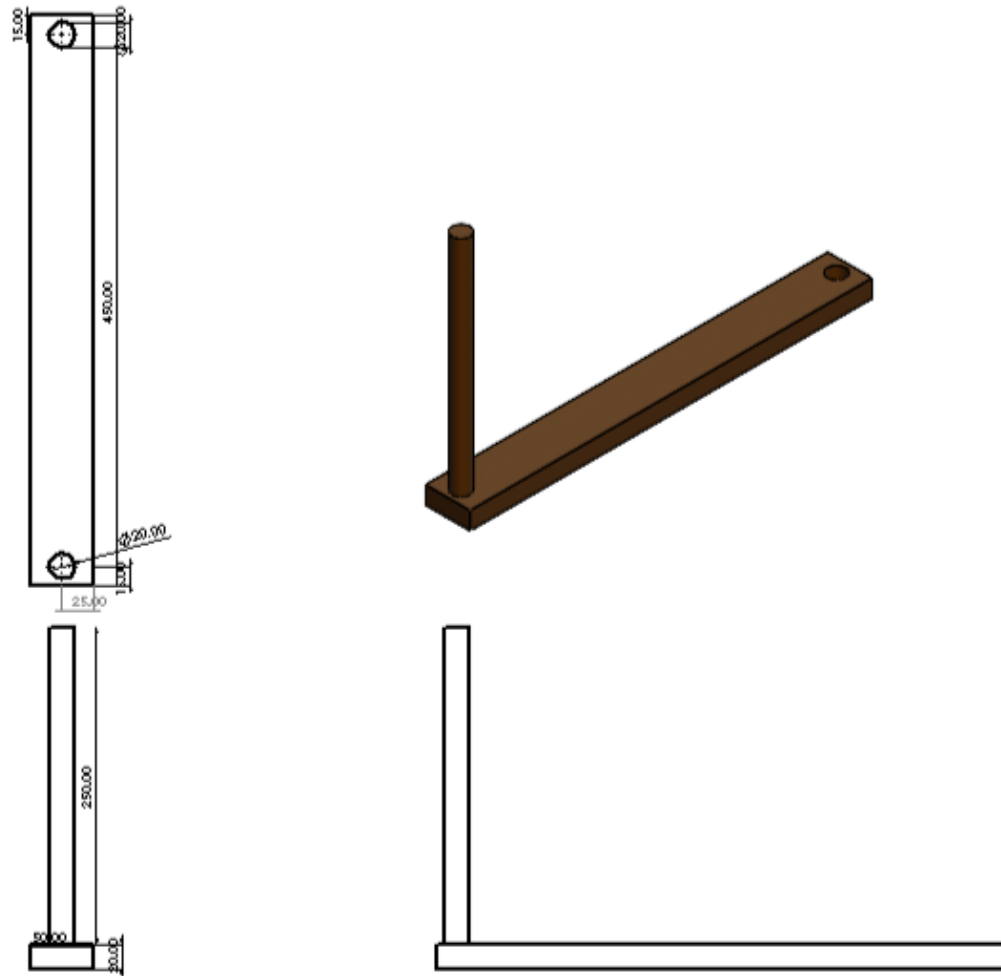


Figure A.6: Handle

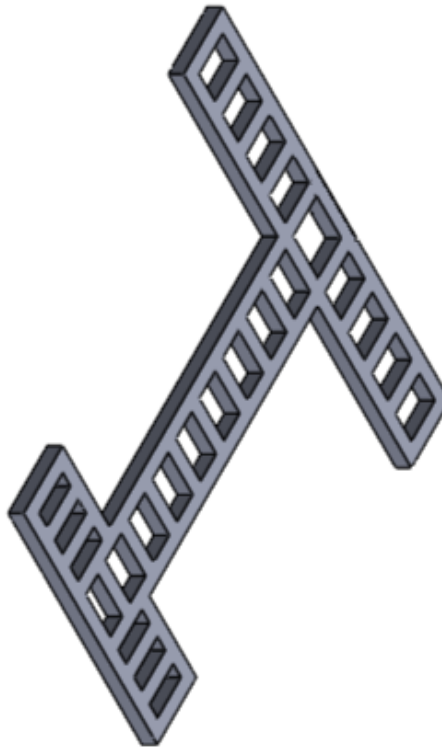
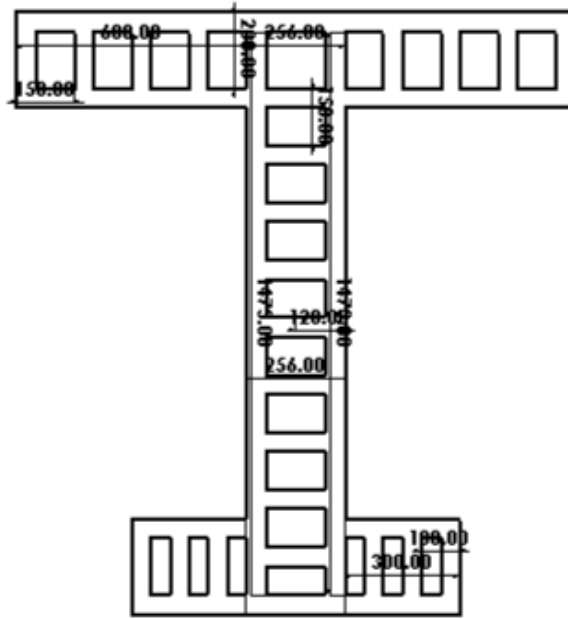


Figure A.7: Main Base

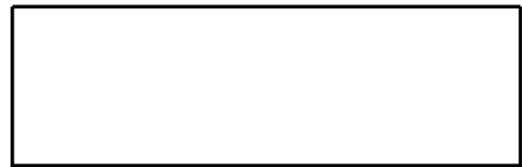
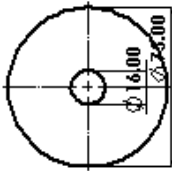
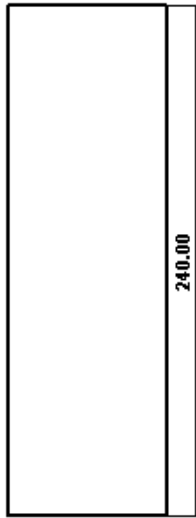


Figure A.8: Nylon Roller



# **APPENDIX B**

**Fabricated Components**



Figure B.1: Fabricated UAV Launcher



Figure B.2: Track (Side View)



Figure B.3: Spring Loaded Clamp



Figure B.4: Carriage (bottom View)



Figure B.5: Carriage



Figure B.6: Damper (top view)



Figure B.7: Nylon Roller



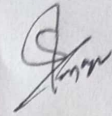
Figure B.8: Elastic Band holding system

# DESIGN AND FABRICATION OF ELASTIC-DRIVEN UNMANNED AERIAL VEHICLE(UAV) LAUNCHER

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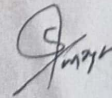
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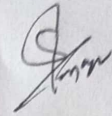


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