RIT | College of Engineering Technology
Department of Manufacturing and Mechanical Engineering Technology

MCET-550 Mechanical Analysis & Design Project

Mechanical Engineering Technology
Technical Report #: 2215-MCET550-10

Date of Submission: 29-April-2022

Project Title: ***Launch Master: Design and Prototype***

Abstract:

For far too long has a commercially available, disc launching robot remained in the hearts, minds, and dreams of disc enthusiasts everywhere. Therefore, our team of engineers endeavor to create a mechanical device capable of not only launching discs at adjustable speeds, angle and direction, but to also imbue the ability to retrieve discs and automatically prepare to launch them again. All of these features combined with its ability to move and relocate itself only asks the consumer to remotely activate each of these functions. It is our goal to make frisbee activities available to a single individual, in a safe and fun manner.

Names of Principal Authors: Daniella Donn
Bethany Folchi
Juztyn Ott
Spencer Szachara

Instructor: **C. Tawaf**   Date:**4/29/202**

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I. Objective

This report will cover the conception, design and fabrication of a device capable of retrieving thrown discs, and launching the discs at adjustable angles and speeds.

II. Define - Customer Requirements

The Define Phase is key to executing or achieving a desired output. Deep research, seeking out Voice of the Customer, planning and prioritizing product requirements are all important precursors to developing a successful product. Various tools are used in the Define phase and are described below.

A. Background Research

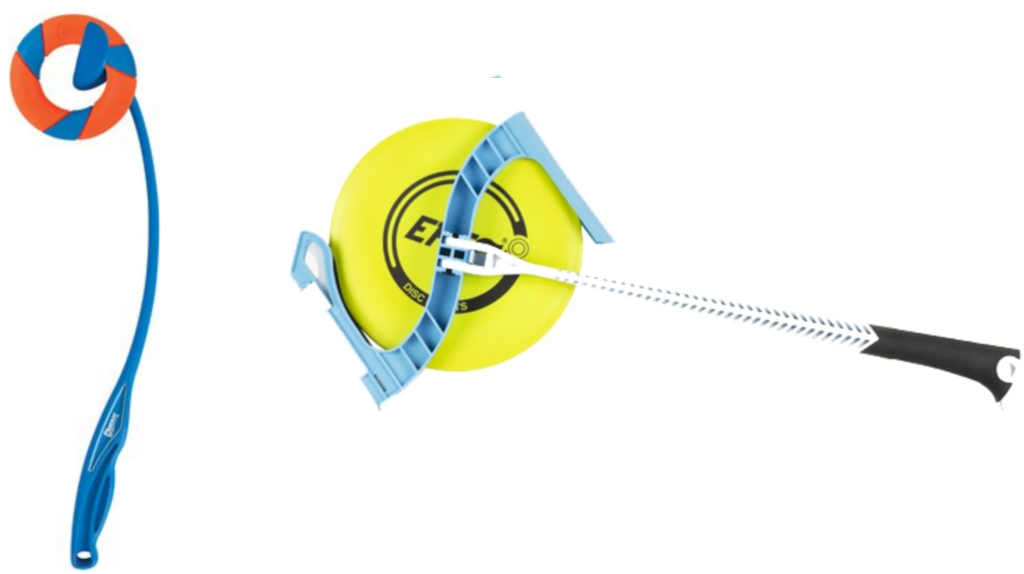


Figure 1: Examples of hand-held, manual frisbee launchers

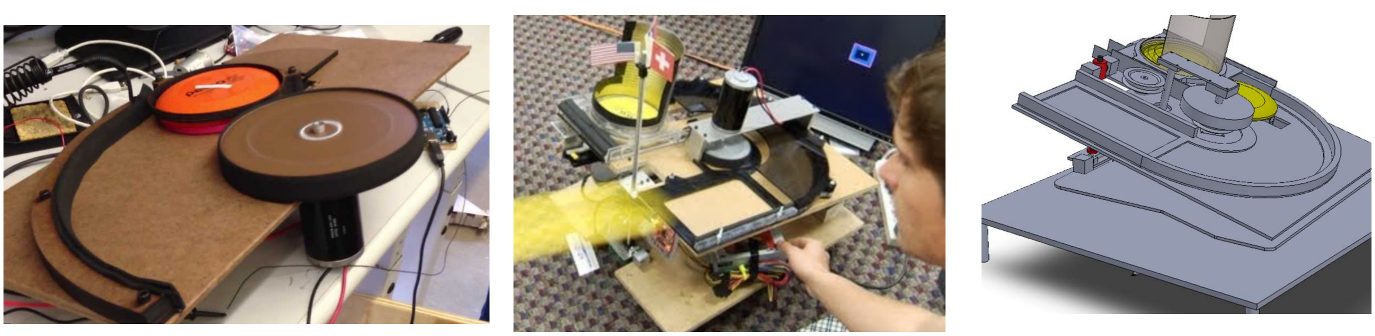


Figure 2: DIY Frisbee Launchers posted to the internet

The Launch Master was conceived to improve the experience of an ultimate frisbee player or disc golfer. It is found that existing frisbee launch devices are hand-held and not automatic (see **Figure 1**), similar to that of a tennis ball fetch toy. Automatic frisbee launchers have been designed and fabricated by individuals as "DIY" projects (see **Figure 2**). None are on the market for sale. Similarly, no patents hinder the design concept for the Launch Master.

Design concepts and development of the Launch Master can be inspired by designs found in the 2013 FIRST Robotics Competition (see **Figure 3**). The *Ultimate Ascent* event presented the challenge of designing and fabricating robots to collect and shoot frisbees. Documentation and research on different robot designs will be utilized to conceptualize the Launch Master.

Figure 3: Examples of Robot design for FIRST Robotics *Ultimate Ascent* Competition

B. Voice of Customer

After background research and talking with potential customers in the community, the Voice of Customer was documented. The following will impact the success of the Launch Master:

- This automated frisbee thrower will travel along multiple surfaces such as turf, grass and concrete. This will be done through a specific wheel built for those specific terrains. It will be able to travel up and down small grade hills.
- The machine should be mobile and light weight allowing for easy transportation to and from fields and will be able to fit within a car.
- There will be various throwing types in order to keep practice time interesting and productive.
- A safety light will be added in order to maintain the safety of the consumer and people around the area.

The different terrains have been a common question amongst the customers. Geographically, fields and areas around the world are very different and the frisbee thrower should be versatile to fit those specific geographical needs. The multiple terrains will depend on the type and size of the wheel. The bigger the wheel, the more versatile the machine will be. This will be taken into consideration when designing the product.

The product will be mobile and lightweight for ease of transportation from storage to different fields. Considering a lot of people have to walk or drive to open fields, it is important for this product to fit in the car. It is also important for the product to be lightweight and easy to pick up and set down. This will help users of all ages be able to use and move this product, as well as expand potential markets across all ages.

Various throwing types allow the product to change angles and velocity of throws. This means the customer will be able to keep practice interesting and never get bored. It will also positively affect the impacts of practice as there is more skill that is developed through different types of throws.

A safety light is essential to keeping the players safe from the product. If the customer is walking in front of the product and it fires, it can be dangerous. It is important to keep the safety of the customer and community when designing and developing this product.

C. Critical to Quality (CTQ)

Critical to Quality, also known as CTQ, are the key attributes of the product that is defined by the customer as important. This tool takes the Voice of Customer (VOC) and creates a specific list of CTQ requirements.

- This automated frisbee thrower will travel along multiple surfaces such as turf, grass and concrete. This will be done through a specific wheel built for those specific terrains. It will be able to travel up and down small grade hills.

CTQ: This automated frisbee thrower will have wheels which will be put through a durability analysis to test the durability of the wheel designed and chosen. This will lead to the correct wheel choice so the machine can move along multiple terrains.

- The machine should be mobile and light weight allowing for easy transportation to and from fields and will be able to fit within a car.

CTQ: The machine should be < 30 lb to be able to easily carry it and hold up to at least 5 Frisbees with the ability to pick up more. The machine should be able to fit into a car seat and will be in the shape of a box. The height of the machine should be no higher than 2.0 ft, with a width and Length of 1 ft as the average disk size is between 8 - 10 inches in diameter.

- There will be various throwing types in order to keep practice time interesting and productive

CTQ: The machine will be able to throw the frisbee at certain angles with varying speeds allowing for the disk to be launched in an unexpected direction with a certain amount of force.

- A safety light will be added in order to maintain the safety of the consumer and people around the area.

CTQ: A light will be turned on when launching the frisbee to warn others around the area that they are in firing range.

D. Project Charter

A project charter was created to describe the project in its entirety. It helps communicate all parts of the project to team members, management and Supervisors. It includes the Project Statement, Project Scope, Team members and Stages/Phases of the project.

Start Date	1/20/2022	**Completion Date**	
Belt Name	Duane Beck	**Champion**	Cindy Tawaf
Element	**Description**	**Team Charter**	
Objective (Goal) Statement	What is the objective (goal) to be achieved?	Design and fabricate a light weight and transportable device capable of retrieving and launching discs at adjustable angles and speeds within 5 months.	
Project Scope	What are the scope and parameters of the project and determine what is in and out of scope?	Develop a device within the size of 1’x1’x2’ (average car seat) that can retrieve and launch discs safely. Complete development activities through the prototyping and testing phases.	
Team Members	Who is on the team, internal and external personnel?	Internal: Daniella Donn, Bethany Folchi, Justin Ott, Spencer Szachara External: Cindy Tawaf	
Project Schedule (Gantt Chart)	What is the projected timeline for each phase of the project?	See attached Document for Gantt Chart	

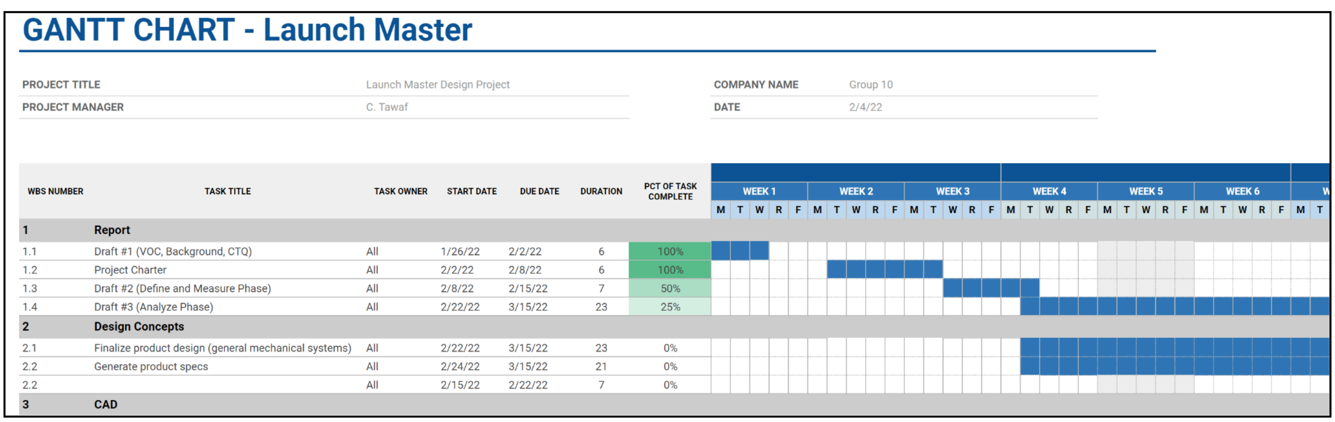
Project Summary for the Green Belt in MET			
Stages / Phases	Goals and Start Date	Deliverable Outcomes	Belt /Champion Approval Signatures And End Date
Stage 1 Define	Assemble teams and exchange contact information; 1/14/2022	Assembled teams assigned	Spencer - 1/14/2022
Stage 1 Measure	Choose team leader, execute background research, publish proposal, define VOC requirements, develop Gantt Chart; 2/4/2022	Gantt chart started, VOC requirements obtained and published, background research published; 2/4/2022	Bethany - 2/4/2022
Stage 2 Analyze	Revise Gantt chart to match new goals, calculate mechanics of machine based on requirements; 2/8/2022	Calculations and stack tolerance analysis updated, gantt chart updated; 2/8/2022	Daniella – 2/8/2022

Stage 3 Design	Draw design, Construct solidworks assembly, approve design; 2/15/2022	Solid works assembly is complete, tolerance analysis is complete; 2/25/2022	Spencer - 2/25/2022
Stage 3 Verify	Test/ build machine, verify function and capabilities, 3/14/2022	Machine does what its intent is for, data is obtained for the limits of the machine; 3/14/2022	Juztyn - 3/14 2022
Stage 3 Written Report	Construct a written report updating calculations, project significance and success, 4/16/2022	The report is complete and updated with all information it, 4/16/2022	Bethany - 4/16/2022
Stage 3 Oral Defense	Present product to potential consumers, express design and machine capabilities ; 4/29/2022	The presentation is complete, practiced and performed; 4/29/2022	Daniella - 4/29/2022

Figure 4: Project Charter for Launch Master

E. Gantt Chart

The Gantt Chart is a live document that schedules the project as a whole and tracks the progress of the project. It lists start dates, due dates and the team member responsible for the task.



GANTT CHART - Launch Master

PROJECT TITLE	Launch Master Design Project	COMPANY NAME	Group 10
PROJECT MANAGER	C. Tawaf	DATE	2/4/22

WBS NUMBER	TASK TITLE	TASK OWNER	START DATE	DUE DATE	DURATION	PCT OF TASK COMPLETE
1	Report					
1.1	Draft #1 (VOC, Background, CTQ)	All	1/26/22	2/2/22	6	100%
1.2	Project Charter	All	2/2/22	2/8/22	6	100%
1.3	Draft #2 (Define and Measure Phase)	All	2/8/22	2/15/22	7	50%
1.4	Draft #3 (Analyze Phase)	All	2/22/22	3/15/22	23	25%
2	Design Concepts					
2.1	Finalize product design (general mechanical systems)	All	2/22/22	3/15/22	23	0%
2.2	Generate product specs	All	2/24/22	3/15/22	21	0%
2.2		All	2/15/22	2/22/22	7	0%
3	CAD					

Figure 5: Gantt Chart for Launch Master

III. Measure

The Measure Phase focuses on the collection and recording of data that is related and/or beneficial to the Launch Master project. Specifically, data relevant to the CTQ found in the Define phase is found in the Measure Phase. Various tools such as the House of Quality and Product Specifications Document were utilized. Areas such as Safety, industry standards and planned sensor/hardware to be used are to be discussed.

A. House of Quality (HOQ)

The House of Quality is a visual approach for translating Customer Requirements into product specifications. It also includes correlations between customer requirements to each other and product specifications. It also prioritizes product specifications to direct team focuses.

To create the HOQ, the VOC information was collected and put into the "Demanded Quality" list, as seen in Figure 6. These were rated from 1 to 5. The Product Specifications were added to the horizontal list. The Roof/Correlation Matrix was then generated to see how product specifications interact with each other. Then, the relationship matrix was generated to see correlation between the customer requirements and product specifications. The Importance rating is then calculated at the bottom. Because the Launch Master does not have competitors, the Competitive Evaluation section is omitted. Based on the HOQ for the Launch Master, the most important product specification is Body/Material Overall Weight, followed closely by Motor Type/Power output capability and Wheel type. The HOQ tool helped identify the specifications the team should focus on to effectively meet the customer requirements.

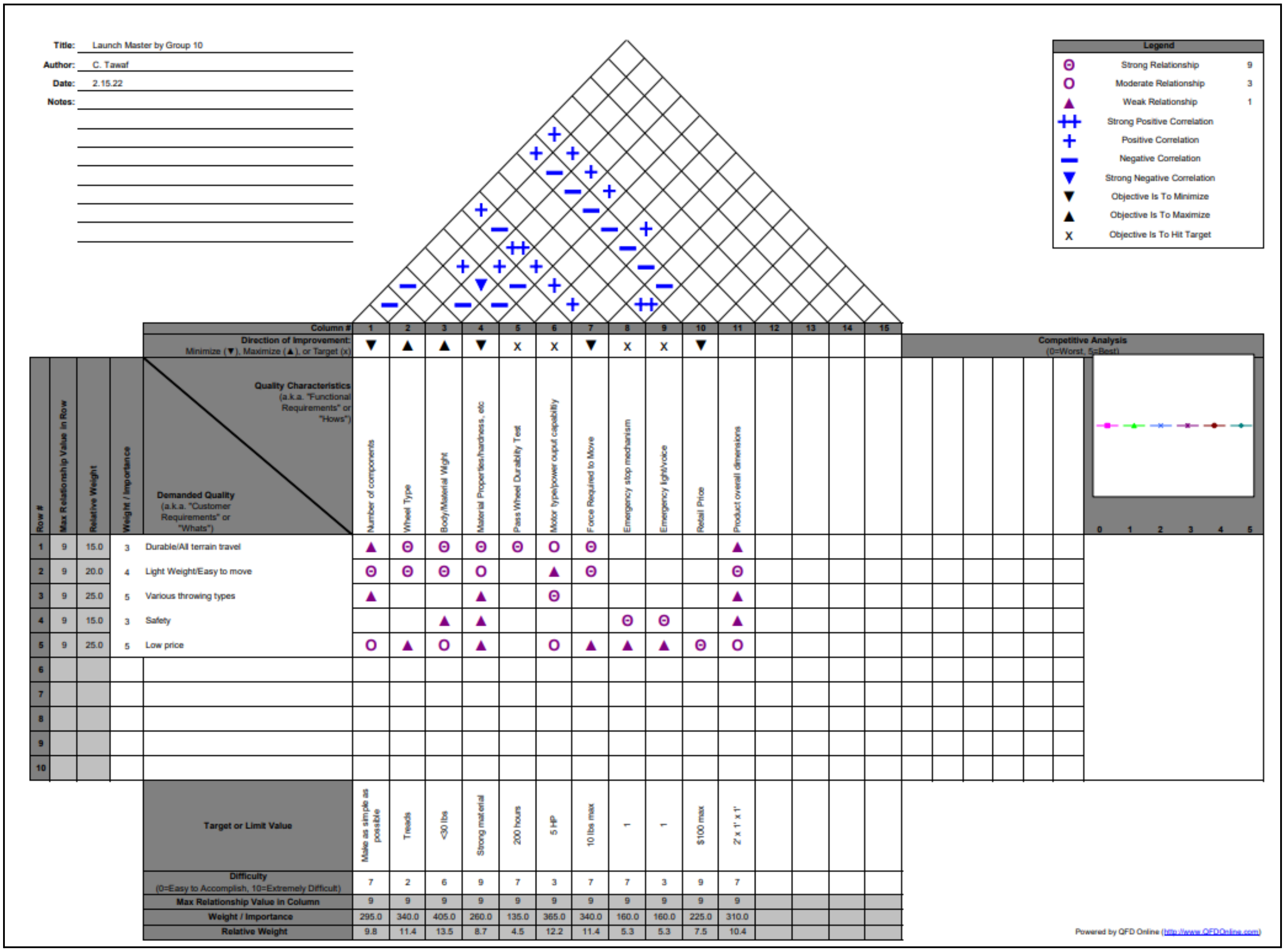


Figure 6: House of Quality for Launch Master

B. Product Specification Document (PSD)

The Product Specification Document is the summary of customer requirements and technical specifications for the Launch Master, with most of the information coming from the HOQ, as seen in **Figure 6**. The Product Specification Document (PSD) is also meant to be constantly changing with different requirements and specifications added as the project goes into development. The Customer Requirements were taken from the Voice of Customer and the engineering specifications were taken from Critical to Quality requirements.

Simplified Product Specification Document (PSD)
Purpose: this document coalesces the user requirements and the resulting technical specifications. Most content will come from the House of Quality though, there may be additional developments throughout the course of the project. Having all of the specifications here makes it straightforward to identify where the current design meets and does not meet the specifications.

Customer Requirement		
Number	Requirement	Whos?
1	The Launch Master must be able to travel across different terrains, such as turf, grass, concrete, dirt and go up/down hills	
2	The Launch Master must be mobile and light weight for easy transportation from use (field, gym) to storage	
3	The Launch Master must have several throwing types to give variety of throws	
4	The Launch Master must be safe to users and those around it	

Engineering Specification				
		Specification		
Number	Specification	Value	Units	Met?
1	This automated frisbee thrower will have wheels/treads which will be put through a durability analysis test to test the durability of the wheel designed and chosen	200	hours	
2	The machine should be < 30 lbs	30	lbs	
3	There will be various throwing types in order to keep practice time interesting and productive	5	throw types	
4	A light will be turned on when launching the frisbee to warn others around the area that they are in firing range.	1	light	

Figure 7: Product Specification Document for Launch Master

C. Safety

During the Measure phase, safety was at the forefront of the design concepts that will make up the Launch Master. Although meeting customer requirements is the ultimate goal, it must be safe for the customer to use. As the *Code of Ethics* from "National Society of Professional Engineers" says "Engineers shall hold paramount the safety, health, and welfare of the public".

In conceptualizing the Launch Master, the launch mechanism is going to be enclosed within the body/casing. Use of plexiglass or plastic will allow the mechanism to be visible without the ability of an object or person to interface with the machinery. Everything being enclosed will ensure no fingers, hands, hair or any part of the user can interface with the launch mechanism. The Launch Master will also audibly alert and flash a light before releasing the disc. This will ensure the user is prepared for the launch every time.

D. Applicable Industry Standards

The applicable industry standards exist with environmental, safety and economic constraints. The electrical component of the launcher shall follow the IEEE standards of safety. The mechanical constraint on the project only exists through the economic costs of the design. The economic cost is established as $275 and limits the design to that amount of value. Environmental constraints are little to none as it is portable but can not operate in any wet weather. Wet weather conditions include snow/blizzards and rain/thunderstorms.

E. Planned Sensor Inputs

The functionality of Launch Master is not entirely heralded by what it senses as this device is controlled by the consumer. There are some aspects of the design that would still be beneficial to utilize sensors to allow for ease of use.

A variety of vision and object detection sensors can be used to allow for ease of automated collection of discs at the base of the machine rather than running a passive operation. The more applicable manner for sensors would be inside the device to indicate whether or not there are discs stored in the internal cassette of the machine. This sensor could be as complicated as visual or capacitive sensors or as simple as limit switches that are depressed when a disc enters one of the empty spaces within the device. Those detectors can be linked to indicator lights or an outward display to inform the operator as to how many discs the machine can launch at any given moment.

Part of the launch mechanism will need to control the speed of the flywheel and if this component needs to be assembled by our team it will require an input capable of detecting passes of the wheel at high frequencies.

IV. Analyze

The Analyze Phase applies analysis techniques to examine performance of concepts, such as loads, stresses, deflections, as well as component analysis on bearings, motors, gears or springs. From this analysis, designs and components are selected and evaluated or rated. Various tools are used in the Analyze phase and are described below.

A. Pugh Matrix and Development

The Pugh Matrix and development is a tool used to compare concept and design ideas to a given datum. A datum is the general or standard design used for a specific product. This tool helps to generate concepts without any bias.

Pugh Matrix

Product: Launch Master — Date: 2/22/22

Project Team: Group 10

Put **+, -, or S** in each cell to represent if concept is **SIGNIFICANTLY** better, worse, or same as the datum concept.

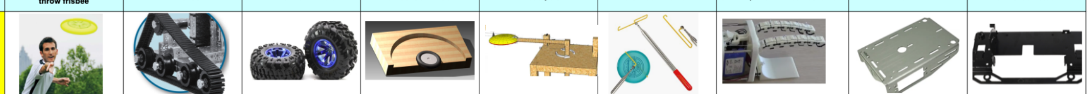
Category:			Transportation	Transportation	Launch Mechanism	Launch Mechanism	Loading/Pickup Mechanism	Loading/Pickup Mechanism	Casing/Chassis Material	Casing/Chassis Material
Functional Requirements / **Concept**	**Importance Rating**	**0 - Base Concept: Manually throw frisbee**	**1 - Treads**	**2 - Rubber Wheels**	**3 - Central Wheel**	**4 - Catapult**	**5 -Rect. Hook Mechanism**	**6 - Ramp with Assist Mechanism**	**7 - Aluminum**	**8 - Carbon Steel**
Concept Pictures/Sketches										
Hands-off, automatic, "no human" process	10		+	+	+	+	+	+	+	+
Durable/All terrain travel	9		+	-	S	S	S	S	S	-
Light weight/easy to move	10		S	+	S	+	+	S	-	S
Various throwing types	8	D	+	S	-	-	+	-	S	S
Safety	8	A	S	S	S	-	S	S	S	S
Low price	5	T	-	S	+	S	+	S	S	-
Can hold several frisbees	7	U	S	S	S	S	-	+	S	S
Asthetically pleasing	2	M	S	S	+	S	-	S	+	+
Minimal Maintenace	4		S	S	S	-	S	+	+	+
S+			3	2	3	2	4	3	3	3
S-			1	1	1	3	2	1	1	2
SS			5	6	5	4	3	5	5	4
Rating w/rt Datum (Overall Total)			2	1	2	-1	2	2	2	1
Importance Rating Score			12	-1	-1	-10	14	3	-4	-8

Figure 8: Final Pugh Matrix

As seen in Figure 8, the datum selected for the Launch Master was a human throwing a frisbee. The concepts chosen were based on different concepts and structures that make up a frisbee launcher. Based on Figure 8, treads scored higher compared to wheels for the types of transportation, center wheel scored higher than a catapult for the launching mechanism and the hook mechanism scored higher than the ramp mechanism for loading the frisbee. It is important to note that the scoring system does not dictate the design chosen for the frisbee launcher. It only helps separate some ideas for a better understanding but does not solidify the design. For example, although Treads scored higher than Wheels in Figure 8, Wheels are still chosen based on price and ease of use for the design concept.

B. Initial Analysis Plan Summary

Further analysis and testing are necessary to decide what components will be used in the Launch Master design. The Pugh Matrix greatly aided the decision making process and was used to narrow down the concept options. Mentioned below are decisions made based on the Pugh Matrix and/or further analysis needed to make final design decisions.

1. Transportation/Movement Method

Based on the Pugh Matrix, treads scored higher than that of tires. However, tires will be used in our final design for a number of reasons. Tires are significantly cheaper (as the group has a financial limit of $275 total), will be easier to source (in terms of supply in the current market), and will be simpler to fabricate/interface to a motor. Analysis will need to be complete on the friction forces of the tires to ensure sufficient stability during movement and launch. Motor selection for wheel transportation of the Launch Master will be discussed under "*Motor Selection Summary"* of this report.

2. Launching Mechanism

The different concepts used for the launch mechanism in the Pugh Matrix was a central/flywheel system or a catapult system. Designs for clay pigeon launching machines were investigated by the team. Based on the Pugh Matrix, the central wheel mechanism scored higher than that of a catapult. The team will continue with the central wheel design concept because it is relatively simple to manufacture (laser cutting), is foreseen to launch with consistency, and will interface with the loading/pickup mechanism well. The analysis plan for the launching mechanism will include 3D modeling and FEA of the central wheel mechanism. Calculations will be complete on the flywheel and disc (such as horsepower, inertia, angular velocity, torque) to ensure the disc is launched at a sufficient speed to "fly" similar to that of a human throw. Connections with the motor and flywheel will need to be investigated for these calculations. Motor selection for the flywheel of the launching mechanism will be discussed under "*Motor Selection Summary"* of this report.

3. Loading/Pickup Mechanism

The loading and pickup mechanism is foreseen to be the most difficult to accomplish with successful and consistent results. The concepts in the Pugh Matrix was a hook or a ramp system. The hook mechanism scored higher than the ramp system. However, more investigation will be put into both concepts before a final decision is made. There is also research to be had on the idea of a rotating shelving system for loading discs to the central wheel. This mechanism would use some motor connected to two gears controlling their rotation. The rotating shelves would allow loaded discs to be carried a certain distance (if programmed correctly) and unloaded in the perfect spot for launch. This shelving system would require more research and electrical components which may raise the economic value of the project. Money and design simplicity is something that must be considered significantly when generating concepts.

4. Casing/Chassis

The casing and Chassis will be solely based on the strength of the material, simplicity when molding/ease of use, aesthetically pleasing and cost. The two materials used for the matrix were carbon steel and aluminum. Aluminum scored higher but may not be selected over carbon steel. The availability, ease of use and cost still impact the use of Aluminum. Other options that are being considered are pre-made casing at local department stores. For example a pre-shape and made casing at Lowes could help establish the shape of the casing. The electronics and motors used to operate the launch will also impact the look and size of the casing which is why it is not a major concern right now. The main value of the project stems from making the launcher operational and building around whatever it takes to function.

C. Motor Selection Summary

1. Required Criteria

Both the flywheel and the transportation wheels will need motors to launch the disc and move itself. For a flywheel, the desired motor should have the flywheel spinning at a constant velocity to shoot the disc at a desired distance. Since we want this to be a constant motion and not too complex, a simple DC motor will be used. For the transportation, the wheels will be controlled by either a servo motor to control the movement precisely or a brushless DC motor which are low maintenance, higher efficiency than a brushed motor, and have a longer run time. However, brushless motors are more complex to set-up and control.

2. Calculations

The main goal of the motor is to have it constantly spinning when the launch mechanism is activated, at a high RPM and a powerful enough torque, in order to launch the disc a certain distance. Since we want the disc to launch a specific distance, an RPM and torque must be calculated. Assuming an initial velocity of 14.1 m/s (Morrison, 2005) and a measured radius of 2.5 inches, we were able to easily calculate the RPM by dividing the velocity by the radius and then dividing it a final time by .1047 in order to go from radians per second to rotations per minute. The final RPM came out to be 2124.

To find the torque of the motor, the equation used was: Torque = .5*Roller_Diamerer*(Total_Friction + Coefficient_Friction* Weight_of_disk*gravity.) In order to gain all of the correct values, many assumptions had to be made including: the coefficient of static friction between rubber and acrylic being equal to .6, a difference between the disk and the wall to be .1 inches, a spring coefficient of k to be 10 for the rubber belt, and only 2 forces acting in the y direction: weight and normal force. To calculate total friction, 3 separate frictions must be calculated first, all of which using static coefficients because the disk should not slide away from the launch mechanism. All 3 fiction values were calculated using the same equation: Normal Force * Coefficient of static friction. However, what made each friction value different was the material being used. For example, there is a friction between the disk and the base of the launch mechanism (made of acrylic), the disk and the rubber belt, and disk to the wall (made of acrylic). Although the wall and the floor are both made of acrylic, the friction values are different since there is a spring value from the wall to the disk. This can also be said for the friction value between the rubber belt and the disk. Since there is a difference between the disk and the wall (this being .1 inches) and a k value of 10, the normal force is able to be calculated using F = x*k.

Once every normal force was obtained, each friction was able to be calculated with the appropriate coefficient of static friction for that material. Adding up those values gave us a total friction value of 11.41. Although there were 2 different coefficients of static friction, only one was used, being the coefficient of static friction for acrylic. This is because both the walls and the base are made with acrylic and since the disk will be launched off the base, the coefficient of static friction should be used. The final motor torque that was calculated, using the equation above and the total friction force with the givens, came out to be 10.54 lb*in. The final motor that was bought did end up being 3500 RPM which was definitely more than enough as our RPM calculated was 2124 RPM, however it did not have the amount of torque needed to launch the disk far enough, resulting in the disk launching only about a foot.

V. Design

The Design phase elaborates on the final design of the prototype. This section will cover the Block Diagram, DFMEA, final control system, the final assembly drawings and analysis plan.

A. Block Diagram

As seen in Figure 9, the Block Diagram was created to illustrate the relationship between the electrical, mechanical and physical parts of the Launch Master.

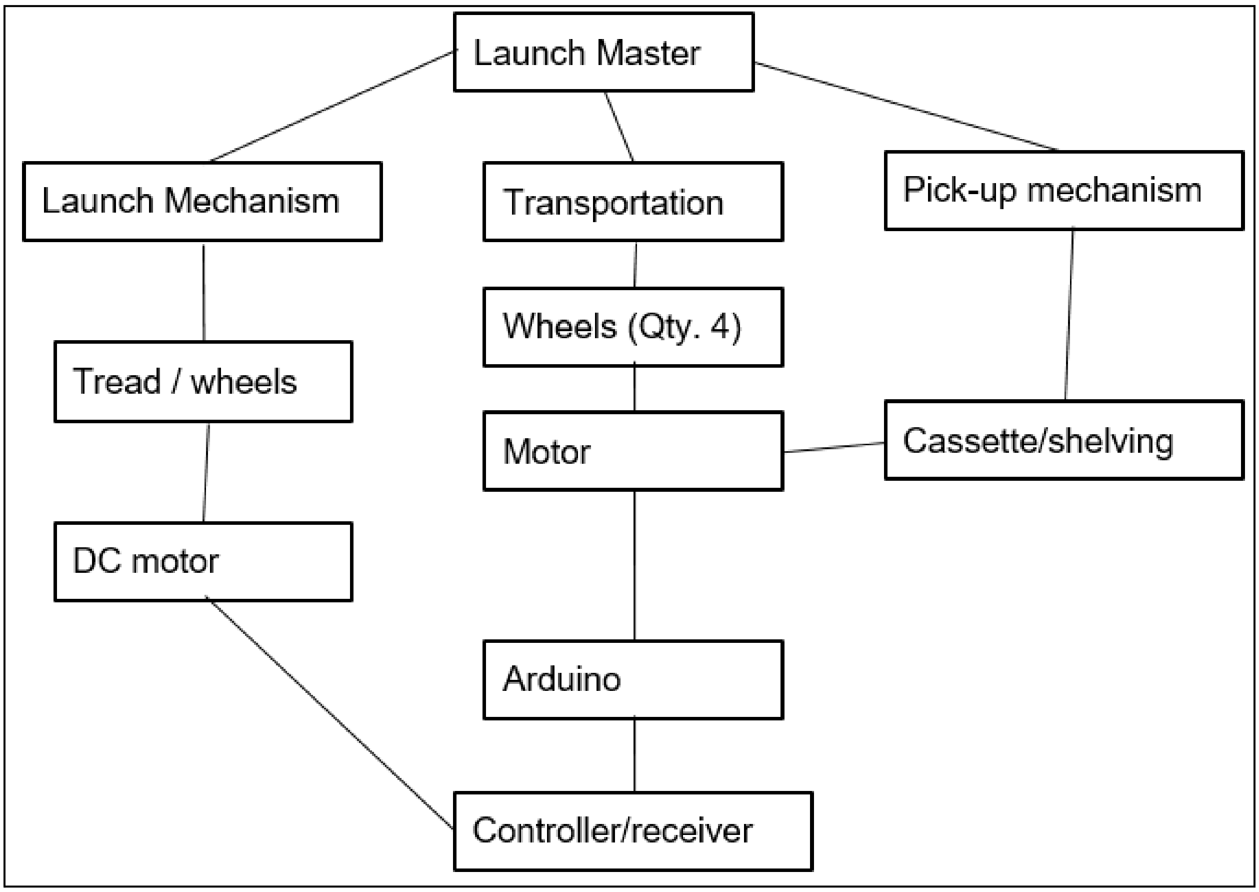


Figure 9: Block Diagram of Launch Master

B. DFMEA

DFMEA, also known as Design Failure Mode & Effects Analysis, is a tool used to identify and prevent design issues that may occur within a product. Potential failure modes are identified, as well as the effect of the failure. Potential causes to the failure are investigated and the controls in place to prevent those causes of failure. Value ratings generated from the DFMEA are Severity, Occurrence and Detection.

Potential Failure Mode and Effects Analysis (Design)

DFMEA No: 1

Document Security Classification: None

Product: Launch Master
Approval:
Team Members: D Donn, B Folchi, J Ott, S Szachara

Prepared By: B Folchi & D Donn
DFMEA Rev Date: 3.28.22
Part Production Drawing Rev:
Part Outline Drawing Rev:

Ident	Item / Function	Potential Failure Mode	Potential Effects of Failure	Sev	Class	Potential Cause(s) / Mechanisms of Failure	Occ	Current Design Controls (P / D)	Det	RPN	Rec. Actions	Resp. and Target Completion Date	Action Results: Actions Taken	Sev	Occ	Det	RPN
1	Launch Mechanism	Tread does not move	)Disc will not launch	9		Design - motor and tread do	1	Functional Testing (Detective Control)	1	9	Revise Design	TBD	TBD				n/a
2	Launch Mechanism	Tread does not move	)Disc will not launch	9		Poor motor choice	4	Functional Testing (Detective Control)	3	108	Recheck Calculations	TBD	TBD				n/a
3	Launch Mechanism	Tread does not move	)Disc will not launch	9		Incorrect tread loop length	1	Engineering Specifications (tire	1	9	Revise Design	TBD	TBD				n/a
4	Launch Mechanism	Disc not launching	)Disc will not launch	9		Track for disc is too wide	1	Engineering Specifications	2	18	revise Design	TBD	TBD				n/a
5	Launch Mechanism	Disc not launching	)Disc will not launch	9		Track for disc is too narrow	1	Engineering Specifications	2	18	revise Design	TBD	TBD				n/a
6	Launch Mechanism	Track moves too quickly	)Disc will launch too quickly	10		Poor motor choice	4	Functional Testing (Detective Control)	3		Recheck Calculations	TBD	TBD				n/a
	Launch Mechanism	Controller not triggering launch	)Disc will not launch)Input triggers another	9		Controller incorrectly	6	Functional Testing (Detective Control)	1	54	Revise Scematic and	TBD	TBD				
7	Launch Mechanism	Controller not triggering launch	)Disc will not launch)Input triggers another	9		Motor and controller not	5	Functional Testing (Detective Control)	2	90	Revise Scematic	TBD	TBD				n/a
8	Transporation	Wheels do not move	)User will not be able to move the Launch	8		Poor motor choice	4	Functional Testing (Detective Control)	2	64	Recheck Calculations	TBD	TBD				n/a
9	Transporation	Wheels do not move	)User will not be able to move the Launch	8		Motor to Arduino to	4	Functional Testing (Detective Control)	1	32	Revise Schemaitic	TBD	TBD				n/a
10	Transporation	Wheels do not move	)User will not be able to move the Launch	8		Controller incorrectly	6	Functional Testing (Detective Control)	1	48	revise schematic and	TBD	TBD				n/a
11	Transporation	Wheels do not move in sync	)User will not be able to move the Launch	9		Controller incorrectly	6	Functional Testing (Detective Control)	1	54	revise schematic and	TBD	TBD				n/a
12	Transporation	Wheels do not move in sync	)User will not be able to move the Launch	10		Motor to Arduino to	5	Functional Testing (Detective Control)	2	100	revise schematic and	TBD	TBD				n/a
13	Pick-up mechanism	Disc is not being picked up	)Will effect the launch mechanism, as discs	4		Cassette/shelving does not	3	Functional Testing (Detective Control)	2	24	Revise Pick-up mechanism	TBD	TBD				n/a
14	Pick-up mechanism	Disc is not being picked up	)Will effect the launch mechanism, as discs	4		Ramp is not low enough to the	1	Functional Testing (Detective Control)	2	8	Revise Pick-up mechanism	TBD	TBD				n/a
15	Pick-up mechanism	Disc is not being picked up	)Will effect the launch mechanism, as discs	4		Not enough force to load	1	Functional Testing (Detective Control)	2	8	Revise Pick-up mechanism	TBD	TBD				n/a

Figure 10: Initial DFMEA for Launch Master

As seen in Figure 10, the functions selected for the DFMEA were the main components of the Launch Master - Launch mechanism, Transportation and Pick-up mechanism. For each function, failure modes, effects and causes were generated. The design controls were listed, as well as action items for each.

C. Control System Overview

The control system of the Launch Master will utilize the components listed below to achieve the customer requirements to launch discs, move freely and pick up discs. *(Please see **Appendix C** for wiring diagrams and Arduino code)*

System control components include:

- (1) Arduino Mega
- (1) Bluetooth Module (HC-06)
- (1) Motor Shield
- (1) Battery Source (LIPO 12V)
- (1) Relays
- (1) Voltage Regulator
- (1) 12V DC Motor (launch mechanism)
- (2) 9V DC motor (transportation)
- (1) Servo motor
- (1) Robot Chassis w/ motors
- (2) Linear actuators
- Wiring

D. Assembly Drawing

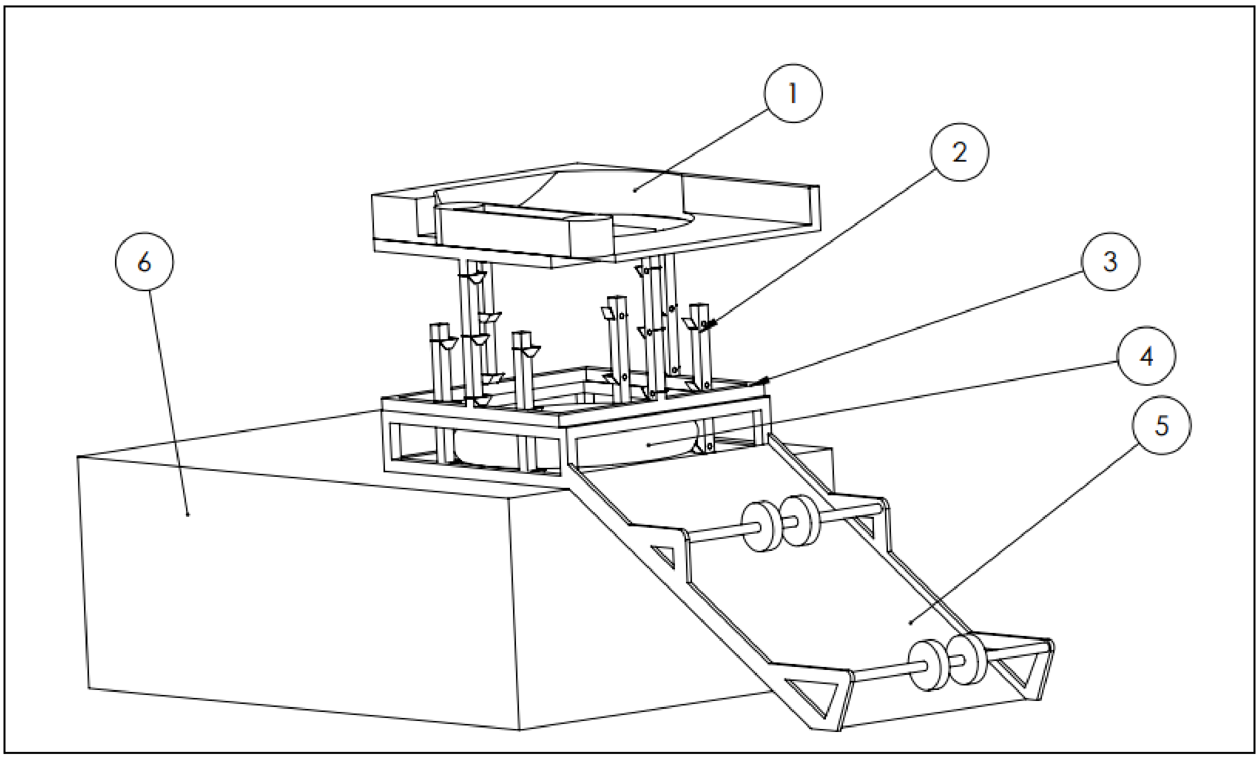


Figure 11: Initial Balloon Assembly Drawing

This assembly drawing was completed in accordance with the original plan for this machine's design. The final assembly of the machine does not reflect this as a result of time and budgetary constraints. Included in this design is: 1. Launching Mechanism 2. Internal Cassette (Vertical Stepper) 3. External Cassette (Frame) 4. 5 inch Frisbees Model 5. Pickup Ramp 6. Dimensional Representation of outsourced tank Chassis.

E. Final Analysis Plan

Analysis Description	Start Date	Due Date	Date	Responsible
Motor calculations	3/2/2022	3/31/2022		D Donn
Launch calculations (torque, motor speed, etc. needed)	3/2/2022	3/31/2022		D Donn, B Folchi
Motor selection	3/2/2022	3/31/2022		D Donn
FEA on Launch mechanism (tread and track)	3/9/2022	4/4/2022		B Folchi
Tolerance Stack Up Analysis - between shelving cassette	3/9/2022	4/7/2022		S Szachara
Tolerance Stack Up Analysis - between	3/9/2022	4/7/2022		J Ott
Logistical Analysis of Loading Methods	3/9/2022	3/31/2022		J Ott

Figure 12: Tabulated Analysis Plan

The final Analysis Plan shown above in Figure 9 was created to organize all analysis to be completed before prototyping the Launch Master. Included is the start date of the task, the due date and the team member responsible for completing the task. All tasks were completed except FEA of the Launch mechanism due to time constraints. The motor calculations and motor selection were completed long past the due date.

VI. Verify

A. Bill of Materials

The Bill of Materials, also known as BOM, is the list of the raw materials, sub-assemblies, and parts within the finished prototype. The BOM also includes part numbers, brand, quantities, a brief description and the cost for each item. This tabulated list can be a means of communication between manufacturing partners or aid operators/engineers when manufacturing.

A brief BOM for the Launch Master includes (*Please see **Appendix D** for full BOM*):

- Fully constructed chassis w/ treads and motors attached
- Arduino Mega
- Motor Shield
- Al Garage tracks
- DC motor
- Linear actuator

Overall, materials for the project were relatively easy to find (from the internet or at a hardware store). All supplies were shipped and arrived quickly. Reflecting on the design and verify processes, the team should have ordered parts sooner to start building sooner.

B. Test Plan

Test Name	Start Date	Due Date	Completion	Responsible	Test Conditions	Number of Parts to be Tested and	Measurements or Evaluations to be done	Pass/Fail Criteria
Safety Light test	4/12/22	4/14/22		All	(Can be completed with launch durability test) monitor 50 launches and ensue the safety light triggers every time	1 prototype	Visual evaluation	Does light turn on? If not - fail
Launch durability test	4/12/22	4/14/22		All	(Can be completed with safety light test) monitor 50 launches and ensure the frisbee launches as intended every time	1 prototype	Visual evaluation, launch distance	Does the launch reach a certain distance Is the launch straight (perpendicular to machine)
Transportation Control test	4/15/22	4/18/22		All	Use controller to move the Launch Master	1 prototype	Visual evaluaton	Does the Launch master follow to
Pickup mechanism test	4/15/22	4/18/22		All	Pick up fallen disk and reload it	1 prototype	Visual evaluation	Is there enough force to reload the dosk?Does the disk go straight into the casset holder once picked up?
Motor test	4/12/22	4/18/2022		All	Can launch the disk at least 20 feet	1 prototype	Visual evaluation	Does the disk get launched 20 feet? Does
Testing of the Launch Master	4/12/2022	4/18/2022		All	The safety light turns on when it launches,	1 prototype	Visual evaluation	Doese the Launch Master follow all of the
Final Testing	4/14/2022	4/24/2022		All		1 prototype	Visual evaluation	

Figure 13: Tabulated Test Plan

The initial Test Plan for the Launch Master is shown in Figure 10. This table lists the test action item, start date, due date, team member responsible, test conditions, number of parts being tested, measurements/evaluations and pass/fail criteria. All the listed action items were completed on the finished prototype of the Launch Master.

C. Results

The Launch Master prototype does work. It is able to move around in every direction. It is able to shoot a frisbee on its own and can hold more than one frisbee. The launches were slightly inconsistent as it was hard to measure and obtain the required tension on the belt. The prototype did in fact work and relatively functioned how it was designed.

Due to time constraints, the testing plan was not completed. The prototype was completed very close to the due date, therefore insufficient testing resulted. The Launch Master was able to shoot numerous times, but structurally and visibly can be seen as unstable. If work were to continue, design modifications would result to ensure a more structurally sound launch mechanism.

D. Discussion / Challenges

The biggest challenge for the Launch Master project was the general idea of the project. It took a lot of research to come up with an idea of how it could successfully work. The transportation of the chassis was the obstacle of the project. Once we had a moving base (which took longer than expected), we built the other parts around that. Another extremely difficult part was the electrical control system. There were more components that needed to be purchased that were not considered during the Design phase.

During preliminary testing, our out-sourced motor shield H-bridge exploded/smoked which delayed the building process. A new motor shield was constructed and used in the final prototype. Overall the Launch Master was successful and was able to perform but didn't meet all customer requirements and would have gone over budget if so.

VII. Conclusion

- The prototype works. It is capable of driving around in every direction. Has the ability to hold more than one frisbee and can load/fire off a phone from a distance.
- The Launch Master (at its current state) is not consistent. It is not safe, stable and not very aesthetically pleasing.
- The idea was very complex for the budget we had.
- There were many problems that came up during the testing phases and should have been addressed sooner.
- Prototyping should have started sooner to allow for design tweaks and modifications.
- The DMADV process proved to be extremely successful. However, it is very important to stick with the Gantt chart to ensure ample time for each phase.

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Luy YitzlachLuy Yitzlach 1111 silver badge22 bronze badges, and Kevin ZywickiKevin Zywicki 1111 bronze badge. "Determining Required Torque for a Chain and Sprocket Conveyor Belt." *Engineering Stack Exchange*, 1 May 1966, https://engineering.stackexchange.com/questions/23565/determining-required-torque-for-a-chain-and-sprocket-conveyor-belt.

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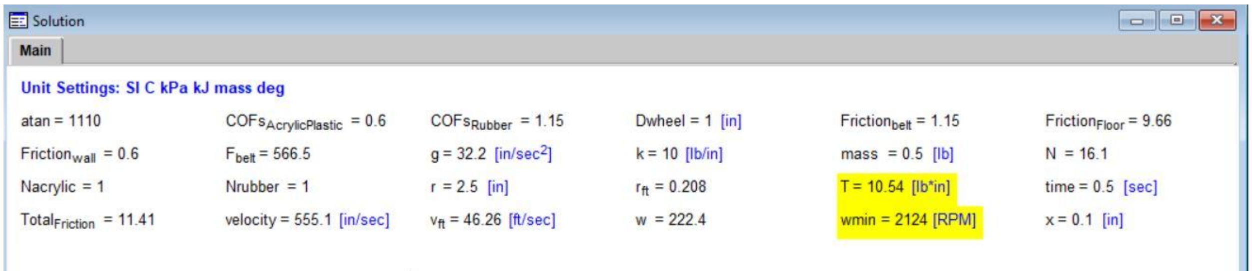
IV. Appendices

Appendix A - Calculations

Motor Calculations: Program - EES

```
"given"
time = .5 [sec]; "assumption"
mass = .5 [lb]; "assumption, need to weigh frisbee"
velocity = 555.118 [in/sec];
v_ft = 46.259 [ft/sec];
r_ft = .208
r = 2.5 [in];
g = 32.2  [in/sec^2];
COFs_Rubber = 1.15;
COFs_AcrylicPlastic = .6; "Assuming .6, need to find definite value"
Dwheel = 1 [in];
x = .1 [in]; "assuming the difference between the frissbee and the track is 5 inches - 4.9."
k = 10 [lb/in] "assuming 10* rubber band thickness"

"analysis"
"y direction; no motion, assume gravity eqauls normal force for disk"
N = g*mass; "frisbee"
Nrubber = k*x; "k is spring force of rubber belt and x is differencec between width of track"
Nacrylic = Nrubber;


"angular acceleration (Rad/Second, to be converted to RPM)"
w = v_ft/r_ft;
wmin = w/.1047

"tangental acceleration for launch mechanism"
atan = velocity/time;

"Friction of rubber as a result of belt"
Friction_belt = Nrubber*COFs_Rubber;

Friction_wall = Nacrylic*COFs_AcrylicPlastic; "assuming wall is not 3d printed and made out of acrylic"
Friction_Floor = N* COFs_AcrylicPlastic; "Assuming floor is also made out of acrylic"

Total_Friction = Friction_belt + Friction_wall + Friction_Floor;

"Force of Belt"
F_belt = Total_Friction + mass*atan;

"Torque for motor (Pully Drive)"
T = .5*(Dwheel*(Total_Friction+COFs_AcrylicPlastic*(mass*g)));
```

Figure 14: Motor Calculations



Solution

Main

Unit Settings: SI C kPa kJ mass deg

atan = 1110	$COFs_{AcrylicPlastic}$ = 0.6	$COFs_{Rubber}$ = 1.15	Dwheel = 1 [in]	$Friction_{belt}$ = 1.15	$Friction_{Floor}$ = 9.66
$Friction_{wall}$ = 0.6	F_{belt} = 566.5	g = 32.2 [in/sec^2]	k = 10 [lb/in]	mass = 0.5 [lb]	N = 16.1
Nacrylic = 1	Nrubber = 1	r = 2.5 [in]	r_{ft} = 0.208	T = 10.54 [lb*in]	time = 0.5 [sec]
$Total_{Friction}$ = 11.41	velocity = 555.1 [in/sec]	v_{ft} = 46.26 [ft/sec]	w = 222.4	wmin = 2124 [RPM]	x = 0.1 [in]

Figure 15: Motor Calculations Solutions (Torque and RPM found)

Appendix B - Drawing Package

Drawing Package: Program - SolidWorks

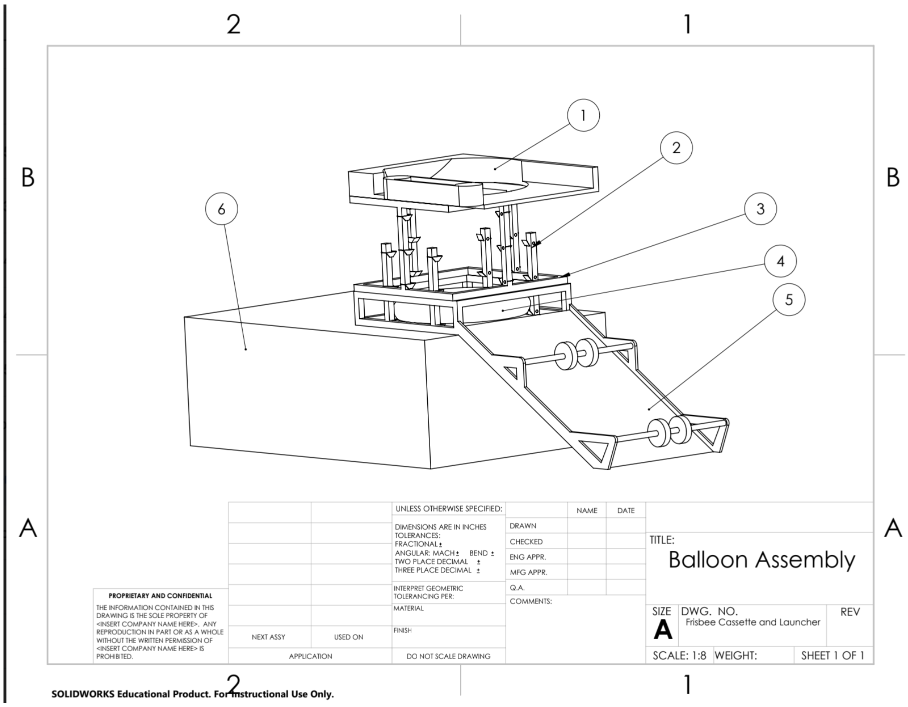


Figure 16: Assembly Drawing

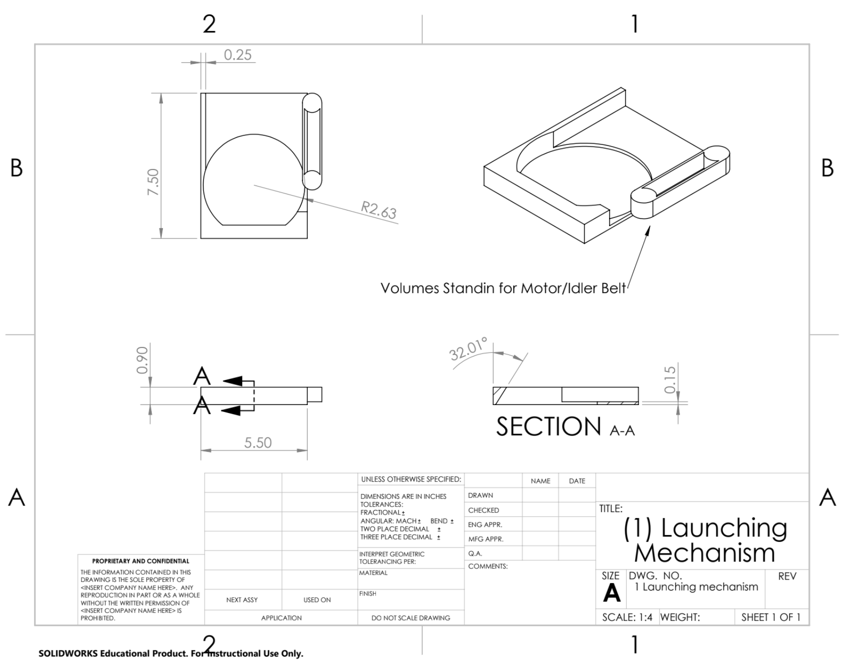


Figure 17: Launching Mechanism

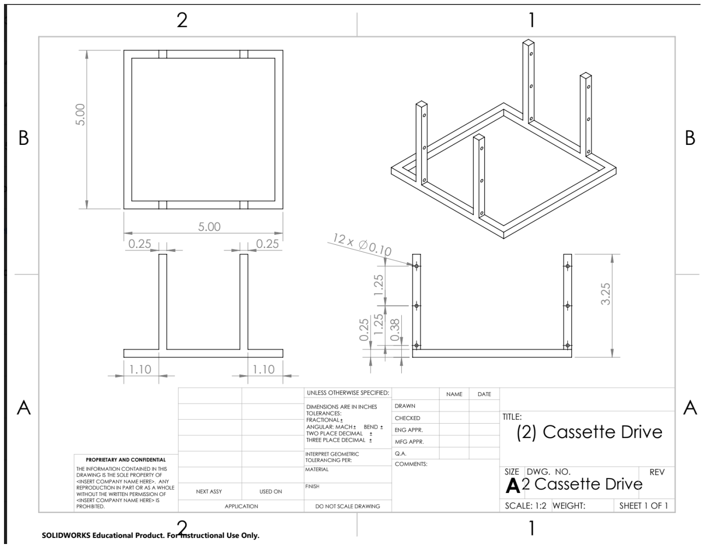


Figure 18: Cassette Drive

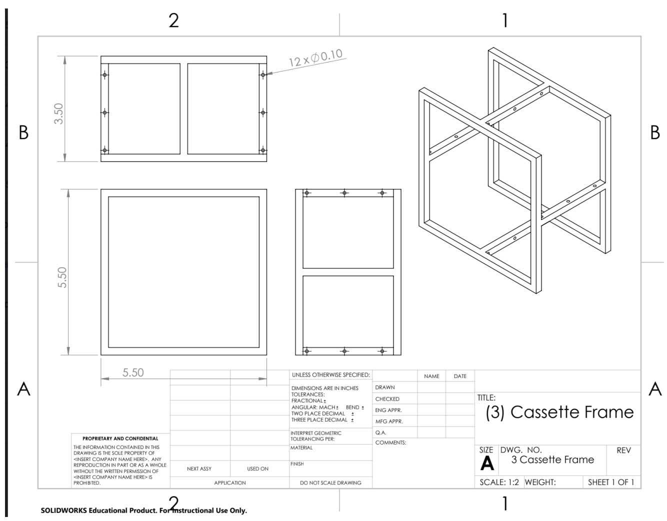


Figure 19: Cassette Frame

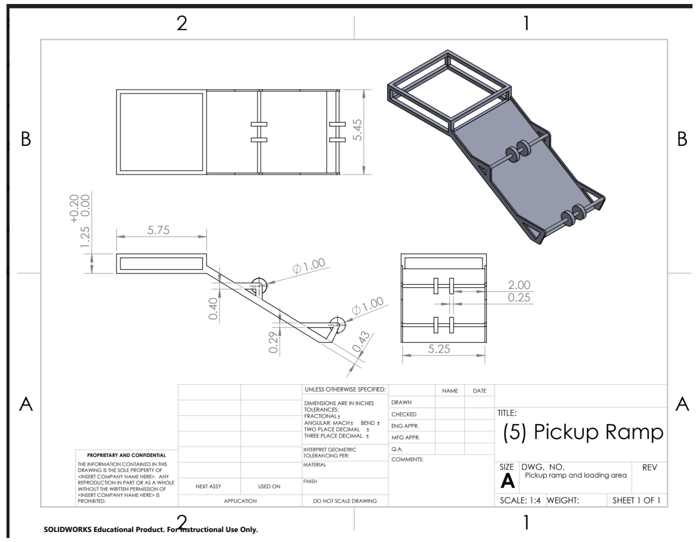


Figure 20: Pickup Ramp

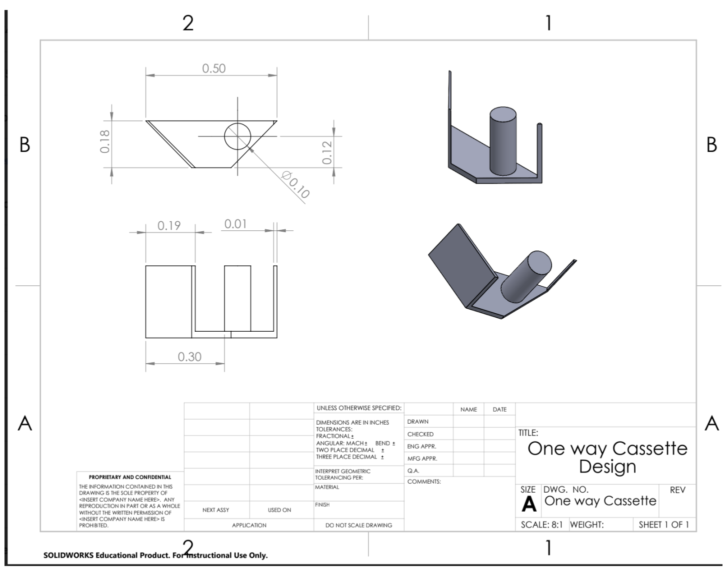


Figure 21: One Way Cassette Design

Appendix C - Instrumentation & Controls

Arduino Code: Program - Arduino

```
#include <Servo.h>
Servo trigger_servo;
int pos = 0;    // variable to store the servo position


bool servo_state = false;

int motor1_speed;
int motor2_speed;
int motor3_speed;
int motor4_speed;

int motor5_speed;

char command;

void setup() {
  pinMode(2,OUTPUT);
  pinMode(3,OUTPUT);
  pinMode(4,OUTPUT);
  pinMode(5,OUTPUT);
  pinMode(6,OUTPUT);
  pinMode(7,OUTPUT);
  pinMode(44,OUTPUT);
  pinMode(46,OUTPUT);

  pinMode(45,OUTPUT);
  pinMode(14,OUTPUT);
  pinMode(15,OUTPUT);

  Serial.begin(9600);
  Serial1.begin(9600);

trigger_servo.detach();
}

void loop() {
  digitalWrite(45,HIGH);
  if (Serial1.available() > 0) {
    command = Serial1.read();
  }
//RETRACT
//  digitalWrite(2,HIGH);
//  digitalWrite(3,LOW);
```

```
//
//digitalWrite(4,HIGH);
//digitalWrite(5,LOW);
//digitalWrite(6,HIGH);
//digitalWrite(7,LOW);
//motor5setSpeed(250);
//motor5run(1);

Serial.println(command);
  switch (command) {
    case 'b':
digitalWrite(4,HIGH);
digitalWrite(5,LOW);
digitalWrite(6,LOW);
digitalWrite(7,HIGH);
      break;
    case'f':
digitalWrite(4,LOW);
digitalWrite(5,HIGH);
digitalWrite(6,HIGH);
digitalWrite(7,LOW);
      break;
    case '!':
digitalWrite(4,LOW);
digitalWrite(5,LOW);
digitalWrite(6,LOW);
digitalWrite(7,LOW);
  digitalWrite(3,LOW);
  digitalWrite(2,LOW);

      break;
    case 'l':
digitalWrite(4,LOW);
digitalWrite(5,HIGH);
digitalWrite(6,LOW);
digitalWrite(7,LOW);
      break;
    case'r':
digitalWrite(4,LOW);
digitalWrite(5,LOW);
digitalWrite(6,HIGH);
digitalWrite(7,LOW);
      break;
//    case'G':
//      forwardleft();
//      break;
```

```
//    case'I':
//      forwardright();
//      break;
//    case'H':
//      backwardleft();
//      break;
//    case'J':
//        backwardright();
//      break;
    case 'X':
    delay(2000);
  digitalWrite(15,HIGH);
  delay(5000);
  digitalWrite(15,LOW);
      break;
    case 'u':
  digitalWrite(2,LOW);
  digitalWrite(3,HIGH);
      break;
    case 'd':
  digitalWrite(2,HIGH);
  digitalWrite(3,LOW);
      break;
    case 's':
    if (!servo_state) {
    trigger_servo.attach(29);
        for (pos = 0; pos <= 180; pos += 1) { // goes from 0 degrees to 180 degrees
          // in steps of 1 degree
          trigger_servo.write(pos);              // tell servo to go to position in variable 'pos'
          delay(15);                       // waits 15 ms for the servo to reach the position
        }
    trigger_servo.detach();
    servo_state = true;
    }
      break;
    case 'm':
    if (servo_state) {
    trigger_servo.attach(29);
        for (pos = 180; pos >= 0; pos -= 1) { // goes from 180 degrees to 0 degrees
          trigger_servo.write(pos);              // tell servo to go to position in variable 'pos'
          delay(15);                       // waits 15 ms for the servo to reach the position
        }
    trigger_servo.detach();
    servo_state = false;
    }
      break;
  }
```

```
}

void forward()
{
  motor1setSpeed(255);
  motor1run(1);
  motor4setSpeed(255);
  motor4run(1);
}

void backward()
{
  motor1setSpeed(255);
  motor1run(-1);
  motor4setSpeed(255);
  motor4run(-1);
}

void left()
{
  motor1setSpeed(255);
  motor1run(1);
  motor4setSpeed(255);
  motor4run(-1);
}

void right()
{
  motor1setSpeed(255);
  motor1run(-1);
  motor4setSpeed(255);
  motor4run(1);
}

void forwardleft()
{
  motor1setSpeed(250);
  motor1run(1);
  motor4setSpeed(10);
  motor4run(1);
}

void forwardright()
{
  motor1setSpeed(10);
  motor1run(1);
  motor4setSpeed(255);
```

```
void backwardleft()
{
  motor1setSpeed(10);
  motor1run(-1);
  motor4setSpeed(255);
  motor4run(-1);
}

void backwardright()
{
  motor1setSpeed(255);
  motor1run(-1);
  motor4setSpeed(10);
  motor4run(-1);
}

void Stop()
{
  motor1setSpeed(0);
  motor1run(0);
  motor4setSpeed(0);
  motor4run(0);
}
////void Launch()
//{
//  // what the heck is this function
//  digitalWrite(motor_pin,HIGH);
//
//  // put your main code here, to run repeatedly:
//  digitalWrite(relay,HIGH);
//  delay(500);
////  digitalWrite(relay,LOW);
//  delay(500);
//}




/*
 * DO NOT TOUCH THE CODE BELOW
 */
void motor1run(bool motor_direction) {
  if (motor_direction == 1) {
    analogWrite(2,motor1_speed);
    digitalWrite(3,LOW);
  }
```

```
  else if (motor_direction == -1) {
    analogWrite(3,motor1_speed);
    digitalWrite(2,LOW);
  }
  else {
    digitalWrite(2,LOW);
    digitalWrite(3,LOW);
  }
}

void motor1setSpeed(int motor_speed) {
  motor1_speed = motor_speed;
}

void motor2run(bool motor_direction) {
  if (motor_direction == 1) {
    analogWrite(4,motor2_speed);
    digitalWrite(5,LOW);
  }
  else if (motor_direction == -1) {
    analogWrite(5,motor2_speed);
    digitalWrite(4,LOW);
  }
  else {
    digitalWrite(4,LOW);
    digitalWrite(5,LOW);
  }
}

void motor2setSpeed(int motor_speed) {
  motor2_speed = motor_speed;
}

void motor3run(bool motor_direction) {
  if (motor_direction == 1) {
    analogWrite(6,motor3_speed);
    digitalWrite(7,LOW);
  }
  else if (motor_direction == -1) {
    analogWrite(7,motor3_speed);
    digitalWrite(6,LOW);
  }
  else {
    digitalWrite(6,LOW);
    digitalWrite(7,LOW);
  }
}
```

```
void motor3setSpeed(int motor_speed) {
  motor3_speed = motor_speed;
}

void motor4run(bool motor_direction) {
  if (motor_direction == 1) {
    analogWrite(44,motor4_speed);
    digitalWrite(46,LOW);
  }
  else if (motor_direction == -1) {
    analogWrite(46,motor4_speed);
    digitalWrite(44,LOW);
  }
  else {
    digitalWrite(44,LOW);
    digitalWrite(46,LOW);
  }
}

void motor4setSpeed(int motor_speed) {
  motor4_speed = motor_speed;
}

// This motor can only go in one direction
void motor5run(bool motor_direction) {
  if (motor_direction == 1) {
    analogWrite(45,motor5_speed);
  }
  else {
    digitalWrite(45,LOW);
  }
}

void motor5setSpeed(int motor_speed) {
  motor5_speed = motor_speed;
}

// This motor can only go in one direction at one speed
void motor6run(bool motor_direction) {
  if (motor_direction == 1) {
    digitalWrite(14,HIGH);
  }
  else {
    digitalWrite(14,LOW);
  }
}
```

Figure 22: Final Arduino Code

Final Code allows for Bluetooth control of Launch Mechanism, Transportation, Servo motor, and Linear actuator

Control System Wiring Diagram: Program - Circuito.io

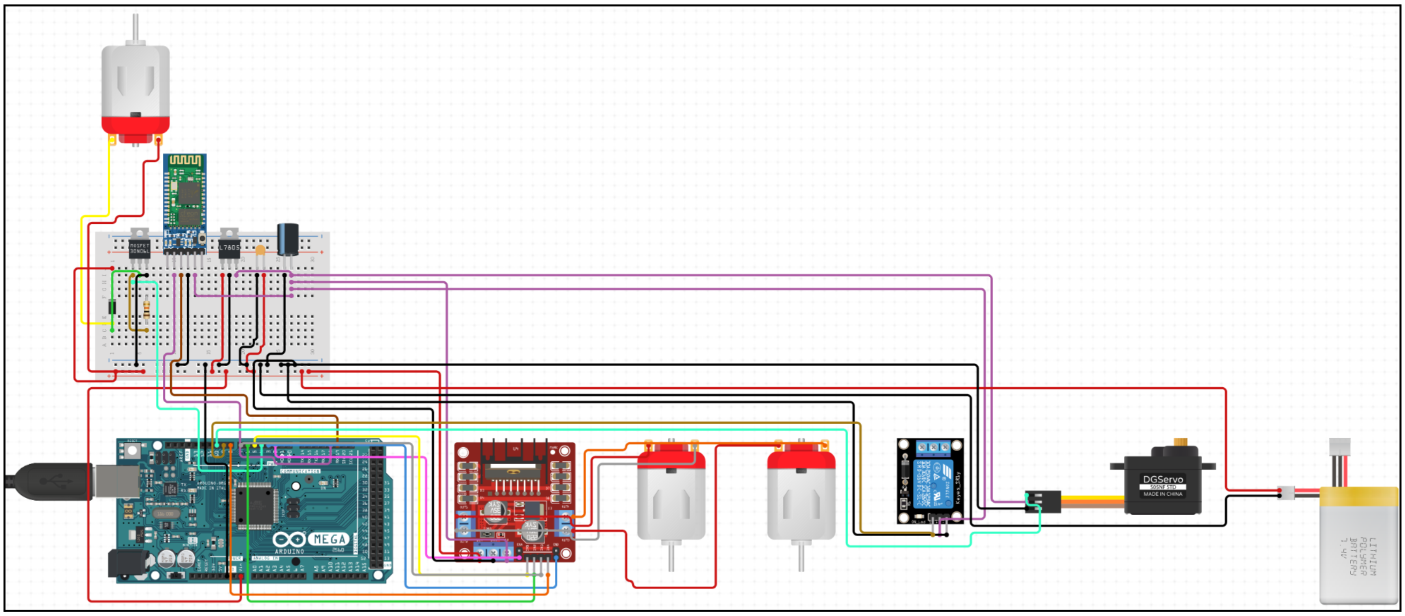


Figure 23: Wiring Diagram for whole Launch Master

Appendix D - Bill of Materials

Bill of Materials

Project Name	Launch Master	Team Members
Date	4/29/22	Daniella Donn
Course	MCET 550	Bethany Folchi
		Juztyn Ott
		Spencer Szachara

Part Number (from respective catalog)	Manufacturer	Retailer	Qty	Description	Cost ($)	General Specs	Part within assembly	Part Image
150L050NG	SureMotion	automationdirect.com	1	Timing Belt	6.50	3/8" L pitch, 1/2" wide	Launch Mechanism	
APB13L050BF-375	SureMotion	automationdirect.com	2	Timing Pulley/wheel	39.00	1/2" wide, 1.552" diameter	Launch Mechanism	
55844	Optix	Lowe's Store	1	Acrylic Sheet	2.14	8 x 10 "	Launch Mechanism	
163055	Plaskolite	Lowe's Store	1	Plastic Cutting Tool	2.34	-	-	
643284	Rubbermaid	Lowe's Store	1	FastTrack Garage Rail	4.99	25" long	Frame	
643283	Rubbermaid	Lowe's Store	1	FastTrack Garage Rail	7.99	47.5" long	Frame	
-	Walfront Store	Amazon.com	1	DC Motor	34.41	3500 RPM, .5A, 12V	Launch Mechanism	
-	SZDOIT	Amazon.com	1	Chassis	86.00	-	Transportation	
-	Arduino	Amazon.com	1	Motor drive sheild and arching board	10.00	-	Transportation	
				juztyn's purchases	70.00			
	DABLIZ	Amazon.com	5	Voltage Regulator Package	14.99	DC Step Down Input 3.0-4.0V Output 1.5-35V		
	-	Amazon.com	MANY	Wires	-	-	Control System	
	-	-	1	Relay	-	3 port Relay	Control System	
	ECO LLC	Amazon.com	2	Linear Actuator	29.00	1.2" stroke, Force 4.5 lbs, 12V	Drop/Shelf mechanism