Slingshot
Final Proposals

Team F7
Abdullah Howaishel
Dhary Aldhefeeri
Abdullah Alzafiri
Fahad Alotaibi
Mubarak Alsuabiee

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NORTHERN ARIZONA UNIVERSITY
College of Engineering, Forestry & Natural Sciences
School of Forestry

Project Sponsor: The Wonder Factory
Faculty Advisor: Dr. Sarah Oman

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EXECUTIVE SUMMARY

Wonder Factory is a orginaization located in the city of Flagstaff in the state of Arizona. This orginazation has different and creative games to create the enjoyment to the childrens. All the products placed in Wonder Factory are unique and creative, and used for children in their learning as well as the basis for STEM.

The purpose of this project is to come up with an idea which is useful for chidren and which they can play with. It must have a sort of wow factor and it must be interesting, entertaining and simple as well. With all these requirements, the team will decide to make a design project based on slingshot.

This paper discusses old and existings designs. Furthermore, engineering and client requirements have presented along with the House of Quality matrix. Then, few designs have been generated and out of those designs one design has been selected on the basis of the Pugh Chart result. From the Pugh Chart the design which has been finalized is a customized design which has a game zone area and a targeted wall. Slingshot is used to hit the target by throwing the ball at it. According to the wonder factory, we have to make it as safe as we could because our customer is children's between 8-12 years old.

Figure 0: Wonder Factory Logo [12]

ACKNOWLEDGEMENT

Our team would like to thanks the people who have showed their positive response towards our project and helped us in all matters related to the project. First of all we would like to say thanks to our client Dr. Sarah Oman who helped us, and giving us a chance to work on such a great idea. Next we would like to thank The Wonder Factory especially Steve and Jackee without their efforts we will not been able to work on such an idea. And the last one to thank is our university Northern Arizona University, because they gave us all the knowledge that we need to break down all the difficulties that we faces in the past 4 studying years. In addition, I would thank student success center particularly Kelsey Rendon for their help editing our report for grammar and spilling mistakes.

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1 BACKGROUND

The idea for this project is to come up with an idea that will encourage the children's to love the science and engineering fields. Also this play will be hoisting by the Wonder Factory.

In order to make such a project which will help the children to decide there field, we have decided that our project will be building big slingshot to make the children's learn about projectiles. Slingshot is an old way of throwing things, this was use in old ages in wars and transfer things from one place to another.

1.1 Introduction

In 2014, a total of 357 Flagstaff citizens were interviewed on the suitability of children play facilities in Flagstaff. Out of those 357, 71% of them said that what current Flagstaff attractions offered was not suitable to meet children's needs, mostly due to the lack of interactive displays [1]. Eighty-four percent of those interviewed also said if something like The Wonder Factory was available, they would visit it and 58% said they'd visit monthly [1]. Additionally, The Wonder Factory visitation can also come from the 4.7 million tourists traveling to Flagstaff each year, 23% of which bring children with them and have no children's-style attraction to visit in Northern Arizona. It is on the basis of these findings that our project was conceptualized.

This project aims at initiating a product to be used in the Wonder Factory where learning can be generated through play [1]. Wonder Factory believes that the next generation must be given opportunities for hands-on, interactive experiences to take their positions as the thinkers, the makers, and the creators of the future. Specifically, our project focuses on designing, developing and commissioning a device that can be part of the wonder factory. The device has to meet all the required specifications and requirements so as to be able to solve the solution at hand [1].

1.2 Project description

The purpose of this project is make such a product which will be fun for the children. we decided to make our slingshot. A Slingshot will allow the children to spend their time in fun. That is why we have decided to make our slingshot to stay for years. The following is the original project description provided by the our client Wonder Factory.

The Wonder Factory is a science, engineering, art, and technology center in Flagstaff, AZ providing handson, interactive experiences for the young and young at heart. It was founded by Jackee and Steve Alston as a movement of concerned citizens working towards getting a STEM/STEAM-based play center in Flagstaff. The Wonder Factory's goal is to lead the next generation of young minds into their place as the thinkers, the makers, and the creators of the future through hands-on interactions with science, technology, engineering, art, and mathematics. Your task is to generate lots of interactive display ideas and to ultimately design build and test one final display ready for public consumption. Your final design must:

- Must be safe to all users per applicable safety standards. Safety is your first priority!!
- Must be ready upon completion of this capstone sequence
- Should generate up to 100 ideas – including existing, new, wacky, and off the wall concepts
- Must select, design, build, and test one final unique idea
- Should test the interactive display in a similar setting to expected everyday use
- Must raise some of the funds required to finish the project

- Must raise some of the funds required to finish the project

1.3 Original system

This project involved the design of a completely new slingshot system. There was no original system when this project began.

2 REQUIREMENTS

In order for our project to be useful and solve an existing problem, it was important to consult with other relevant stakeholders that were affected in one way or another by this project. The stakeholders were the key and the Wonder Factory was our client. The team is designing a product that is going to be used by kids and as such, certain requirements have to be met so as to make sure the interests of the user, the kids in this case, were well incorporated in the project. Additionally, we had to meet the needs of our client while at the same time achieving other goals such as compatibility with any existing regulations, minimal budget and high efficiency. It is for this reason that we came up with the engineering requirements that would ensure that our project was acceptable even by local and international standards.

2.1 Customer Requirements

According to our client, the basic requirement for the device was that it must have a "wow factor". Aside from the kids coming to play with the device without any assistance, the device should be able to trigger the kid's mind and make them fascinated by the simplicity yet the effectiveness of the device. Additionally, since the device had to be operated by kids without any assistance, that meant that it had to be simple. Other customer requirements were as summarized in the table below.

Table 1.1: Customer needs summary

Customer Requirements	Description of customer requirement
Safety	Every exhibit should be **safe to operate**.
Wow factor	Every exhibit is a celebration of **child-like wonder**, (i.e. have a wow factor)
Simplicity	Exhibits should be as **simple to operate** as possible.
Reality	Exhibits should be places where a visitor can **project themselves into the role** of that reality as much as possible. (i.e. They should see themselves as an engineer, a scientist, a storyteller, a medical professional, naturalist, or an artist.)
Empowerment	Exhibits should empower visitors to **"feel" smart** so they will excel in perpetuity
Entertaining	Exhibits should be able to entertain **multiple visitors**
Easy to Move	Portability factor to move the product easily anywhere

2.2 Engineering requirements

The engineering requirements came both from our team and also as guided by the client. The key for our project to pass is the safety. All materials used in the design had to embrace safety of the user and also of the team building the design. Other engineering requirements included; the weight of each part and strength of device. The engineering requirements are summarized in table 1.2.

Table 1.2: Engineering Requirements

Engineering requirements	Targeted Values	Accuracy
Range of Ball	4 Meters	$\pm 1\ Meters$
Height of Ball	3 Meters	$\pm 1\ Meters$
Angle of Projectile	45^o	$\pm 3^o$
Weight of Ball	0.5 Kg	$\pm 0.2\ Kg$
Elasticity in Rubber Band	300mm elastic Length	$\pm 150\ mm$
Energy Transmit	1 kJ	± 200 J
Weight of Product	30 Kg	$\pm\ 5\ Kg$
Edge Break Radius	1 cm	± 0.5 cm
Weight of Target	10 Kg	$\pm 3\ Kg$
Number of Targets	3	± 1
Distance between target and slingshot	4 meters	$\pm\ 1\ Meters$
Diameter of Ball	0.1524 meter	$\pm 0.02\ Meters$
Size of Target	0.381 meter	$\pm 0.0762\ Meters$
Length of Rubber band	0.3048 meter	$\pm 0.0508\ Meters$
Front Wall	3x3 meter	$\pm\ 1\ Meters$

Range of Ball

The maximum limit the ball can go towards the target to hit it. The range of ball is range for any projectile motion is the maximum distance covered in horizontal direction. So the distance from the slingshot towards the ball will be the range and it will be covered by the ball.

Height of Ball

The maximum height achieved by the ball at a specific angle. This is the height achieved by the ball when it is launched in to the target. This height will be calculated from the horizontal axis and the horizontal axis will equal to the point from where the ball has been thrown. During that projectile the ball will reach a specific height, which is usually the center point of projectile motion. Distance from the slingshot to the maximum height will be the height of ball.

Angle of Projectile

The angle of projectile would be the angle at which the ball will be thrown through the target. The angle that the projectile will make with its horizontal axis is the angle of throw. This angle is important because the ball will reach the target if the throw ball was at the correct angle. Slingshot takes the target by making some angle and that angle calculates by the horizontal surface so when the ball will be thrown it will go at some angle.

Weight of ball

The weight of the ball that the slingshot can throw. As the ball with heavy weight needs more elastic force to hit the target. In addition the lighter ball weight will need less elastic force to hit the target. That’s why the weight of ball is important for projectile motion.

Elasticity in Rubber Band

The maximum expansion that the rubber band can give is the elasticity and that elasticity will store the energy and when the energy will store and rubber band will release it will throw the ball.

Energy Transmit

As the elastic energy will throw the ball so the elastic energy will convert into kinetic energy and then the ball will be thrown towards the target with that energy, so energy will determine it. When the rubber band will stretch, it will save the energy and that energy will hit the ball towards the target.

Sharp Edge

Any sharp edge can harm the children so the product must not have sharp edges. Like every wall must have round edges.

Weight of Target

As the target will hang on the wall so the weight of that target has to be not light and not too heavy.

Number of Targets

Because the both is 1.5x1.5 meters we decided that the number of targets will be three.

Distance between target and slingshot

The distance between the target and the slingshot is the maximum distance which is 4 meters.

Size of Ball

Ball that will throw towards the target has some size so it defines that radius of that ball will be 6 inch maximum.

Size of Target

Each target will have the same size and to not excide 15 inch.

Length of Rubber Band

As the rubber band will stretch so the maximum length of rubber band will be 12 inch.

Front Wall Size

Size of front wall will be around 1.5 x 1.5 meters.

2.3 Testing Procedures

In order to test the engineering requirements the following tools and machines must be used. The testing procedures are used to verify that engineering requirements meet the targeted values stated in the ER section.

Range of Ball

The range of ball can be measured with a metric units tape measure. The ball will be launched and the distance measured to the nearest millimeters. A tape measure of at least five meters in length will be needed, with a resolution of 4-5 meters.

Height of Ball

The ball height can be measured through a measuring tape. A simple scale available in the market can do this, by just throwing the ball towards the target and measure the distance in the sky. We can detect the most accurate distance by recording it by the high-speed video cameras.

Angle of Projectile
The projectile angle can be determined through the Semi-Circle scale by placing it on the horizontal axis. This can easily measure through the protractor available in the market.

Energy Transmit
It can calculate through the elastic force apply by the rubber band or can determine by finding the velocity of ball. We can detect the most accurate velocity of the ball by recording it by the high-speed video cameras. After that we will measure the kenotic energy.

Sharp Edge
Any sharp edge can harm the children so the product must not have sharp edges. Like every wall must have round edges. Edges can calculated through the protractor which is available easily in the market.

Weight of Target
As the target will hang on the wall so the weight of that target is basically weight of target. Weight can be measured by the scale easily available in the market.

Number of Targets
Count the number of targets that we bought.

Distance between target and slingshot
Distance will measure through the measuring tape which available in the market.

Size of Ball
Size of ball can calculate easily by the measuring tape. It can be measure by the circumference of ball and through the formula to calculate the radius of the ball.

Size of Target
Target size will also measure in the same way as the ball.

Length of Rubber Band
Rubber band length will also measure through the scale easily.

Front Wall Size
Size of wall can calculate through the measuring tape, simply measure the length and width.

2.4 House of Quality

The customer needs and the engineering requirements comprise the two main parameters for our design. The two result to dissimilar effects and impacts on the design. The HOQ will be useful in the planning process for our design, which will start with the voice of the customer. It will enable us to think together.

These parameters possess different weights that they enforce on the exhibit when they are re-weighed relative to each other. HOQ is useful when weighing the parameters that are in the HOQ relative to one other. From this evaluation it can concluded that the parameters are most significant to contemplate in the design process.

Table 1.3: HOQ model

House of Quality (HoQ)																
Customer Requirement	**Weight**	**Range of ball**	Height of Ball	Anlge of Projectile	Weight of Ball	Elasticity in Rubber Band	Energy Transmit	Weight of Product	Sharp Edge	Weight of Target	Number of Targets	Distance between target and slingshot	Size of ball	Size of Target	Length of Rubber Band	Front Wall Size
Safety	9	3	3	9	1	1	3	9	9	1	9	3	1	3	3	3
Wow Factor	3	3	3	3	9	3	9	3	3	9	3	3	9	9	3	
Simplicity	3	1	1		3	9	1	1		3	3	1	3	1	1	3
Reality	9	9	1	3			1		3		3	9		1	1	
Empowerment	3	1	1	1	1	1	3	3	1	1	1	1	1	3	1	3
Entertaining	3	3	1	3	3	9	1	1	3	3	1	3	3	1	1	1
Easy to Move	1	1	1	1	1	1		1	1	1	1	1	1		1	
Absolute Technical Importance (ATI)		133	55	130	58	76	78	106	130	58	133	133	58	78	55	48
Relative Technical Importance (RTI)		10%	4%	10%	4%	6%	6%	8%	10%	4%	10%	10%	4%	6%	4%	4%
Target ER values		4	3	45	0.5	300	1000	30	-	10	3	4	6	15	12	9
Tolerances of Ers	%	1	1	3	0.2	50	2	5	-	3	0	1	2	3	2	2
Testing Procedure (TP#)		m	m	deg	kg	mm	J	kg	-	kg	-	m	in	in	in	m

The HOQ shows the relation between engineering requirements and client requirements. From the relation it has clear that the top engineering requirements according to the customer requirements are range of ball, angle of projectile, sharp edge must not be there, distance between the slingshot and target. As these requirements are the major design requirements that's why they got the priority.

3 EXISTING DESIGNS

For a long time, kids have taken Y-shaped branches, overextended some surgical tubing or a heavy rubber band over it, and shot at tin cans, birds, and windows on abandoned buildings. Slingshots have existed before. However, our design has been customized to have additional features that did not exist in previous designs. Common to all existing designs is that they focused on the materials. They needed to be light but not too light. They need to be strong and not brittle, and they need to be able to be formed into somewhat complex shapes. Lastly, the materials need to have an attractive finished look.

3.1 Design Research

Design research is fundamental to making services, products, and systems that answer to human requirements. In the international and public development sectors, comprehending and meeting human requirements is important for better livelihoods and improved governance [1]. In our case, design research will provide engineering insights that focus on design analyses of previous models and existing designs. We conducted primary research fundamentally so as to generate new data to comprehend our client as well as helping users concerning their needs and what we would possibly plan on designing. It enabled us to validate our thoughts with our users and design a further eloquent solution for them. We collected this data via surveys, interviews with individuals, and questionnaires. Our main interview was done with our client so as to understand their basic requirements for their dream exhibit. It is upon these interviews that we obtained a set of customer needs as listed in Table 1. Surveys were done of several children's playgrounds in order to see what kind of play facilities were available for children to play. However, we were not successful in finding any slingshot play devices on any of the playgrounds. Nevertheless, typical Y shaped slingshots were found with some boys and they could use them for shooting at birds for fun. We additionally conducted a secondary research utilizing prevailing data including the Internet, articles, and books to back up our design choice and the perspective behind our design. Secondary research is also used as an approach to further authenticate user comprehensions from the primary research and generate a stronger case for the whole design [2]. This research helped us to identify and analyze several designs as will describe in detail the system level below.

3.2. System Level

System-level design is a procedure where the engineer takes accountability for all the constituents of a system when scheming the solution [3]. For the slingshot, for example, the system designer considers the functionality of the device, the different parts that make up the slingshot, and the materials used to make the different parts.

3.2.1 Existing Design # 1: The Scout Slingshot

This Slingshot is a 100% American finished, high-quality hunting slingshot. It's made ultra-tough from a contemporary polycarbonate material that is utilized in the firearms industry. The Scout comprises the best performers among hunting slingshots, offering sufficient power, precision, and robustness to fulfill anyone requirements. It obtains its power for shooting from heavy-duty flat bands. Its glass filled nylon frame renders it lightweight, yet robust to the roughest usage. One feature that stands out about this slingshot is its simplicity. Nearly nothing can go wrong with it considering its simple, yet functional build.

Figure 1: Scout slingshot [3]

3.2.2 Existing Design # 2: Torque Slingshot

This is a solid choice from Simple Shot, and it is made from ultra-strong glass packed nylon. This kind is nearly unbreakable. Indeed, it's manufactured to the utmost standards of quality in the USA. It is one of the smallest hunting slingshot choices in the market and its compact size and lightweight makes it perfect for carrying in the pocket as well as putting it in a bug out bag. Its simple design tells volumes as far as design goes. This model was conceived by Simple shot with the assistance of Mark Seljan, an industrial designer. It's modest, sturdy, and functional. The Slingshot comes equipped to shoot with 2040 twisted tubes, but it can as well handle powerful flat bands. This can simply be changed out through its fork slots.

Figure 2: Torque Slingshot [4]

3.2.3 Existing Design # 3: Outdoor Life Stainless Hunting Slingshot

This is a flexible design that can be adjusted and offers a completely adjustable solid steel frame. It is heavier than other designs, but it's however super strong and gives a bit of customization with the position of the fork. It is assembled with a solid steel frame, which enables fork position tunings to deliver the best shooting position. Additionally, it can be adjusted on the fly quite easily with a single big steel screw. This as well makes it more adaptable if it is necessary to add longer or shorter bands. The ergonomic precast handle is non-slip and provides the grip required in whichever conditions. One thing to note is that it is weighs more than other models as a result of its steel frame and bigger molded handle.

Figure 3: Outdoor Life Stainless Hunting Slingshot [4]

3.3. Functional Decomposition

The functional decomposition describes a set of steps in which the overall function of a device, system, or process is broken down into its smaller parts. This is usually accomplished through thoughtful analysis and team discussions of project information and the result is a chart that describes the problem and or solutions in increasing detail. Following is the black box model for the current system.

3.3.1 Black Box Model

The Figure 4 will be our Black Box Model

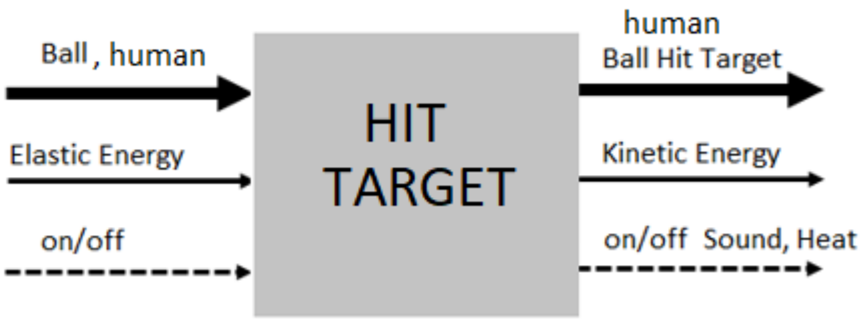

Figure 4: Black Box Model

This model is useful for understanding the inputs and outputs of the system. As the system has three inputs which are the ball, elastic energy and a signal of the on and off the system. The three outputs are hitting the target through the ball, kinetic energy obtained by the ball to hit the target and the on and off signal. Sound and heat will also release when the ball hits the target. The Black Box model for any system identifies the inputs and outputs without knowing the workings of the system inside the product. In addition the functional model is the one that view the workings inside the system.

3.3.2 Functional Model

Following is the Functional Model for the slingshot design project:

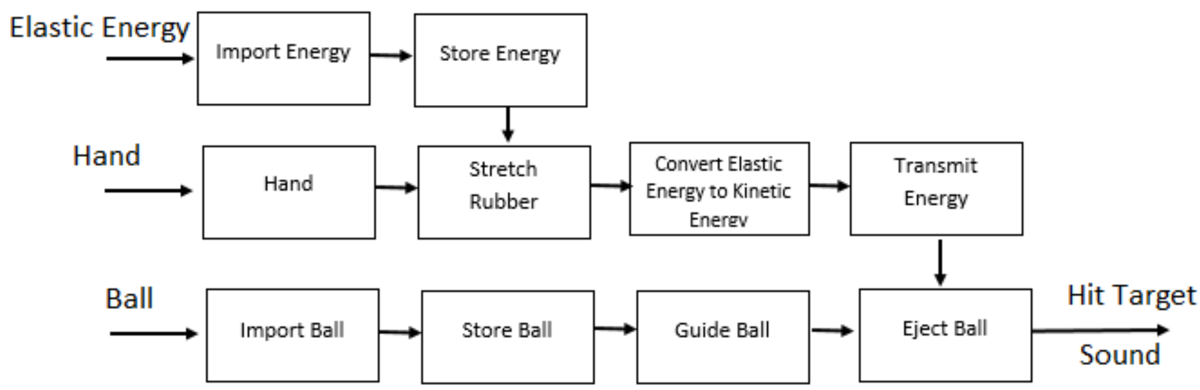

Figure 5: Functional Model

The sole aim of the device is to enable kids to play with minimal supervision while efficiency is achieved. For this to happen, our device will be able to employ two functionalities at ease. These will be the throwing and striking functions. Mechanical energy will be employed via the human hand to stretch the slingshot, which is holding the ball. This will build up potential energy that will see the ball move towards the target when released. The dangling boxing balls possess potential energy, which will be used to hit the approaching ball, building up pressure, which will direct the balls to the pulley system.

Before the drawing of our functional decomposition chart, the problems, processes, and overall projects seemed intricate. However, this complexity vanished as soon as we took a closer look and broke them down into a portions. Comprehending the precise functions and sub-functions that made up the system made it easier for more effective organization and enhanced planning. Additionally, each function could be viewed as an independent unit, making the problems at the lowest level.

3.4. Subsystem Level

The subsystem level comprises the smaller mechanisms of the design that have a critical role to make it working successfully. Several sub-systems were considered with help of the subsystem level as discussed below.

3.4.1 Subsystem # 1: Elastic Bands

The elastic band is one of the major components for this project, as the slingshot has two portions: one is the elastic band and the second is the frame. The elastic band is quite important for our project because a good band with good elasticity will able to throw the ball correctly all of the time at some distance. There are multiple elastic bands already available so in this section will consider existing designs for elastic bands.

3.4.1.1 Existing Design # 1: Rubber bands

The rubber bands can be regarded as the slingshot's hand. They stock and release the energy that is utilized in propelling the ammunition. Bands can be replaced, and numerous features of the slingshot change along with them. They can come in diverse forms, dependent on design and material. For instance, a band that is made of a superior quality rubber guarantees the best user experience. This elastic is available in a 6-yard length that enables consumers the suppleness to make custom slingshot band shapes and sizes. Wizard bands are intended for high speed and reliably, and deliver distance and velocity. In our project, the durability of the bands will be an important aspect to consider. It must be high quality and efficient while also having a reasonable cost.

Figure 6: Rubber Bands [2]

3.4.1.2 Existing Design # 2: Plastic Bands

There is another type of band available on the market that is made of plastic material, but the elastic limit of such a material is not equal to the rubber band. That band is also useful for this project if it gives enough elasticity as is required by the project.

Figure 7: Plastic Bands [1]

3.4.1.3 Existing Design # 3: Plastic Tubes

Another option is the use of plastic tubes that are already available on the market, like the tube used for the inflation of tires and the tubes used for swimming in the water.

Figure 8: Plastic Tubes [3]

3.4.2 Subsystem # 2: Frames

The frame is the part that is held by the shooter, and keeps the rubber bands in place. It is not as important as it seems, but it plays its part in keeping the shooting process comfortable and obtaining a good sight picture. Safety considerations are important when constructing the frame, as failure of this part can lead to severe injuries.

3.4.2.1 Existing Design # 1: Wooden Frame

A frame made up of wood is a good choice for this project because it is already available on the market. Wood is strong and has a good hold as well which is why it is a good option. Another thing is that wood has the least elasticity, so when making the V shaped hands, wood is strong enough to bear a lot of force exerted by the rubber band when it stretches by any human hand.

Figure 8: Wooden Frame [4]

3.4.2.2 Existing Design # 2: Plastic Frame

A frame made up of plastic is also an existing design but the problem is that plastic has higher elasticity and it is not strong enough to bear the force applied by any human hand. But, as the project is for children, the plastic frame can also be used for this purpose.

Figure 9: Plastic Frame [3]

3.4.2.3 Existing Design # 3: Steel Frame

A steel design is also a good option to use for this purpose because it is strong and can bear a force applied by any human body.

Figure 10: Steel Frame [4]

3.4.3: Subsystem # 3: Holding Pouch

A pouch is required to grip the projectile in place prior to and during the shot. Having it at the right weight and size is important to get a virtuous performance. Only scarce materials can endure the stress that the pouch undergoes during the shot, and as such leather is both cheap and affective for this task. It needs to be soft and supple, frivolous and robust. A typical choice is fragmented leather from cow or pig, with a thickness of 1-3mm for standard draw bulks. It endures a lot of pressure and strain whereas being soft, supple and lightweight.

3.4.3.1 Existing Design # 1: Leather pouch

A pouch of leather is good to use because the leather is rough and has high friction that's why it becomes easy to hold the ball for throwing it. As more force will apply to stretch the rubber band, at the same time it will become important to hold the ball tight.

Figure 11: Leather Pouch [1]

3.4.3.2 Existing Design # 2: Rubber Pouch

Mixed rubber is also an available design for holding the ball and make the pouch for slingshot. This is also useful option for this project.

Figure 12: Rubber Pouch [1]

3.4.3.3 Existing Design # 3: Rexene Pouch

This is a replacement of leather and is used intensively for such pouches. It is also useful for this project because it has a good hold.

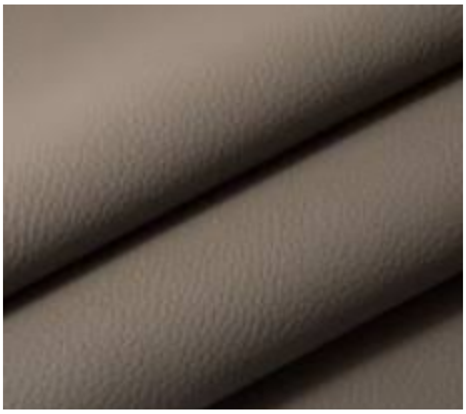

Figure 13: Rexene Pouch [4]

4 DESIGNS CONSIDERED

There are a few designs, which were created for this project, and these design are shown below along with their description.

4.1 Design #1: Scout slingshot

This design is made ultra-tough from a contemporary polycarbonate material that is utilized in the firearms industry. This one comprises the best performers among hunting slingshots, offering sufficient power, precision, and robustness to fulfill anyone requirements. A stand will be made using plywood, which will form a bouncing wall to act as the ball target.

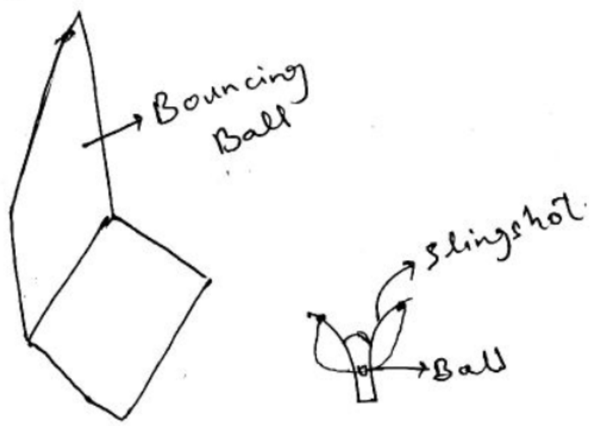

Figure 14: Scout slingshot

4.2 Design #2: Torque slingshot

This one is made from ultra-strong glass packed nylon. This kind is nearly unbreakable. It is one of the tiniest hunting slingshot choices in the market and its compact size and light weight makes it perfect for carrying in the pocket as well as putting it in a bug out bag. A customized pole with a ring at the top comes with it and the aim of the game will be to place the ball inside the ring using the slingshot.

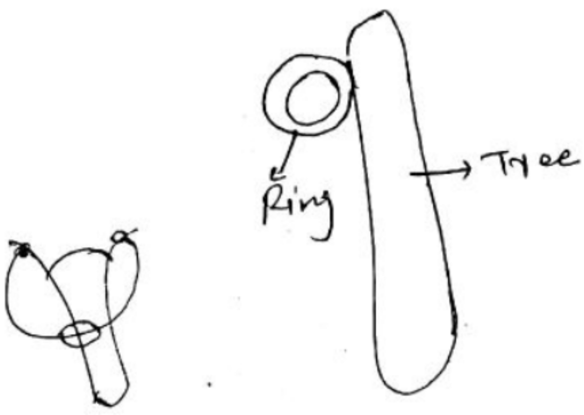

Figure 15: Torque slingshot

4.3 Design #3: Outdoor Life Stainless Hunting Slingshot

This is a flexible design that can be adjusted and offers a completely adjustable solid steel frame. It is heavier than other designs, but it's super strong and gives a bit of customization with the position of the fork. A wooden block comes with it acting as the target for the ball.

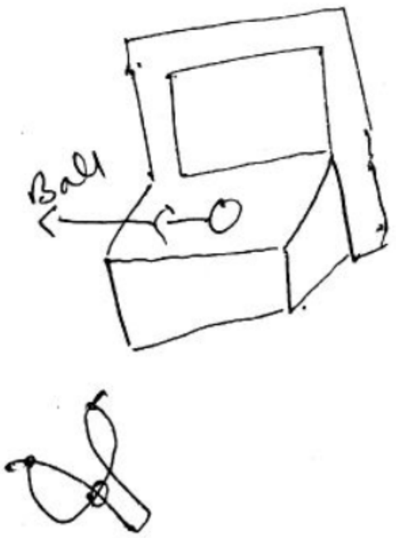

Figure 16: Outdoor Life Stainless Hunting Slingshot

4.4 Design #4: Traditional Y shape

This incorporates the concept of the traditional Y shaped frame with rubber strips attached to the forks. Balls are then hanged on a post to appear like dangling fruits which children can hit.

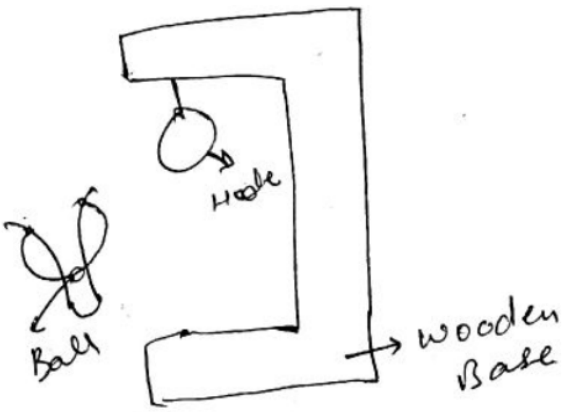

Figure 17: Traditional Y shape

4.5 Design #5: Bow slingshot

This design is designed to shoot arrows. The main dissimilarity with the others is that they have an arrow rest and arrow nock. Arrow rests, like the whisker arrow rest, grip the arrow in place and enable the user to shoot with a high mark of accuracy. A dart like board hangs on a wall acting like the target.

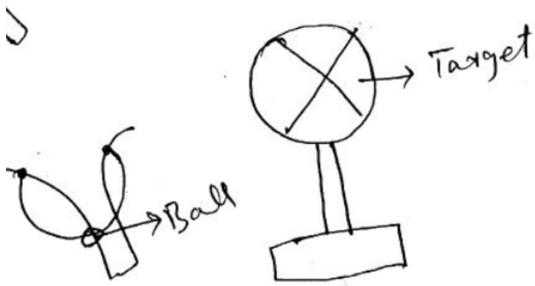

Figure 18: Bow slingshot

4.6 Design #6: Mug Shaped slingshot

This one is capable of being shot with or in absence of a wrist brace, as it provides the user with the chance to have one unit to support many shooting disciplines.

Figure 19: Mug Shaped slingshot

4.7 Design #7: Bone Collector Sport Slingshot, Laser & Light

This one is designed to hold a Mini Maglite 2AA flashlight and is known to shoot day or night with bulls-eye precision and accuracy. At night the light can be switched on providing clear visibility for the target. Indeed, it possesses optic sensors that capture light rays that make the red and green sights glow for better accuracy for shooting.

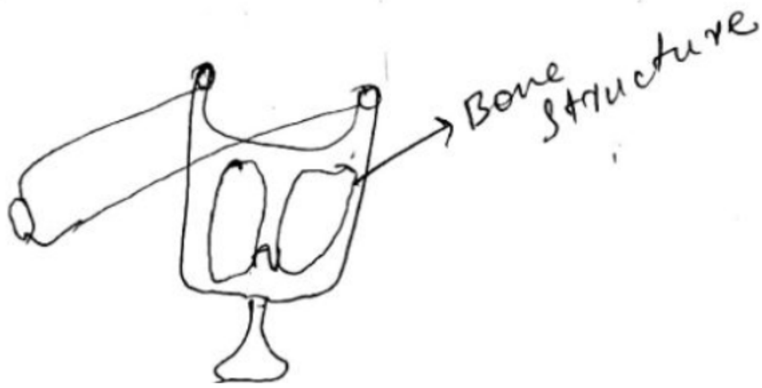

Figure 20: Bone Collector Sport Slingshot, Laser & Light

4.8 Design #8: Beeman Laserhawk slingshot

This design is designed for easy keeping and fetching and has a hinged arm support that folds for appropriate storage. It also comes with a molded finger pleated grip for extra comfort, hardened steel yoke as well as an arm support, and utmost quality hollow thrust bands that shoot 1/4" and 3/8" steel shot.

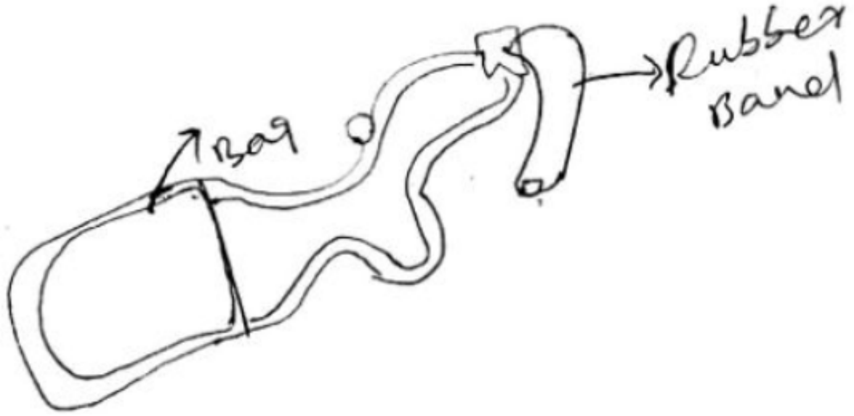

Figure 21: Beeman Laserhawk slingshot

4.9 Design #9: Yusylvia slingshot

This comes with an adjustable wrist brace including a golden proportions making precision excellent in hunting. This slingshot is particularly good for a beginner. Its high speed, precision, and powerful magnetic leather renders it possible to reload bullets fast.

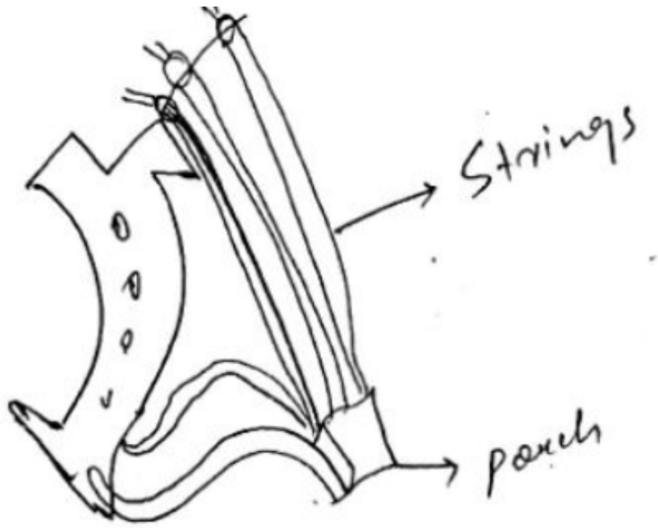

Figure 22: Yusylvia slingshot

4.10 Design #10: Customized slingshot

This one is able to shoot a ball into a target which is a ring that is held on a wooden pole. Once the ball was shot into the target, a pulley is used to drag the ball back to the slingshot for it to be thrown again instead of someone going there to pick the ball.

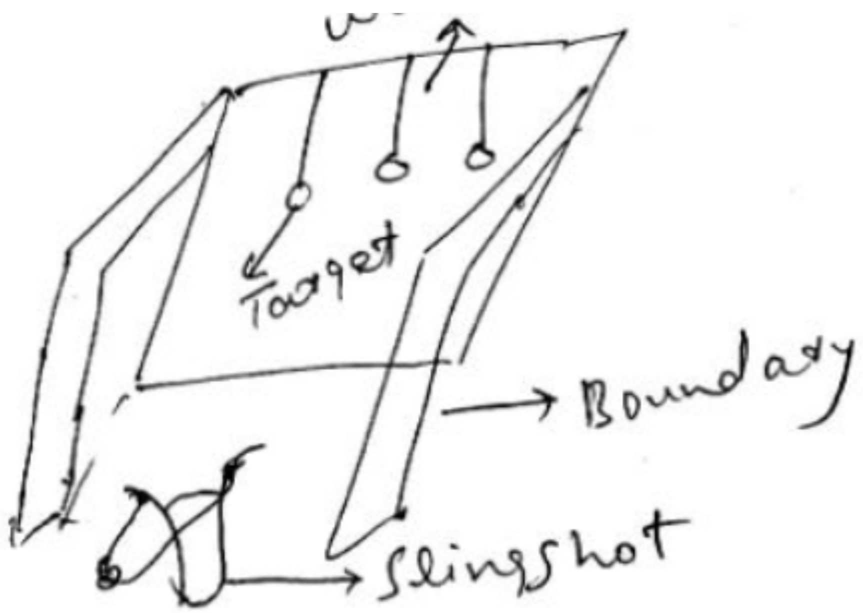

Figure 23: Customized slingshot

5 DESIGN SELECTED

Selection of the final design relied upon a thorough analysis of all considered designs while assessing them against the HOQ. This gave the criterion that was utilized in the design selection. The identified criteria were utilized in the decision matrix to determine the best model amongst the designs considered. After a thorough analysis and evaluation of all the designs, we selected the tenth design since it had the most desired qualities.

5.1 Rationale for design selection

All the customer and engineering requirements discussed in Chapter 2 were assessed critically against the ten considered designs. Scores were assigned for each design as to the degree in which it satisfied each of the requirements. In order to select the design, we have used the Pugh Chart.

Table 1.4: Pugh Chart

10 Designs for SLINGSHOT	Weight	Scout Slingshot	Torque Slingshot	Outdoor Life	Traditional Y shape	Bow Slingshot	Mug Shaped Slingshot	Bone Collector	Beeman Laserhawk	Yusylvia Slingshot	Customized Slingshot
Range of Ball	8	+	+	+	+	D	-	-	+	+	+
Height of Ball	7	S	S	+	-	A	S	+	+	+	+
Weight of Ball	6	-	+	+	+	T	-	S	+	-	+
Angle	5	+	+	+	+	U	S	-	-	-	+
Elasticity	4	+	S	+	S	M	+	-	-	S	+
Safety	3	+	+	-	-		-	S	S	-	+
Wow Factor	2	-	+	+	+		-	-	S	S	+
Simplicity	1	-	+	-	-		-	+	-	-	+
Pluses		4	6	6	4		1	2	3	2	8
Minuses		3	0	2	3		5	4	3	4	0
Total		1	6	4	1		-4	-2	0	2	8

From the Pugh chart we narrowed it down to the top three designs, which then were analyzed with a decision matrix to finalize the design. Three deigns were selected because they got the maximum numbers. These three designs fulfilled all the requirements for this project. In order to narrow down the final result, we will move towards the decision matrix, which will finalize it.

Table 1.5: Decision Matrix

	Range of Ball	Height of Ball	Weight of Ball	Angle	Elasticity	Safety	Wow Factor	Simplicity	Total
Weight	8	7	6	5	4	3	2	1	
Customized Slingshot	5x8=40	6x7=42	2x6=12	7x5=35	7x4=28	5x3=15	5x2=10	1x1=1	183
Scout Slingshot	4x8=32	5x7=35	1x6=6	5x5=25	6x4=24	4x3=12	4x2=8	1x1=1	143
Outdoor life	4x8=32	5x7=35	3x6=18	1x5=5	2x4=8	4x3=12	2x2=4	2x1=2	87

The decision matrix has three projects, so comparing these three projects according to the requirements and their weight as defined by the HOQ. Each project is assigned a specific number, which it possesses for the corresponding requirement, then summing up all those numbers to form the total. The highest number in total is the final result from the decision matrix.

5.2 Design Description

Figure 26 below shows the chosen model through the decision-making criteria. Our choice was a customized slingshot that would be able to throw a ball into a target, which is a ring that is held on a wooden pole and an auto set target. Once the ball was thrown into the target, a pulley made out of steel would be used to drag the ball back to the slingshot for it to be thrown again instead of someone going there to pick the ball. A cubic wooden booth with dimensions of 3x3 meters will be built and in the middle of the booth will be the the dangling targets. On the opposite side, a slingshot made of steel capable of rotating up to 45 degrees will be built and the pulley will be connected to a tube on the left side of the slingshot. The shooting ball will be covered in netting made of polyethylene twine, which will be connected to a rope. The first end of it will connect to the net and the other end will connect to the pulley to drag the ball down again to the slingshot. Finally, a plastic fence with blunt edges will be built in front of the slingshot so as to contain the ball and prevent it from getting lost.

The design won due to its additional customized features that made it fit for the task intended. Additionally, the materials used in this design were durable and of high quality yet cost effective and easily available in the market. Most of all, the design brought out the “wonder factor” in an outstanding way since it had customized features that were not available in any of the other designs. This would results in the kids yearning to play with the device while learning about projectile motion at the same time. The Final CAD design is shown below from Figure 24-26

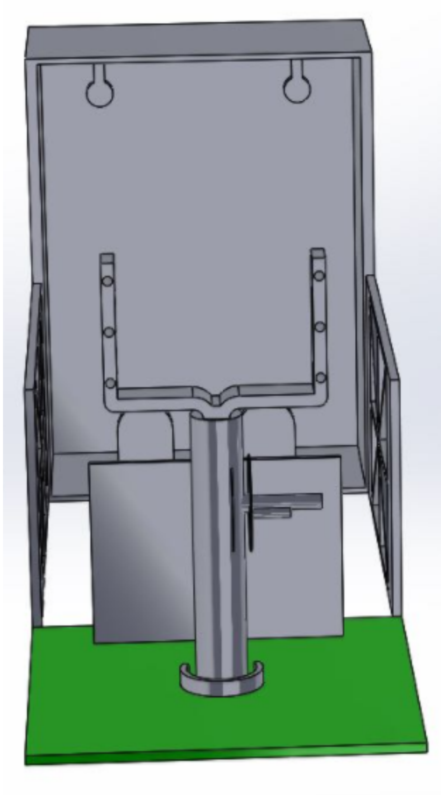

Figure 24: Front View CAD Model

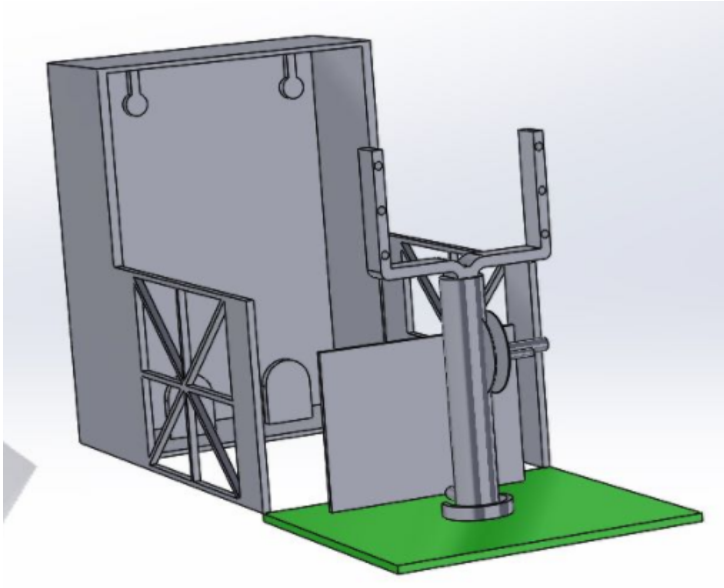

Figure 25: ISO View

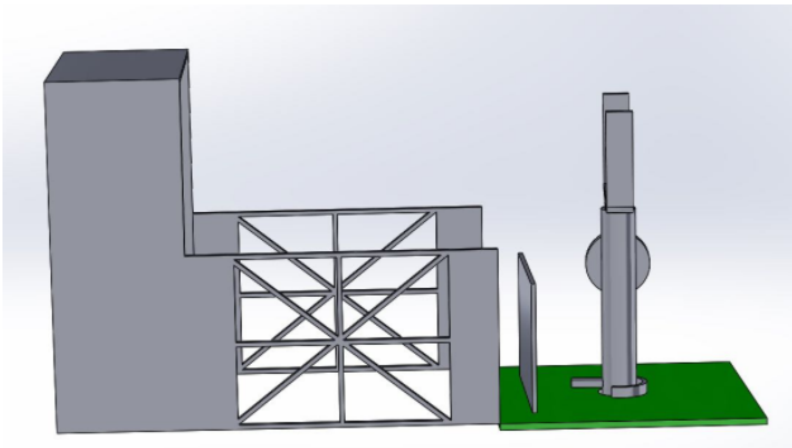

Figure 26: Side View

6 PROPOSED DESIGN

The design below includes a wall fence all around three sides to cover the area because the ball will go out of range while throwing it towards the target, which is why it is necessary to put the walls all around it. There is a slingshot placed in front of the area to hit the target and 3-target boxing balls will be dangling from the middle of the booth. The Prototype model shown below in Figure 27 is the initial Prototype design of the proposed system.

Figure 27: Prototype Design

6.1 Resources

For this system, the project resources that will be needed are shown in the following table.

Resources	Material
Slingshot Rubber	Rubber
Slingshot Frame	Steel
Slingshot Prong	Steel
Slingshot clips	Steel
Slingshot base	Steel
SPI Sponge Ball	Plastic
Hook	Plastic
Pouch	Leather
Fence	Plastic
Boxing Balls	Rubber
Pole	Wood
Color	Powder
Room walls	Wood

We will be using all the materials that provided to us to create our project. We will be using a list equipment listed in the down table:

Equipment	Uses
Circular saw	Cutting the wood and the steel
Tap Metal	Creates screw thread
Hammer	Hitting the nails
Welding machine	Weld the metal
Screwdriver	Install the screws
Brush	Paint the walls
Drill	Makes holes into a wall

6.2 BOM

A bill of materials states all the parts, which will used to build the project and the material of each item that will be used. The bill of materials is important for any project and it has helped us because we now have a list for the items that will have to be bought for building the project. Now, we know that the structure of our product will consist of plastic and the slingshot will consist of the iron rod and rubber band. In this way the BOM made it easy to implement the project. The bill of materials is shown in appendix A.

6.3 Cost and Budget

The budget to implement this project is shown in the following table for each item.

Item	Cost
Slingshot Rubber	$7.59
Slingshot Frame	$558
Slingshot clips	$7.29
SPI Sponge Ball	$10.98
Hook	$8.55
Fence	$30
Boxing Balls	$30
Paint color	$28.98
The wooden booth	$600
Total	**$1281.39**

6.4 Schedule

The schedule for second semester is in the Gantt chart in Appendix B. A Gantt chart is a useful way to describe the schedule because it mentions the deadlines in a visual form. And with the help of this chart, the project can be completed on time because we will track the work and see if we are behind schedule or ahead.

7 IMPLEMENTATION:

On the implementation we did our best to unsure the best quality that we could deliver. On this project we ordered the materials from a lot of places. As a team we reviewed each part that we needs to order by all the group members before ordering it. We ordered the project materials through Amazon.com, homedepot.com and there are parts that we purchased on our self's.

When we finished ordering the materials and the materials is here we started to manufacture the project. We started with making it as our CAD design that we design in the first semester. The first thing that we started on is the slingshot. We took our slingshot design to be reviewed by Dr. Oman and our client to be sure that our design met there needs and there aspirations. After that we started to work on manufacturing the slingshot part by part. Because of that the group has no experience on the welding field. We want to a local welding place called (Eager Welding). We started to manufacture the slingshot there and we finished it on the middle of March.

The last thing that we finished working on is the Wooden booth. We take on consider all the engineering requirement and the customer need to met the highest quality that we could reach.

7.1 MANUFACTURING

The project manufacturing took a bit of time. We order the materials that we need to start the work, after that when all the materials are here we started to work on it. The fist thing that we started on is the slingshot. We cut the materials to the measurements that we need to stick with the engineering requirements. In addition, we started with the steel base it was bigger than what we need, because of that we cut it to be 4x4 ft. we weld a small tube to the steel base and we cut it 45 degree from to side. Before that we weld all the tube and carving all the sharp edges. In addition we dug a hole in the slingshot on the down side of it. We make the hole to but a screw and make it stable, easy to assemble and disassemble to make it rotate 45 degree. Moreover there is steel pulley that welds on the left side of the slingshot. That will help to drag the ball back to the slingshot. On each of the Y-shape arms there is a 3 holes the distance between each one of them is 1 inch. We made those holes to insert the eye screw in it. Those eye screw will help us to assemble and dissemble the rubber hooks. This eye screw will help us to ensure that the children's with different high to enjoy playing the game without high being an issue. The last thing that we made to the slingshot we paint it to the yellow color and this is half of the Northern Arizona University tag.

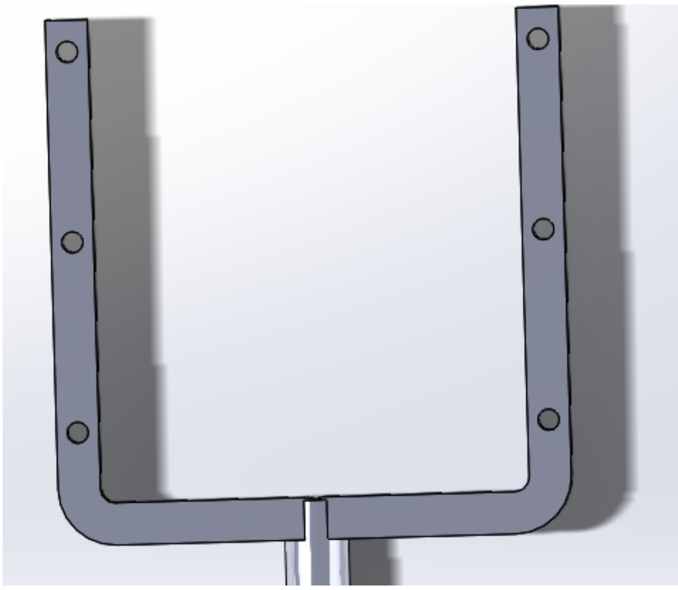

Figure 28: Y-ship holes

Figure 29: Slingshot pulley

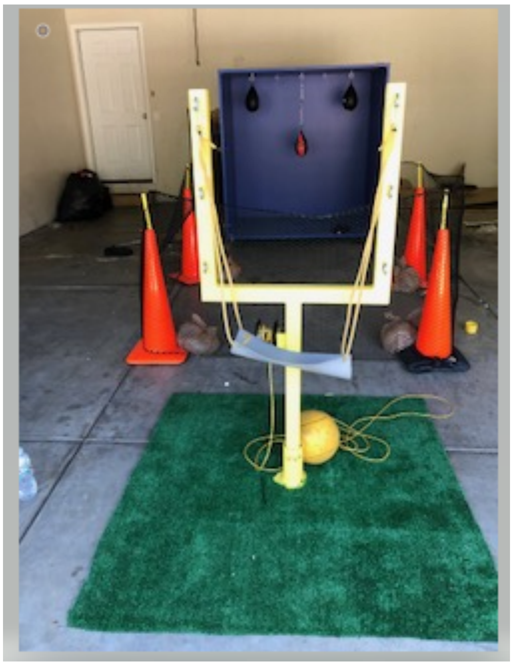

Figure 30: slingshot manufactured

The big part of manufacturing was the booth. The booth is 1.5x.1.5 meters wooden walls. Because of the lack practice that we have on the sawing field, we build it with the help of local wood saw that located next to the flagstaff downtown. Firstly we made it clear that we need things that will stand for long time and with high quality. The second thing was that we need it safe and we accomplish that by sweep all the sharp edges on the booth. The third was panting the booth to the blue color, and it is the next half of the Northern Arizona University tag.

Figure 31: Booth from inside

Figure 32: Booth from outside

The third part was the patch made on tailor and it is made from leather. We tying the rubber to the patch to create the slingshot.

Figure 33: rubber attached to patch

Attaching the fence to the booth made by making 2 holes to the right and left walls of the booth. On those holes we attached an eye screw, which will help us to make the hang the fence and make it stand still.

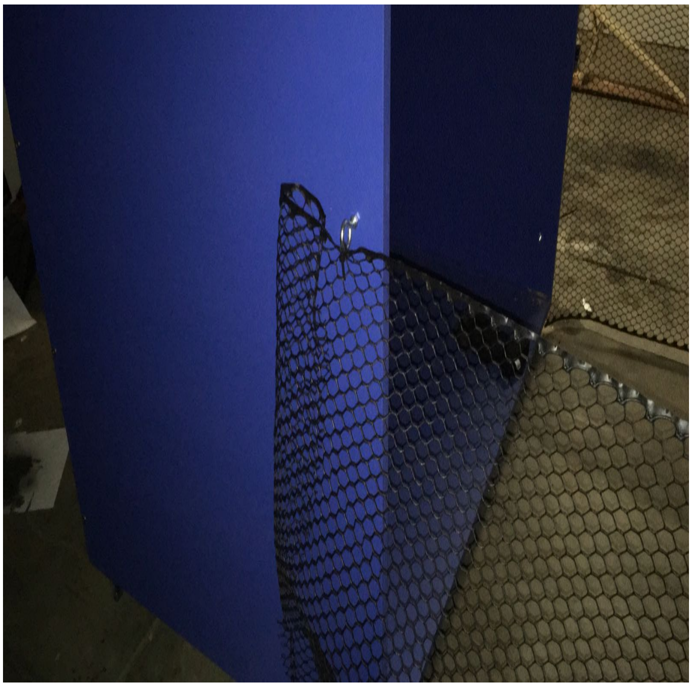
Figure 43: fence attaching to the booth

7.2 DESIGN CHANGES

After some changes with consultation with the client and Dr. Omen, it is pertinent to say that that this design meets the proposed customer and engineering requirement. Going ahead, this plan will be tried and changed to the better fulfill the necessities. First, we asked our client what else they would like to remove or add to the design template. As a group we looked at the functional model as well as the QFD to find if there is anything that we might have left based on the customer requirement. We changed a lot of things to make our design less cost and to make it like what the client needs it.

The first change that we made on our design was the slingshot rotating. We change it to make it easy to move, easy to assemble and dissemble and less cost. See Figure 26.

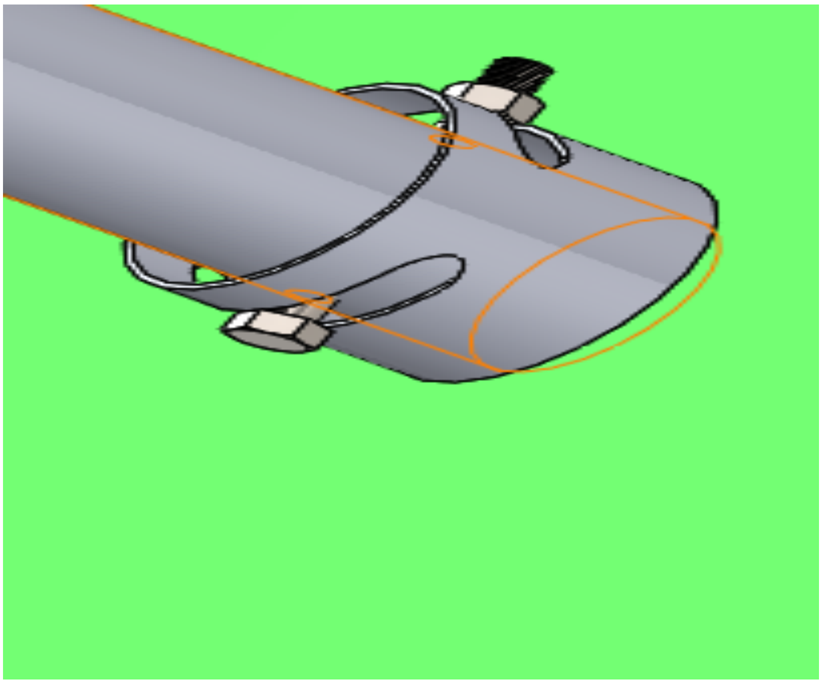

Figure 35: changes of rotating

The second thing is that we change the wooden booth from 3x3 meters to 1.5x1.5 meter according to Dr. Oman instructions. This change made it easy for us to manufacture, less cost and east to carry and move. We added caster wheels to ensure that it can be easy to move. See figure 27.

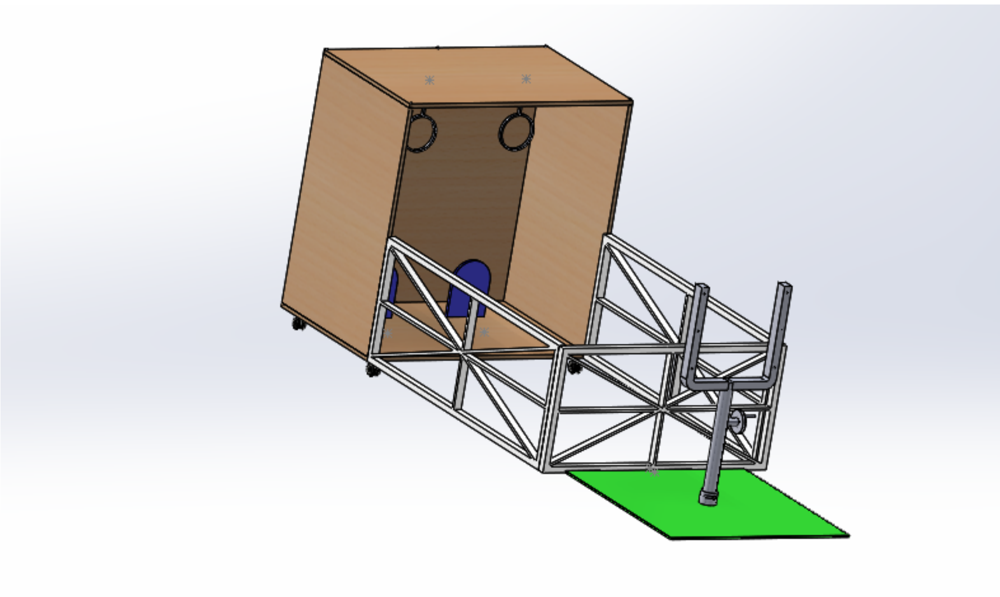

Figure 36: changed booth

Third thing that we changed was the fence. Firstly we chosen that the fence would be from hard plastic. However when we discuss it without client he prefer that we use a fence that easy to bend and really light.

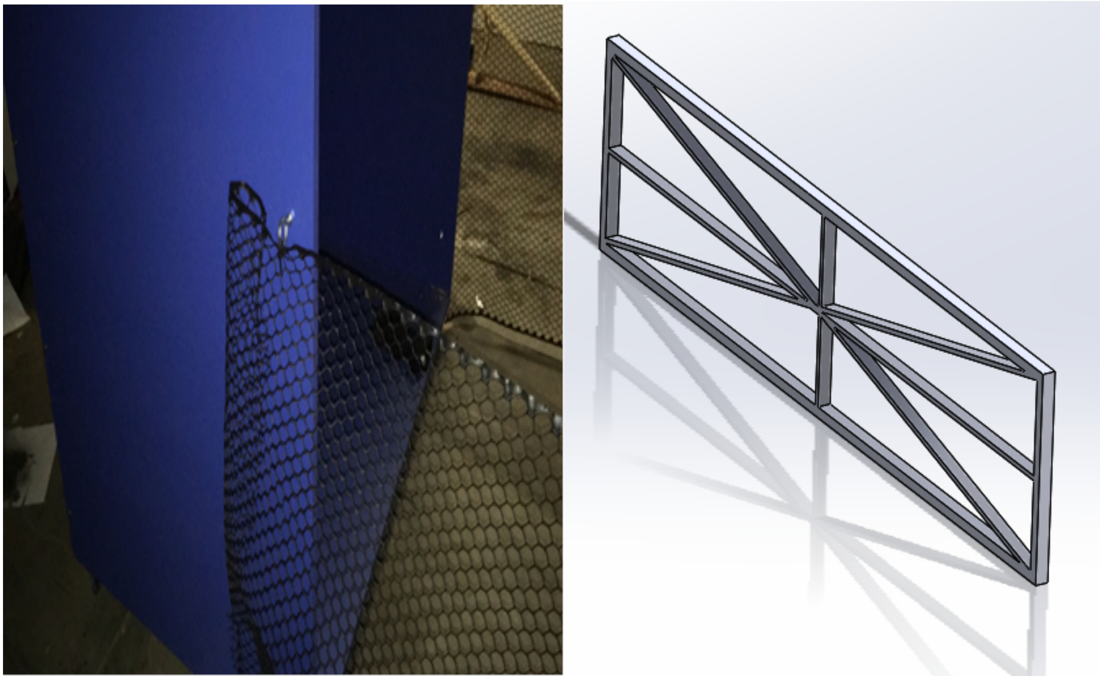

Figure 37: new fence & old fence

Overall, it is pertinent to say that the design is almost achieved our aspirations, but it can be further improved later on integrating more ease and designing. The more it is comfortable, the more complete it becomes.

Table 1.6 – Material used for final model

Item	**Source**	**Use**	**Cost**
Slingshot Rubber	Amazon.com	Stretching	$7.59
SPI Sponge Ball	Amazon.com	Ball that will hit the target when will throw using slingshot	$14.95
Booth	Homedepot.com	Will hold the ball from hitting the children	$600
Slingshot Frame and base	Homedepot.com	Provide the hold for the rubber band to stretch properly and make the throw	$500
Hook	Amazon.com	To hold items	$8.04

Fence	Amazon.com	Boundary around the gameplay area to keep the ball within the area	$55
Boxing Balls	Amazon.com	Target that will hit by plastic ball for play	$50
Color	Amazon.com	Dye the walls to make them colorful	$65
Total cost	-	-	$1281.39

8 TESTING:

For our testing part of the project, we first listed our engineering requirements / design requirements. After this we brought our final design and started to test each part of the design individually. Sling shot to test the Range, height, and angle of projectile, weight of ball and elasticity of the rubber band. The testing procedures are used to verify that engineering requirements meet the targeted values stated in the ER section

Range of Ball and the Distance between target and slingshot

The range of ball can be measured with a metric unit's tape measure. The ball will be launched and the distance measured to the nearest millimeters. A tape measure of at least five meters in length will be needed, with a resolution of 4-5 metes. Then we launched the ball to a distance then we measured it. It was between 4 to 5 meters.

Figure 38: Range and Distance of the Ball

As shown in the figure 1 and 1.1 the engineering requirement has been met because it came with the 4 to 5 meters long.

Height of Ball

The ball height can be measured through a scale. A simple scale available in the market can do this, by just throwing the ball towards the target and measure the distance between the ground and the location of the ball in air. We can detect the most accurate distance by recording it by the high-speed video cameras. Then play the video in slow-motion to see what distance it reached. Distance reached was 1.0668 meters which also met our ER requirements.

Figure 39: Height of Ball

Angle of Projectile

The projectile angle can be determined through the Semi-Circle scale by placing it on the horizontal axis. This can easily measure through the scale available in the market. Afterwards we pulled the ball and measured the angle of projectile. For doing multiple attempts we found the most accurate angle was 45 degree to insure to hit the target safely.

Figure 40: Angle of Projectile

Energy Transmit

Energy transmit can be calculated through the elastic force applied by the rubber band or can determine by finding the velocity of ball. We can detect the most accurate velocity of the ball by recording it by the high-speed video cameras and use a speed detector. After that we will measure the kenotic energy.

The elastic energy equation for rubber band is:

Elastic Potential Energy Formula

$$U = \frac{1}{2} k x^2$$

U – potential energy of spring in joules
x – string stretch length in m
k – spring force constant N/m

Figure 41: Elastic energy equation [1]

According to the elastic energy equation the energy that rubber band or can determine is 12.4335 J

Sharp Edge

Any sharp edge can harm the children so the product must not have sharp edges. Like every wall must have round edges. Edges can be calculated through the scale which measures corners and aim for the lowest degree of sharpness.

Figure 42: No Sharp Edge

Target weight

For this part tests of target we measured the weight and it showed it weight was 0.198 kg and we attached three targets

Figure 43: Target weight

Distance between target and slingshot

Distance will measure through the measuring tape and the slingshot part is adjustable we can take it to whatever distance far away from the targets which let us meet our ER easily

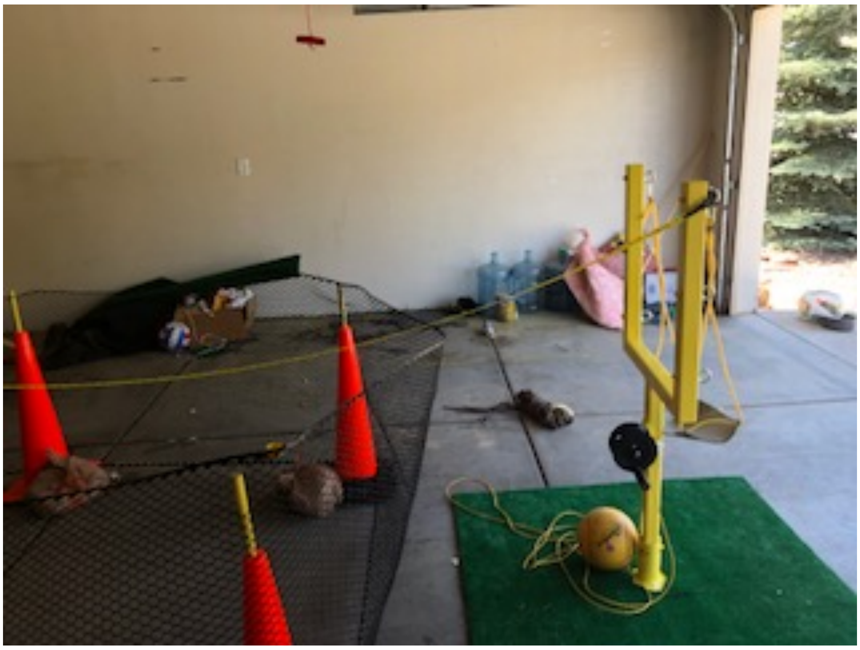

Figure 44: Distance between target and slingshot

The distance between target and slingshot is 4.1 meter.

9 conclusions:

The idea for the capstone project is to come up with an idea for a device that will be incorporated at Wonder Factory that will help children with disabilities to play and also learn at the same time. Wonder Factory is a engineering and science center in Flagstaff that has various creative games for the enjoyment of children. The different facilities in Wonder Factory are not only unique and creative but also help with children's learning and development in the STEM category. In order to design a project that will amusee the children, the team has decided to use the slingshot. The slingshot is a traditional tool that was used since ancient times in wars to project objects from one place to another.

Motivation

The following is the original project description provided by the client Wonder Factory:

The Wonder Factory is a science, engineering, art, and technology center in Flagstaff, AZ providing hands-on, interactive experiences for the young and young at heart. It was founded by Jackee and Steve Alston as a movement of concerned citizens working towards getting a STEM/STEAM-based play center in Flagstaff. The Wonder Factory's goal is to lead the next generation of young minds into their place as the thinkers, the makers, and the creators of the future through hands-on interactions with science, technology, engineering, art, and mathematics. Your task is to generate lots of interactive display ideas and to ultimately design build and test one final display ready for public consumption. Your final design must:

- Must be safe to all users per applicable safety standards. ***Safety is your first priority***!!
- Must be ready upon completion of this capstone sequence
- Should generate up to 100 ideas – including existing, new, wacky, and off the wall concepts
- Must select, design, build, and test one final unique idea
- Should test the interactive display in a similar setting to expected everyday use
- Must raise some of the funds required to finish the project

Abiding by the requirements of the project, discusses the aspects of safety including an analytical model that justifies the viability of the project.

For toys used in the United States, the United States Consumer Project Safety Commission has laid out standards that the toys used by children need to comply with. The toy safety standard refers to ASTM F 963-16. All children's toys *manufactured* on or after April 30, 2017, must be tested and certified to ASTM F963-16 [13].

ASTM F 963-16, *The Standard Consumer Safety Specification for Toy Safety [14],* is a very comprehensive standard that addresses numerous hazards that have been identified with toys. Previous versions of ASTM F963 were voluntary industry consensus standards that represented the collective work of industry, consumer groups, the government, and others to provide adequate industry-wide standards for toys. In 2008, the CPSIA mandated that the voluntary toy safety standard then in effect become a nationwide mandatory children's product safety rule [13].

Specifically, Section 4.8 of the standard refers to 'Projections', which is particularly relevant to the current project since a slingshot can be considered to be a projectile.

Some of the aspects of safety that need consideration when used as a children's toy are:

1. Flammability: The standard does not include flammability requirements. However, a children's toy—during its customary and reasonably foreseeable handling or use—must not be a hazardous substance that may cause substantial personal injury or substantial illness during, or as a proximate result of, being a highly flammable or extremely flammable solid. This requirement, which is from the Federal Hazardous Substances Act, does not require premarket, third party testing from a CPSC-accepted laboratory.
2. Lead and Soluble Heavy Elements: Testing for lead is not necessary. Not necessarily. While Section 4.3.5.2(1) of ASTM F963-16 says that the accessible substrates and all small parts must be tested for total lead and eight soluble heavy elements, the term "accessible" is defined in 4.3.5.2(1)(a), and it is very important to determine whether the toy is subject to this additional requirement. In our case since the material of the SPRI sponge ball does not contain any metal, it is unlikely that the ball will contain any lead. The handle uses metal components and it is important to avoid substances that may contain lead in the components of the handle for the slingshot. Similar requirements also apply for the presence of Cadmium.
3. Batteries: ASTM F963-16 incorporates new testing requirements on certain button and coin cell batteries of 1.5V+. There are four new testing methods – overcharging, repetitive overcharging, single-fault charging tests and short-circuit protection test. See section 8.19. Since, the sling shot is a mechanical device, no batteries are used. Hence requirements related to use of batteries is not a concern.
4. Projectile Toys: Kinetic energy density level changes allowed for certain types of projectile toys. Of particular note, CPSC staff issued a letter on March 31, 2017, exercising its enforcement discretion under section 4.21.2.3, to apply the KED requirements only to projectiles with energies greater than 0.08 J. This enforcement discretion extends to testing and certification requirements, under Section 14 of the Consumer Product Safety Act (CPSA), 15 U.S.C. § 2063, so that testing would not be required for projectiles with energies less than or equal to 0.08 J. This enforcement discretion will go into effect immediately, and it will remain effective until further notice [18]. The current device for slingshot will be categorized as a projectile toy. However, since the projectile is used in a restricted environment with the slingshot strictly aimed at the target, it is unlikely that there would be issues related to safety. However, if the projectile is aimed inadvertently at another subject, then the aspect of safety due to impact of the projectile becomes important and it will be investigated in this section.

Since the only item of concern in terms of safety is item-4 above, the analytical modeling and analysis will correspond to projectile toys.

9.1 ANALYTICAL MODELING

In order for our project to be useful and solve an existing problem, it was important to consult with other relevant stakeholders that were affected in one way or another by this project. The stakeholders were the key and the Wonder Factory was our client. The team is designing a product that is going to be used by kids and as such, certain requirements have to be met so as to make sure the interests of the user, the kids in this case, were well incorporated in the project. Additionally, we had to meet the needs of our client while at the same time achieving other goals such as compatibility with any existing regulations, minimal budget and high efficiency. It is for this reason that we came up with the engineering requirements that would ensure that our project was acceptable even by local and international standards.

Kinetic Energy in the Slingshot

Slingshot physics involves the use of stored elastic energy to shoot a projectile at high speed. This elastic energy comes from rubber bands which are specially made for slingshots. This energy is provided initially by the muscle energy of the slingshot operator. One of the goals of a slingshot is to fire the projectile at the greatest speed possible. To do this two basic physics conditions must be satisfied. First, you must maximize your draw length, and second you must maximize the draw force you can personally exert over the draw length. In other words, the slingshot must be designed (for you) such that you are able to pull back on the projectile as far as you can and as hard as you can, before releasing it. This maximizes the elastic energy stored in the rubber bands which translates into the maximum kinetic energy of the projectile upon release, which results in the maximum release speed of the projectile. This in turn results in the greatest impact energy, and therefore damage inflicted on the target when it is struck by the projectile.

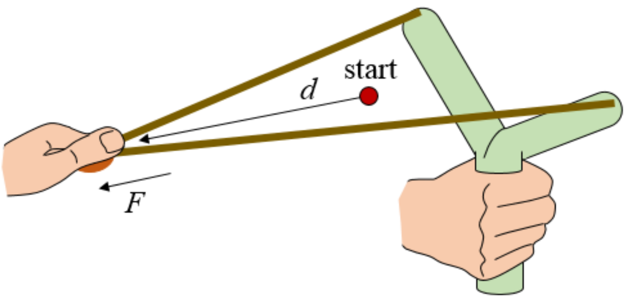

Figure 45: Conventional Y-shaped slingshot [15]

Figure above shows a conventional Y-shaped slingshot. The red dot represents the position at which the rubber bands start being pulled (drawn). At this point there is no tension in the rubber bands. Due to the slack in the rubber bands this start position lies ahead of the plane of the Y-shaped fork. The distance d represents the draw distance and the force F represents the draw force. Due to the slack in the rubber bands the distance *d* can be less than the maximum draw length of the person operating the slingshot. The red dot also represents the approximate release point of the projectile since it is the point at which the rubber bands no longer "pull" on the projectile. At this point the rubber bands have returned to their initial unstretched length and all their stored energy has (in theory) been given to the projectile. In reality though, a fraction of the energy is always lost through internal and external friction. Naturally we want to keep this fraction of energy loss as small as possible.

When pulling back on the rubber bands the draw force F increases as the draw distance d increases, just like when a spring is stretched. Ideally, we want the maximum draw force (F_{max}) of the person operating the slingshot to be at the point at which his/her draw length is a maximum (d_{max}). This results in the maximum amount of energy stored in the rubber bands (provided by the slingshot operator), and therefore results in the most powerful shot. To achieve this ideal situation a rubber band made of appropriately selected material would have to be used which matches the strength limits of the slingshot operator. However, this is not necessarily practical.

Figure 46 below illustrates the draw force F as a function of draw distance d for a conventional Y-shaped slingshot.

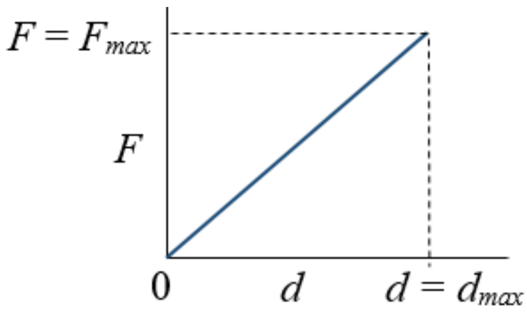

Figure 46. Draw force F versus draw distance d

The energy stored in the rubber bands, and delivered to the projectile (assuming zero energy loss), is given by the area under the curve, which is given by

$$E = \frac{1}{2} d_{max} F_{max} \quad (1)$$

where E is the stored energy. Assuming zero energy loss, this energy is equal to the kinetic energy of the projectile upon release, which is given by

$$E = \frac{1}{2} M V^2 \quad (2)$$

where M is the mass of the projectile and V is the speed of the projectile upon release.

Equating stored energy with kinetic energy we have the equation

$$d_{max} F_{max} = M V^2 \quad (3)$$

Note that we are ignoring the mass of the rubber bands and pouch in this equation, which is a reasonable assumption for the cases where the projectile has a much greater mass than the combined mass of the rubber bands and pouch. Also note that the above figure shows a linear relationship for the draw force versus draw distance. This is not necessarily the case. In reality there may be a non-linear relationship between draw force and draw distance. Nevertheless, the stored energy is still the area under the curve, which for non-linear functions can be determined using integral calculus.

Velocity of the Ball due to Air Resistance

As mentioned earlier, the key aspect of project is safety. This is achieved by the use of an inflatable sponge ball that is of light weight. The smaller mass of the ball coupled with the resistance of air during the projectile motion of the ball places a limit on the maximum velocity of the ball. This assures safety in case the projectile is inadvertently pointed towards an unintended subject.

Edwards *et al* [16] have done a lot of research on the effect of air resistance on project as part of Science and Mathematics Education Commons program.

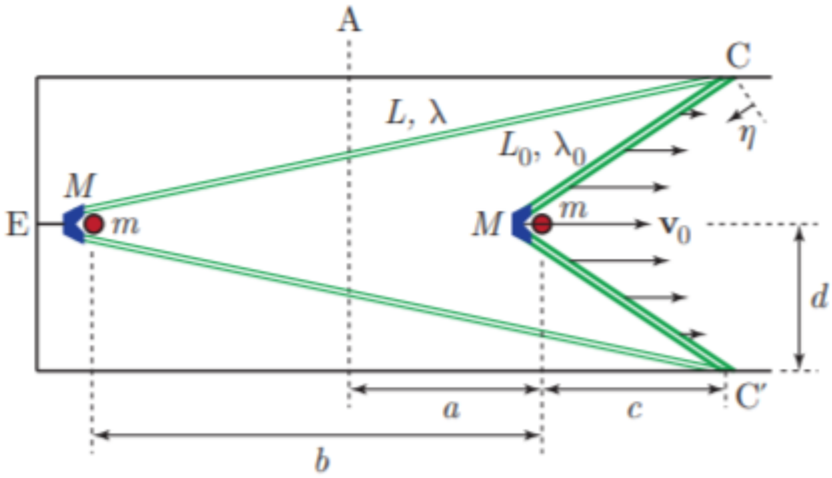

Figure 47. Schematic of the launch platform [16].

As shown in Figure two bands of latex surgical tubing, each of natural length L_0 and linear mass density λ_0, attach to the platform at *C*, and two similar bands attach at *C′*. The four bands meet at a pouch of mass *M* that holds a projectile of mass m. Displacing the pouch a distance b and attaching it to a trigger at *E* stretches each band to length *L* and linear mass density $\lambda = \lambda_0 L_0/L$. After releasing the trigger, the bands return to their natural lengths and the projectile is released by the slingshot with velocity v_0. Because L0 is larger than the platform half width *d*, the slingshot releases the projectile before it passes the line joining *C* and *C′* . Shown also are the platform pivot axis *A*, the distance a from this axis to the launch point, and the distance c from this point to the line joining *C* and *C′*.

While linear "Stokes" drag applies for small velocities and microscopic projectiles, quadratic drag applies for the conditions of interest, namely, macroscopic projectiles with speeds v in the range 20–40 m/s. It is expected that the maximum velocity of the slingshot will not exceed this range. In addition to drag, spinning balls experience a Magnus force that is perpendicular to the direction of motion, such as the lift force on a ball with backspin. This spin is generally negligible and it is ignored in the current analytical model.

From engineering mechanics and physics courses, we know that the launch angle φmax that maximizes the range R for projectile motion of a projectile. Without drag, $\phi_{max} = 45^\circ$.

The work done by the elastic force is given by,

$$W = \int F_x(x)dx \quad (4)$$

where the limits of integration for x are from x_1 to x_2.

We define the elastic potential energy *U(x)* and so $F_x = -dU/dx$.

The initial velocity of the projectile from the sling shot is given by [3]:

$$v_o(m) = 2\sqrt{\frac{2U(X)}{m'+m}} \quad (5)$$

where $m' = M + \frac{4\lambda_0 L_0}{3}$, $\lambda_0 = 0.0427$ kg/m, and $U(x) = \frac{1}{2}kx^2 + Ax - \frac{A}{\alpha}(1 - e^{-\alpha x})$, where $k = 22.68$ N/m, *A*=12.08 N, and $\alpha = 4.79$ m-1.

Drag Coefficient

In the absence of other forces, quadratic air drag produces an exponential spatial decay of the speed as follows:

$$v(x) = v_0 e^{-k(x-x_0)} \quad (6)$$

Where v0 is the initial speed, x is the direction of motion and x0 is the initial position.

The drag coefficient *C* depends on the Reynolds number $Re = vr/\nu$. Values of v_0 and *r* together with the kinematic viscosity of air, $\nu = 1.6\times10^{-5}$ m^2/s yield values of *Re* in the range 5.1–6.7×10^4 . These values fall in the range $3\times10^2 < Re < 1.3\times10^5$ for high-Reynolds-number flow that is laminar on the windward side of the projectile and turbulent in its wake, with $C \approx 0.5$ in this range for smooth spherical projectiles [17]. When the Reynolds number exceeds the upper limit of this range, the drag coefficient drops to $C \approx 0.1$.

From [16], the drag coefficient is given by:

$$\kappa = \frac{3}{8}\frac{\rho_a}{\rho_{in}}\frac{C}{r} \quad (7)$$

Where ρ_a is the density of air and ρ_{in} is the density of the medium inside the sponge ball. In our project, this is also air, the radius *r* can be obtain from the volume relationship of the spherical ball since the mass is known.

Finally, the terminal speed of the ball is given by

$$v_t = \sqrt{\frac{g}{\kappa}} \quad (8)$$

The drag constant and the terminal velocity are plotted in Figure .

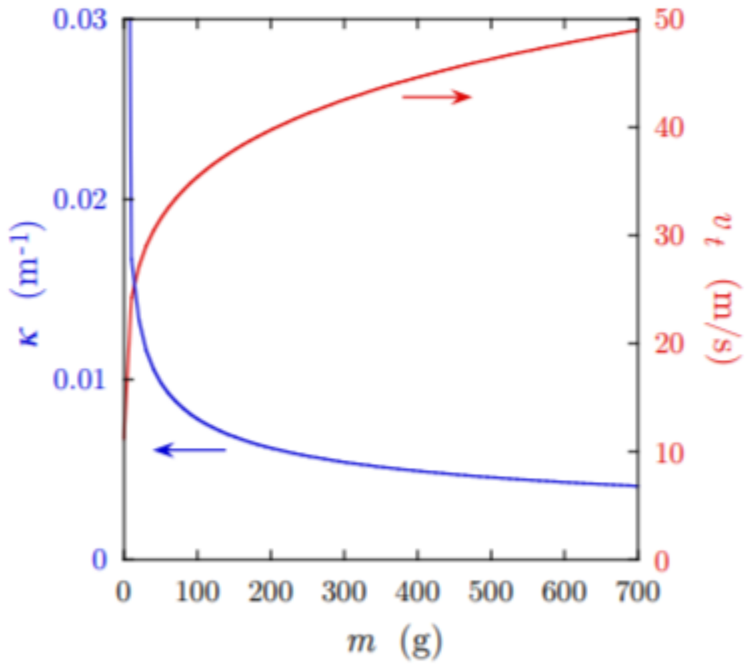

Figure 48: Drag constant κ in inverse meters and the terminal speed $v_t = \sqrt{\frac{g}{\kappa}}$ in m/s vs. balloon mass m in grams, from Eq (7) and Eq (8).

Finally, the equation for the range of the ball can also be expressed as [16],

$$R = x_0 + \frac{v_{0x}}{g}\left(v_{0y} + \sqrt{v_{0y}^2 + 2gy_0}\right) \quad (9)$$

Assumptions used in the Analytical Model

1. Magnus force, such as the lift force on a ball with backspin is considered negligible.
2. Deformations or vibrations of our flexible sponge ball during flight are ignored.
3. The energy losses due to nonlinear elastic energy and hysteresis for the stretching of the elastic band are ignored.
4. The average drag coefficient of water balloons for vertical launches using time-of-flight measurements (1D equations are used).
5. Assume that the ball is spherical in shape
6. Assume drag constant κ and drag coefficient C are constants that apply throughout the duration of the flight.

In conclusion, a thorough analytical model was developed to assess the safety of the project design based on the recommendations by the United States Consumer Product Safety Commission for toys used by children. Since the current design of sling shot can be categorized as a projectile, the equations related to the trajectory of the slingshot and the effect of the air resistance on the motion of the sling shot have been discussed using equations for the drag constant. Based on the analytical model, the terminal velocity of the ball and the drag constant have been used to calculate the kinetic energy of the slingshot. The calculated kinetic energy of the slingshot is approximately 8J indicating that the slingshot is safe in case of accidental impact to an unintended subject. The analysis undertaken in this report mathematically justifies the viability of the project

9.2 opport. For improvement

For future reference. Some parts needed to be replaced due to heavy usage on the device. For example the rubber band needs to be replaced each time it get loose from the usage if not changed it will lose it elasticity. And, many parts like that issue need to be replaced also like:

- **Rubber band**
- **Targets**
- **Eye bolts**
- **Slingshot patch**
- **Wheels maintenance**
- **Paint if was moved a lot " portable"**
- **hooks**
- **ball**
- **ropes**

Improvements:

Some improvement can be made to make our design a better toy for children are:

- **make the room of the targets larger**
- **use lighter materials**
- **improve the fence martial**
- **rubber band elasticity**
- **try to improve the wow factor by adding picture in the targets**
- **LED parts to make it more fun**
- **Create a contest game with points to make it more fun**
- **Make the room taller to hit higher target**

Over all the device parts are good which can provide more of life time. But just to make sure we listed the required parts needs to be check each time before usage and see if it needed change. Also, in the process of making slingshot on our products, we found that we can use the smallest size eye bolt that is 1/4 "in diameter to withstand the tensile force of 150Newton given by the children while playing. The maximum attraction that each eye bolt can hold is 2200 Newton. Based on this calculation, maybe the eye bolt that can be installed do not need a number of 3 pieces, because by using an eye bolt alone is enough to withstand the tensile force that is expected to be issued by children aged 6-11 years.

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