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Fetching Interactive Dog Occupier (FIDO)

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FIDO MQP

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ABSTRACT

Dogs are great companions but they require a lot of attention and exercise. Many households are a two-salary household, which leaves the dog alone for many hours. Usually the dog is left with nothing to do but wait for their owners to get home. The Fetching Interactive Dog Occupier, or FIDO, team has designed a prototype to entertain and exercise dogs that are left home alone. FIDO plays fetch with the dog without the help of the owner. The owner simply sets up the machine and turns it on. The dog can drop the tennis ball in the hopper system and the machine will shoot it out. The dog can continually play fetch with FIDO while its owners are at work. FIDO was designed with different setting for either indoor and/or outdoor use. Safeguards exist to prevent tossing a ball if the dog or child is in close proximity of the discharge tube. The prototype has been successfully field tested.

EXECUTIVE SUMMARY

Dogs have often been called “man’s best friend,” and befitting this title, dog owners should treat their pets as a close and loyal companion. Unfortunately, dog owners often are forced to leave their pets alone at home with little to no exercise or entertainment. In other instances, such as in the cases of the elderly and the physically disabled, owners can have difficulty playing with their dogs. Fetching Interactive Dog Occupier 3.0 or FIDO 3.0 designed an automated fetch simulator that allows dogs to play with a tennis ball to not only entertain the dog, but also provide them with the necessary exercise that all animals need. It was designed as an indoor and outdoor automatic entertainment center.

The final design is a vertically mounted flywheel that is used to accelerate a tennis ball along a circular path into a launcher nozzle where it is discharged. The FIDO launching system is composed of several subsystems such as motors, chain drives, sprocket combinations that determine the angle of launch. A servomotor-mechanized hopper dispenses a single tennis ball into the launcher, and a CIM motor is used to drive a flywheel that discharges the ball. All components of the system was designed to efficiently fit together to save space and minimize the profile of the housing design.

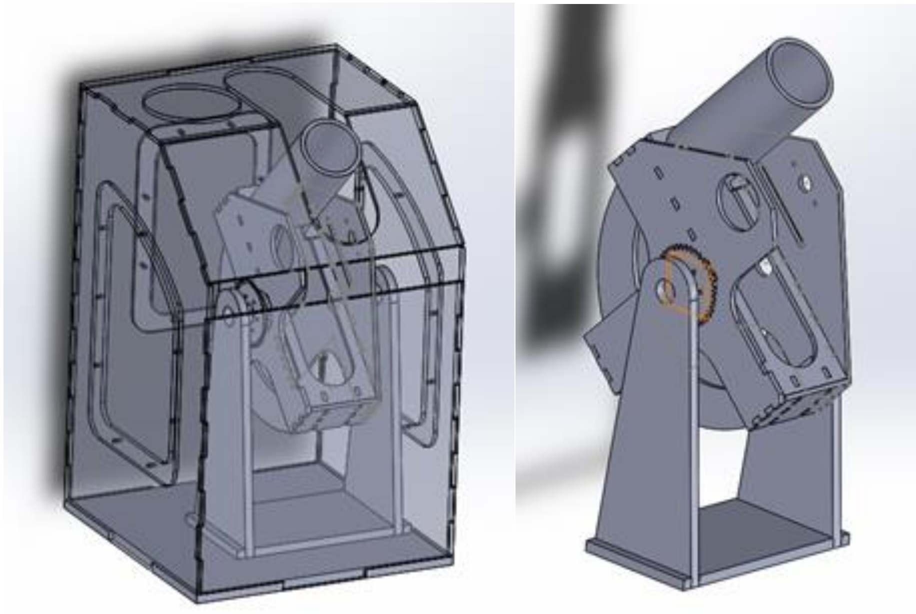

Figure A: CAD drawing of final design

The team designed the FIDO system using Solidworks CAD, as seen in Figure A. Importing these files as *.dwg files, the team laser cut the majority of the components. Using Medium Density Fiber as the main material, the team reduced cost and took advantage of the MDF's durable yet flexible properties. The team milled the flywheel for a uniform weight distribution, which reduced the vibrations when spinning at high speed. A half inch keyed shaft and shaft collars kept all the components positioned appropriately along the drive.

The automatic tennis ball launcher utilizes a CIM motor to drive the flywheel through a tooth sprocket and belt pulley drive train. A pair of ball guide rails oriented concentric to the shaft of the flywheel allowed the tennis ball to accelerate along the semicircle launch path. A circular launch path is induced a spin on the tennis ball and utilized the Magnus force (i.e. the spin effects) to give the launch an upwards boost. To change the angle of launch, a motor adjusts the launcher using a chain and sprocket. The hopper system dispenses a single ball into the launcher after checking whether there is an obstruction in the path of launch to prevent injury to the dog or owner.

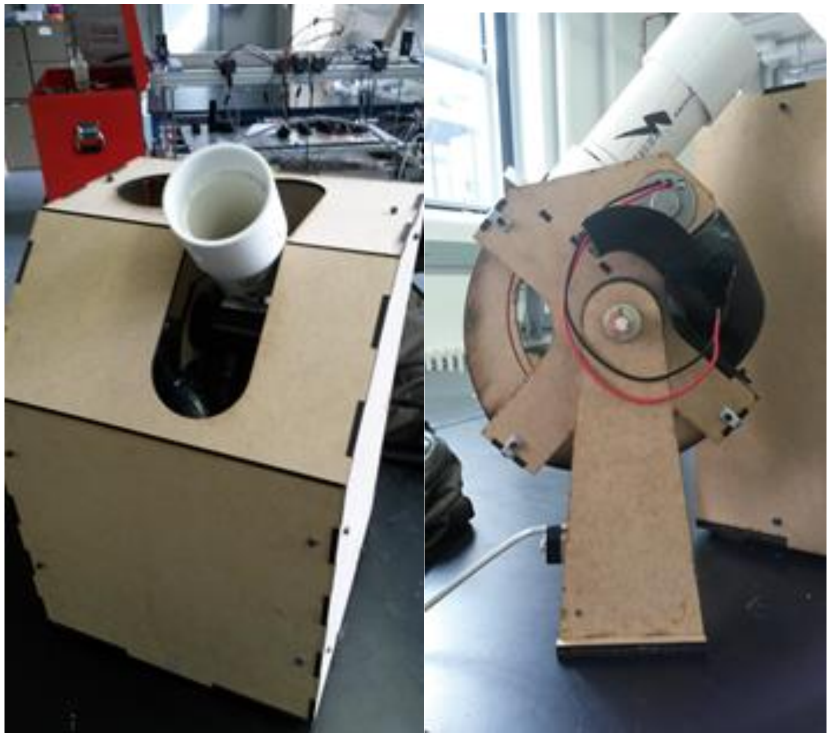

Figure B: The final system

The system, seen in Figure B, uses a Raspberry Pi as the computer and every electrical component is controlled through this interface with a 12-volt drill battery and battery charger as the power source. The codes for each motor, sensor and switch were tested individually and then merged together for a unified system. The ball is automatically detected by the push switch in the hopper, which initializes the system. The computer checks the proximity sensor status to verify no obstructions prior to launcher discharge. Through this process, the team is able to avoid injury to the dog or children that might be in the path of launch.

As a result of the FIDO 3.0 build, the automatic tennis ball launcher can launch a tennis ball up to 35 feet. This range diversity allows for outdoor and/or indoor use. The team recommends an alternate proximity sensor. The current one must be mounted horizontally, creating a blind spot above the launcher.

The overall design of the FIDO 3.0 can be improved and/or tweaked for manufacturing purposes. Milling the flywheel out of steel was expensive and a difficult process, so the team recommends to either purchase an aftermarket 6-inch wheel or use aluminum as the wheel material as aluminum is much easier to machine. Adding rubber grip material onto the wheel edge also improved the launching capabilities for the team, so investing more time into testing the grip between the ball, wheel and rails can boost launch distances. The team further recommends mounting the discharge orientation motor on the side of the housing so that the clearance between the base and the launcher can be improved. This mounting modification will lower the overall height by 4 to 5 inches and will save on material costs in the launcher frame and housing. The housing seams should also be sealed using silicone sealant and the hull covered in polyurethane for water resistance. With these modifications, the FIDO 3.0 becomes a safe, efficient and reliable dog entertainment product.

AUTHORSHIP AND CONTRIBUTION

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	Abstract	Johnly Lin
	Executive Summary	Johnly Lin
1.0	**INTRODUCTION**	Team
2.0	**BACKGROUND/LITERARY REVIEW**	Team
2.1	Previous Launcher Designs	Joseph Alvarado
2.2	Previous Hopper System Designs	Johnly Lin
2.3	Previous Elevation/Angle of Launcher Design	Johnly Lin
2.4	Previous Team's Programing	Bianca Espinoza
2.5	Previous Power Systems Design	Tiana Vasquez
2.6	Previous Electronic Hardware	Tiana Vasquez
2.7	Previous Housing Design	Bianca Espinoza
2.8	Target Consumer Survey	Bianca Espinoza
3.0	**PROCEDURE/DESIGN PROCESS**	Team
3.1	Preliminary Constraints	Joseph Alvarado
3.2	Launcher Design	Johnly Lin
3.3	Hopper System Design	Johnly Lin
3.4	Elevation/Angle of Launcher Design	Joseph Alvarado and Johnly Lin
3.5	Programming/Electrical and Power Systems Design	Tiana Vasquez

3.6	Housing Design	Bianca Espinoza
4.0	**CONSTRUCTION, ASSEMBLY and TESTING**	Team
4.1	Final Design	Johnly Lin
4.2	Launcher	Joseph Alvarado and Johnly Lin
4.3	Hopper System	Doon Nordemann
4.4	Elevation/Angle of Launcher	Johnly Lin
4.5	Housing and Frame Assembly	Johnly Lin
4.6	Electrical Systems	Tiana Vasquez
4.7	Power Systems	Tiana Vasquez
4.8	Program Codes	Bianca Espinoza
4.9	Testing	Johnly Lin
5.0	**CONCLUSION AND RECCOMENDATION**	Team
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1-Introduction

Dogs have been mankind's companions for thousands of years and gives tremendous health benefits besides their everlasting loyalty. Studies have shown that having a dog in a room helps lower blood pressure, cholesterol and anxiety when under stress. Many people have applied for Emotional Support Animals (ESA), service animals and therapy dogs that help people with mental illnesses or disabilities. Recently, Golden retrievers were used to comfort survivors of the Newtown school shooting and Boston Marathon bombing. Dogs can even serve technical jobs such as scent detection, being able to smell in parts per trillion (InSitu Foundation). Their keen nose allows them to smell out narcotics, gunpowder, bacteria in water, missing persons and even detect cancer. Dogs are not just services animal used to help make a person's lives easier; they are friends, companions and family members.

Of course it is necessary for dog owners to leave the house at times, however, that does not stop owners from being personally worried about the wellbeing of their pets alone at home. According to the People's Dispensary for Sick Animals (PDSA), more than a quarter of dog owners leave their dogs at home alone for more than 5 hours at a time. Statistics show that more dog owners are leaving their pets at home to go to work, which can have negative effects on the dog's health. Dogs need love and attention; without which, dogs can develop serious behavioral problems and depression. Given a dog's active lifestyle, dog owners would often play fetch to alleviate their primal need to chase. Dogs were domesticated from wolves and this predatory ancestry allows them to aid in hunting and retrieving prey. This instinct to chase is simulated in fetch, which allows the dog to obtain its daily exercise while satisfying their primal urges. As more dog owners struggle to find time in their busy schedules to play with their pets, a need for a solution to entertain and exercise their dogs grow.

The purpose and goal of the Fetching Interactive Dog Occupier (FIDO) is to entertain a dog through the action of playing fetch by designing a device that can safely launch a tennis ball and, after the dog has retrieved the ball, launch it repeatedly. The FIDO unit is a completely automated entertainment center that can launch standard tennis balls at various distances, which allows both indoors and outdoors use. Multiple design features such as a sensor at the nose of the launcher to prevent injury to the pet has been implemented for safety and reliability. Features from previous FIDO design projects and existing similar products have been assimilated into the 2017 design to create the ultimate dog entertainment center that prioritizes efficiency, durability, and safety.

2-Background/Literature Review

The team has researched and analyzed previous MQP designs as well as other competitor designs to create the ideal dog entertainment center. Two similar existing products are discussed in this background: the "iFetch" and "GoDogGo." In order to better study the previous MQP's pros and cons, the design was broken down into the following major components:

- Launcher
- Hopper system
- Elevation/angle of Launcher
- Programming
- Power system and electronics
- Housing

The advantages and disadvantages of each existing product and past MQP project will be stated and the FIDO 3.0 team improved upon, avoided or adapted these features into their design during the design process.

Previous Launcher Designs

The previous two MQP teams used two different concepts for their launching mechanisms. The 2015 MQP utilized a “pin-ball” style spring-powered launcher while the 2016 team used a rotary “pitching machine” launcher. The 2015 MQP did consider using the wheel based system but ultimately ruled it out so their product was unique compared to competitor’s. Both teams utilized decision matrixes in order to choose what they believed would be their best design.

Figure 1: Previous FIDO MQP systems (Left: 2015, Right: 2016

Ultimately, both teams had different designs regarding their shooter system. The 2015 team concluded in their MQP report, “Our final design for the pullback mechanism was one that could be easily accomplished, but ultimately did not work to its fullest extent. It required three separate systems, and even though each one was simplistic, the combination remained problematic." The previous team determined that a spring system is inefficient because of the energy requirement needed to overcome the spring coefficient of the spring as a launching mechanism. The overall design was bulky and heavy which required two people to transport it. Although their overall design was not as effective as they had hoped, they came up with many new ideas to improve the system in the future, which the next MQP team tried to implement.

The 2016 team had greater success with their iteration of the launcher system. They were able to cut the time needed to launch the ball significantly, increasing the rate of fire from 2 minutes and 15 seconds to around 25 seconds. The trade-off was that their maximum distance was only 23 feet as compared to the 2015 version, which was 50 feet. The main issue with the 2016 launcher was with their launching tube. It contained an unavoidable 22 degree interior angle, which inevitably reduced the distance due to friction. The ball was forced to strike the angled tube from a horizontal position and energy was lost during this launching process.

Two major competitors in the dog fetcher market currently are the GoDogGo and the iFetch. The GoDogGo model used a funnel to launch a standard tennis ball between 30-35 feet. Figure 2 identifies the funnel at the upper end of the fixture where gravity directs the ball into a launch point. A hammer then strikes the ball through a chute releasing it from its housing, launching it to the distance set by the operator. The force that launches the ball out of the system is generated by a spring as seen in the right of Figure 2. It launches a ball every 4, 7, and 15 seconds, which is a major advantage compared to the previous 2015 and 2016 project's launch times of 2:15 and 0:25, respectively.

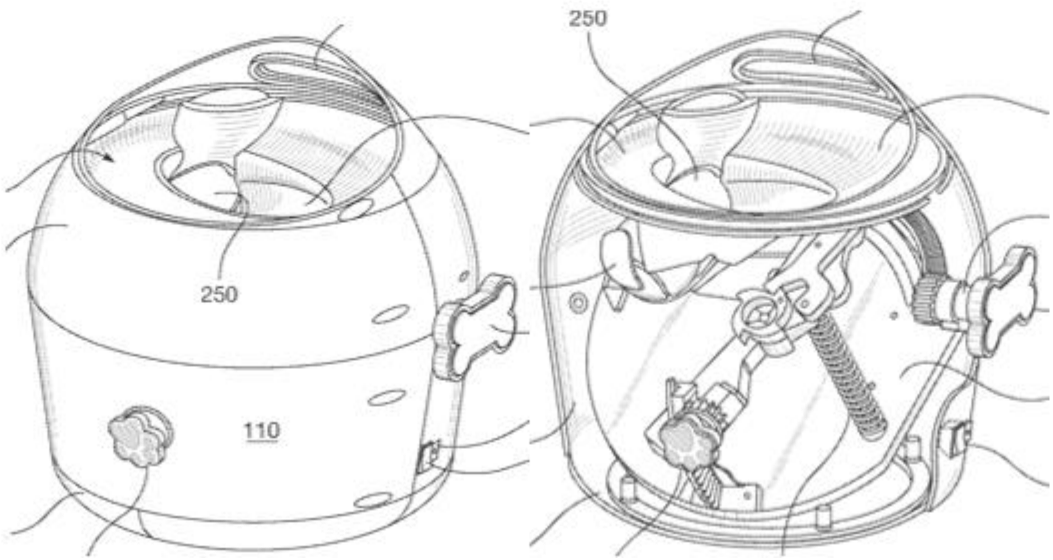


Figure 2: GoDogGo Patent Design

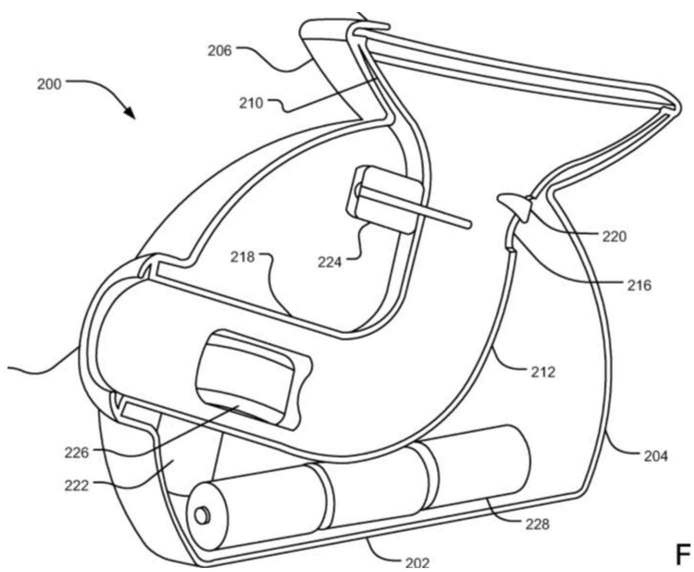


Figure 3: iFetch Patent Design

In comparison, the iFetch has a launch funnel with one or more wheels rotated by one or more motors. The motors power up and trigger the release operations that allow the ball to be launched. The launch end of the chute includes the wheels which are rotated by the motors allowing the ball to thrown in a projectile motion. It does not use a standard tennis balls, but instead uses its own manufactured 1.5-inch balls. For marketing purposes, the use of a unique ball may benefit the company financially, since it obligates the buyer to purchase the company's balls. However, the design uses a standard tennis balls for consistency and convenience to consumers. The newer version of iFetch has recognized the benefits of standard tennis balls for launching and modified their design accordingly. The iFetch can be set up to project balls at three settings: 10 feet, 20 feet and 30 feet.

Previous Hopper System Designs

The 2015 MQP had originally planned on 3D printing interlocking sections of a tube that was collapsible and could rotate around to a certain degree. This allowed a ball to easily fall into the correct launcher position even if the angle of elevation was changed. By the end of the project, the 2015 team compromised with a flexible dryer hose for cost efficiency, simplicity and flexibility. Using this dryer hose hopper, the dog can drop the ball directly into the dryer hose and the ball will be guided into the launching position ready for the spring launcher. A disadvantage to the design is that it does not allow for multiple balls. The dryer hose hopper also opens opportunity for water to enter the launching mechanism. The position of the hopper is on the very top of the machine, making it difficult to reach to for smaller dogs.

The 2016 MQP took a different approach in their hopper and feeder system. Their hopper was composed of several 3D printed tubes and a 180-degree servo motor. The ball is funneled through the 3D printed tubes and waits in the tube until the servomotor rotates 135 degrees to isolate one ball. If the sensor detects an obstruction, the obstruction being the ball, then the servomotor will rotate another 90 degree to dispense the ball into the launcher. Since the hopper tube is curved, it allows for multiple balls, preventing balls from continuously flooding into the launcher. The hopper is placed at the rear of the machine, forcing the dog to place the ball in a small vertical hole in the back. Depictions of both the 2015 and 2016 MQP team's internal mechanism can be seen in Figure 1.

While both MQP teams took very different approaches, they ultimately accomplished the task of feeding the ball into the launcher. There are however, flaws to both hopper systems. The 2015 team decided to simply use a flexible tube to funnel the tennis ball into position from directly above the launcher. This means that liquids and debris can enter the hopper directly into the launching mechanism, leading to malfunctions. The hopper position at the very top of the machine also makes loading the ball very difficult for smaller dogs considering the height of the FIDO machine. The 2016 team decided to use a servomotor and sensor to feed balls into the launcher one at a time, which is a much safer method than the previous team. A drawback to this hopper design is the vertically mounted hole in the rear for loading the ball. It is very difficult for a dog to insert a ball compared to simply dropping the ball into the hopper. This small vertical hole does have some benefits as it minimizes water and debris from entering the machine.

One of the top competitors, GoDogGo has utilized a special type of bucket for easy drop and return of the ball. This basket-like structure funnels the ball into a path, allowing the device to hold multiple balls at once. This could be an advantage since it does not need to be refilled constantly and provide extra balls in case a ball is lost. It is designed with an automatic sensor/safety switch for the dog's safety so it will not harm the dog upon launch. The iFetch has a funnel-like frame that allows the dog to dispense the ball into the funnel. From there the ball travels into the chute and prepares for launch.

Previous Elevation/Angle of Launcher Designs

The 2015 MQP team used a three bar linkage system with a sliding joint. The launcher is mounted on the top bar and the sliding joint is controlled by a thread bar and threaded nut. A motor is used to rotate the threaded bar through the nut that is connected to the linkage system. This "slides" the joint adjusting the angle of launch for the mounted launcher. This elevation system allows launch angles between 15 to 45 degrees. This method creates a lot of noise and wastes energy from the constant friction between the nut and threaded bar. This method also took several minutes to adjust across the entire spectrum of angles.

The 2016 MQP team used a much simpler model in their angle adjuster. The launcher is connected to a PVC pipe angled at 22 degrees. The launcher itself is also angled at 22 degrees such that the firing angle is parallel to the horizontal surface. This angled firing nozzle can be rotated 360 degrees, meaning that the range of angles is 0 to around 45 degrees. This also means that any angle between 0 and 45 degrees obligates the ball to travel either left or right of the machine's front. Making the launching nozzle angled also means that some launching power is lost when the ball bounces in the angled launcher, limiting the potential range of the ball.

Both MQP groups used very different and unique elevation designs. The 2015 team's elevation adjuster was entirely mechanized and can be adjusted by the consumer. This design however made the changing of angles very noisy and long to complete. Energy is also wasted in this nut and screw slider that has very little mechanical advantage. The 2016 team used a manually rotated nozzle to adjust angles. Energy is lost when the ball is fired at an angled surface, which limits the launching power. It is also inconvenient to clients that any angle that is not 0 or 45 will force the ball left or right of the machine. The 2016 team also had the plan to balance the launcher on a "see-saw" and have that be mechanically adjusted using a motor mounted at its center of mass. This has great mechanical advantage and has huge potential in the FIDO design.

For the iFetch, the product is set at an approximately 22-degree angle in order to form a conical shape. This angle is relative to the plane upon which the device sits on. The GoDogGo has a pivoting platform that the user is able to adjust so the angle the ball is launched is between 20-45 degrees. The ball launching is controlled by pivoting this platform which adjusts the angle. The user can adjust the angle by turning or sliding the adjustment knobs external to the device's housing.

Previous Team's Programming

Both the 2015 and 2016 MQP team chose to use a Raspberry Pi as a means to run their code. Both teams' code reflects the method implemented as a means to launch a tennis ball. An important feature utilized by the previous MQP groups is a method of interrupts in their code. The main purpose of these interrupts is to allow for safe interaction between the dog and the device. By using a sensor, if the FIDO device detects an object (usually a dog) in front of the shooter it will suspend shooting operation until the object is no longer in the ball's path.

Both MQP teams were satisfied with the Raspberry Pi board. It has ample pins to accommodate a multitude of subsystems. Additionally the large libraries for Python as well as other code resources make the Raspberry Pi an attractive choice for the team to continue using in their project. The team decided to continue to use the Raspberry Pi as it was a convenient and capable computer for the system. The team paired this computer with a conventional breadboard and opted to use this instead of a custom solder motherboard as there were disadvantages to using a PCB board at this stage of the design process. The main barriers being a high upfront design cost as well as lack of versatility that a custom board provides making custom board design not viable until the unit is closer to a mass production stage.

Previous Power System Designs

The 2015 MQP initially discussed having their battery charge outside the main unit; however, in the end they settled on having the battery charge from within the unit for convenience. The battery chosen was a lithium ion drill battery. The advantages to these batteries include having a large power capacity and an even release of power over time. Unfortunately, lithium ion batteries also come with some inherent drawbacks. They are sensitive to power spikes and overheating which can lead to catastrophic failure of the battery. The 2015 team weighed the pros and cons and found that simplicity, cost effectiveness, and 3 amp hours of battery life to be sufficient advantages. The team decided to use an IFC 320 C6 connector to connect the plug from the outlet to the power input of their device. These connectors are commonly found on computer power supplies and laptop-charging blocks (technically still power supplies).

FIDO 2016 also used a lithium battery and IFC 320 C6 connector in their project, but their circuit configuration posed a problem. The Raspberry Pi would turn on using the lithium battery's power but would only last a couple of moments before shutting down. Their teams decided to include a 6 V battery pack to the machine that fixed the problem.

The iFetch can be powered by multiple sources. It has a built in AC power system that can be recharged to continue powering the machine. The machine can also use six 1.5 V C cell batteries. The batteries not only power the iFetch but also help balance the machine by adding weight to the bottom of the machine. The extra weight at the bottom makes the machine less prone to tip over if the dog gets over excited. As well as the batteries and AC power system, the iFetch can be powered by solar power. Like iFetch, GoDogGo can also be powered by multiple power sources. GoDogGo can be powered by six D cell batteries, a small lithium battery or solar power.

Previous Electronic Hardware

FIDO project 2015 and 2016 had a few things in common electronics in their machines. Both projects used a Raspberry Pi to operate their systems. They also used sensors to detect if there was anything in harm's way of the launcher. As well as sensors, the teams used switches to connect the power to the systems in the machine. The Raspberry Pi is an excellent computer to use for the FIDO project and the team continued to use this board because of its reliability, compatibility, and plentiful online resources.

iFetch uses multiple sensors and switches to operate their product. Once the dog or owner sends a ball into the machine, sensors activate the power to the motors in the iFetch. Once another sensor determines the ball has been shot out, the motor will power down. This feature saves battery so that the motors are not running if not needed.

GoDogGo also uses multiple sensors and switches in their design. When a ball is inserted to the machine, a switch sends a signal to rotate a shaft for a pre-designated period of time. This causes the machine to wait a pre-designated time before launching the ball. A distance sensor in front of the launcher can detect if there is a presence in harm's way of the ball. If the motion sensor detects something blocking the launch path, the motor's power is switched off. After a certain period of time, the motion sensor will scan again and if the coast is clear, it will launch the waiting ball. The team incorporated these features into the design by using a push switch to determine that a ball has been deposited into the hopper and using this signal to tell the program to power the motor for a specific amount of time. However, before releasing the ball into the launcher, the computer checks for obstruction using a distance sensor. This program process is a safety feature and the most efficient method the team could devise taking into account the previous team's program and existing product's design.

Previous Housing Designs

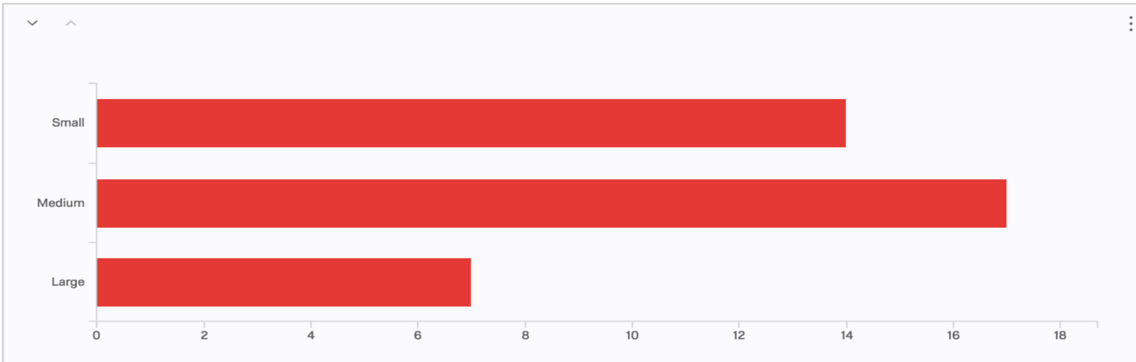
The previous 2015 FIDO MQP group used a strong 3-D printed plastic housing that protects the internal mechanisms from harsh environments. They made sure that the exterior casting was durable and resistant to bite and claw marks. The shell for the 2015 team was made out of a prototyping method called stereolithography. This prototyping method is used for creating 3-D objects in which a computer controlled laser beam builds up the structure from a liquid polymer that hardens on contact with laser light. Their housing was rather large and extremely heavy, making portability a major issue. The 2016 FIDO MQP's housing consisted of a plywood and Plexiglas octagonal construction that had a height of 14.5 inches and base width of 22 inches. The side panels alternated between acrylic Plexiglas and birch wood to allow the consumer to see the inside mechanics. This method, however, made the entertainment center bulky and unnecessarily heavy. The weight of the whole unit was approximately 35 pounds and had a large amount of unused space within the housing.

The two competitors on the market currently, GoDogGo and iFetch have molded plastic housing that covers the electronics and mechanisms of the device. The iFetch housing includes a base that is flat to allow the placement of the device to be mounted. The conical outer shell covers the internal components and provides support for the launch funnel. The outer housing and funnel are made out of thermoplastic polymers such as polycarbonate, ceramics, rubber foam and other injection-molded plastics. The benefits of this molded plastic housing is that it allows a certain degree of water resistance and durability. The GoDogGo also sports detachable hoppers of different sizes for the larger and smaller dogs. This feature makes this product highly adaptable and marketable for all types of dog owners.

Target Consumer Survey

The MQP team created a survey on Qualtrics in order to collect data about potential customer's interests for an automatic dog fetcher system. By utilizing this survey, the team was able to gather information from the consumer's point of view. Since the team only distributed the survey within the WPI community, there will be a bias limited within college students who may just have a family dog. This only covers students between the ages 18-24, but the ideal target consumers are dog owners that are older and more likely to work during the day.

Q3 - What is the size of your dog?   Page Options



#	Field		Choice Count
1	Small	36.84%	14
2	Medium	44.74%	17
3	Large	18.42%	7

Figure 4: FIDO Qualtrics Survey Question 3

One of the questions included approximations for the weight and age of the dog in order to capture the most common size for dogs. This helped the team determine an appropriate size dog for the dog entertainment centers so that the team was able gear it towards consumers. By reviewing the data below, the team found that most owners have dogs that fall in between the small and medium category. Because of this data, the team had limited the total high to 2 feet so that smaller dogs can reach the hopper to return the ball. The material of the housing has to be strong enough to support larger dogs and heavy enough to not tip over and shift for safety purposes.

#	Field		Choice Count
1	Ball	67.57%	25
2	Frisbee	13.51%	5
3	Stick	10.81%	4
4	Other Option	27.03%	10

Figure 5: FIDO Qualtrics Survey Question 6

The survey also asked what their dog's favorite item to fetch, giving them a selection of options to choose from as shown in the image below. The majority of the responses from the survey voted that most of their dogs preferred to fetch a ball. This supports the team initial plan to uses the standard tennis ball, which is both convenient for design and inexpensive to the consumer to replace.

Q9 - Which features of a dog entertainment center would be of interest to you? (10 being the best)

Field	Minimum	Maximum	Mean	Std Deviation	Variance
Doggie Treat Reward System	1.00	10.00	6.24	2.60	6.78
Adjustable range and angles	2.00	10.00	6.03	2.48	6.14
Portability	2.00	10.00	6.28	2.42	5.87
Safety Features	0.00	10.00	8.16	2.41	5.81
Be able to record your voice	0.00	10.00	5.75	3.77	14.19

Figure 6: FIDO Qualtrics Survey Question 9

Another important aspect the team considered was the features that would be of most importance to the consumer. As shown in figure 6, the feature that ranked the most important was safety features. This shows that people care about the safety and wellbeing of their dogs therefore making safety features one of the priorities. The team incorporated distance sensors into the design to prevent the ball from launching if the dog or any presence obstructs the launcher.

3-Procedure/Design Process

At the beginning of the project, the team started with extensive research on the two previous MQP designs and existing competitors' products. The team has taken advantage of previous project's success, but has also noted their mistakes to avoid. To analyze the components side by side, the resulting analysis is broken up into the following sections: Launcher, hopper system, elevation/angle of launcher, programming, power system and electronics, and housing.

These major subsystems would ultimately be the basis in how the team split up responsibilities and tasks for the term. The team has brainstormed various designs for each subsystem that are simple yet effective.

Preliminary Constraints

The team proposed constraints and goals for the design after analyzing the MQP designs and products in the background.

- Design must minimize risk of harm to dog and children
- System must be available for use indoors and outdoors
- System must be water resistant
- System must not exceed 20” by 20” in width and depth
- System must not exceed 24 inches in total height
- System must be under 30 pounds or 13.6 kilograms
- Ball must travel within 2 seconds between the hopper and launcher
- System must launch tennis ball of a minimum of 15 feet
- The system must be able to launch standard size tennis balls
- Bill of Material (BOM) must not exceed $200 for product manufacturing

Launcher Design

The launcher is a crucial component that determines the velocity and distance the ball will be launched. The aspects that were prioritized were the energy transferred from the motor to the ball, and the time it takes to launch the ball. In order to determine the best possible method, the team created two initial designs for the launcher. The best design of the two was determined by weighing the advantages and disadvantages of each design.

Design number one utilizes a spring to store energy and releases the energy to launch the ball as shown the in design Figure 7. This design starts with the motor turning a worm gear that then turns a cam system. The worm gear's importance is that it prevents the motor from backtracking under load. The cam system turns an arm bar clockwise that keeps the spring under tension. When the end of the cam is reached, the arm bar is released and contacts the ball at extreme force. This design is impressive in that it contains many concepts such as gears, cams, springs and linkages. The disadvantage to such a design is its complexity and its low efficiency since energy is transferred through a lot of moving parts. There is friction between each contact, making a simpler design more efficient. Design number one, however, is relatively space efficient as these parts can be compacted into a smaller volume.

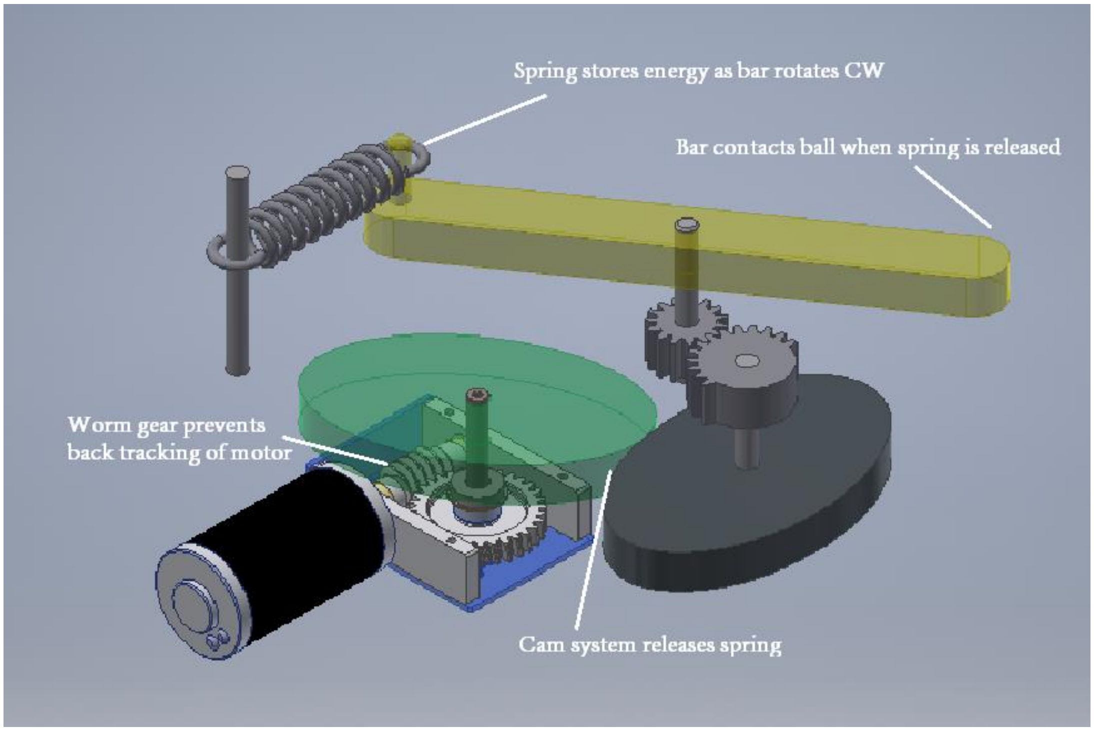


Figure 7: Launcher Design 1

Design number two uses a rotary wheel to launch the tennis ball but also utilizes an upwards spin to take advantage of Magnus force. As defined by Richard Fitzpatrick of the University of Texas, the Magnus force occurs “when the unequal drag forces acting on the ball's upper and lower surfaces are added together there is a component of the resultant force acting *upwards*. The team utilizes this force to give an upwards boost to the tennis ball. As shown in figure 8, a motor will turn a wheel at high RPM and one the wheel gets to speed, the ball will be inserted at the bottom of the launcher. The ball will be accelerated by the wheel along the arched path giving the ball and upwards spin once it launches at the top of the rotary wheel. This design is very similar to baseball pitching machines used by baseball teams to simulate a fastball as shown in Figure 9. The 2016 MQP team used a similar concept with two wheels, but by utilizing one wheel, the team takes advantage of Magnus force. The backspin gives a Magnus force applied perpendicular to the spin of the ball, which allows the ball to experience an upwards force as it travel through the air. This is advantageous to the team’s design because it allows the tennis ball to travel higher at the same velocity if there were no backspin applied to the ball.

Another advantage to this design is the angular momentum of the rotary wheel. The momentum generated by the wheel allows the motor to uses less power to get to speed before launching the ball. The rotary wheel is expected to spin at an idle speed between launches and accelerate to launching speed when ready. Because the wheel is not static, it will not take as much energy between launch cycles. A disadvantage to design number two is the bulkiness and volume that it requires since it contains large pipes and a large rotary wheels. A spinning wheel may also generate a lot of vibration and unwanted noise.

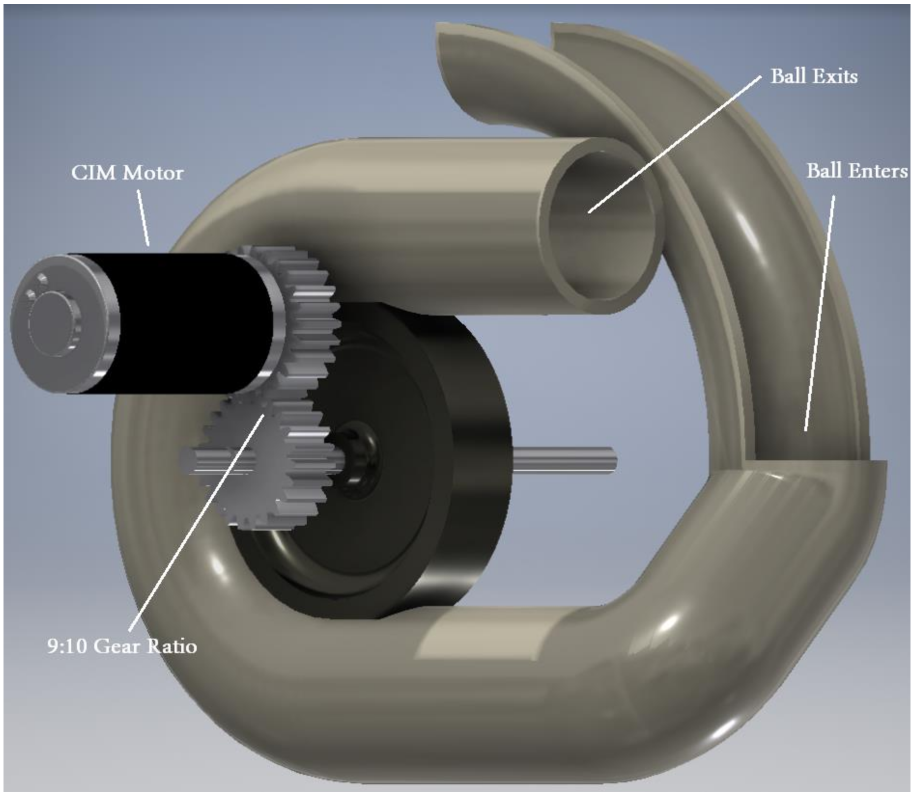


Figure 8: Launcher Design 2

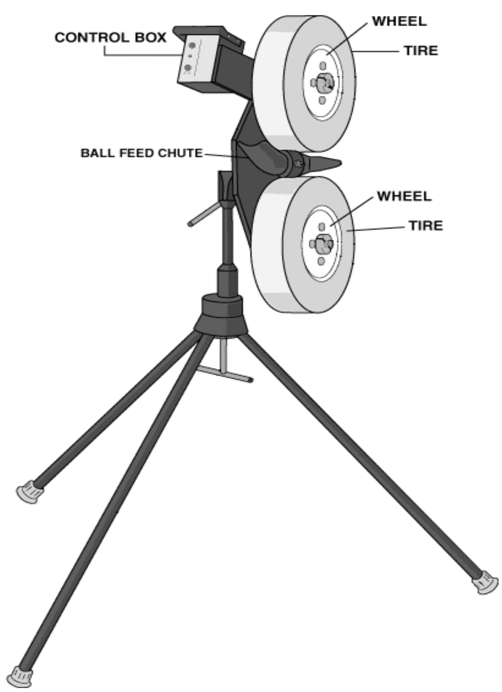


Figure 9: Baseball Pitching Machine Design

Decision Matrix for the Launcher

	Design #1 (Spring)	**Design #2 (Rotary)**
Innovative/unique	3	2
Size and weight	2	2
Vibration/Noise	2	2
Feasibility	2	3
Cost	2	2
Durability	2	3
Rate of Fire	2	3
Total	**15**	**17** *Based on a 1-3 scale

Table 1: Decision Matrix for Launcher Design

After analyzing the advantages and disadvantages of the design through a decision matrix, the team decided that design number two is a better design for the project. The design number one is was more innovative as it included a lot of concept and was unique compared to existing products, but its complexity was also a disadvantage. The excessive moving parts meant that there was more opportunity for wear and tear of the machine. Because of this, the durability section was won by design number two. The rotary design also had a superior rate of fire since the rotational inertia of the wheel meant that it required a lower time between launch. Because of these advantages, the team decided to use the rotary wheel launcher for the final design.

After choosing design number two, the team improved the design by using a rail system to accelerate the ball instead of using a tube. As shown in the figure 10, the same concept is used, but the ball will travel on specifically designed rails that give the ball a much better backspin.

There are several advantages to a rail system, such as a greater spin which relies on the distance between the rails, and also the ability to laser cut the assembly instead of creating tubes of the exact dimensions. Laser cutting the components would but a much easier process for both the design process and also the manufacturing process.

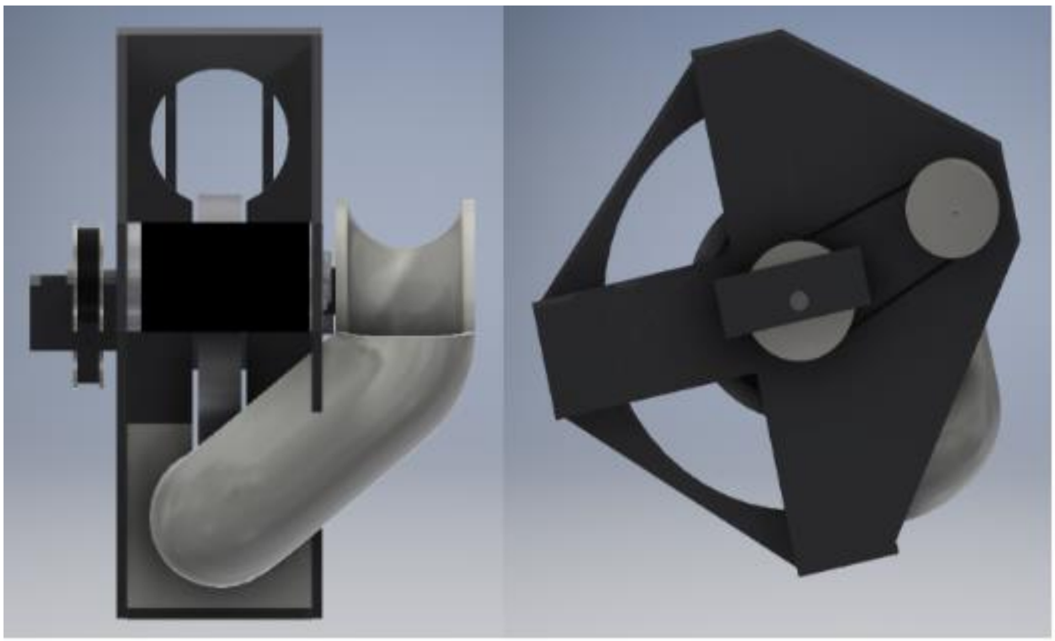


Figure 10: Rail Launcher Design

Power calculations, in the appendix, were completed to determine the torque and power necessary for the motor to drive the rotary wheel. It was determined that 2.354 Nm of torque is required of the motor, which is well within the capabilities of a standard CIM motor. It was determined that the time it takes after launching a ball to get back to launching speed was less than second. This fast rate of fire is ultimately unnecessary because the rate of fire will be limited by the time it takes the dog to retrieve the ball and the speed of the hopper system, but does highlight the efficiency of this launcher design.

Hopper System Design

The goal and objective of the hopper system is to funnel a ball into a central location in which a sensor and mechanism is in place to load one tennis ball in the ready position for launch. The hopper should also be water resistant to remove the chances of water entering the internal mechanisms to allow for outdoors use. The sorting station is placed after the funnel, but before the launching station since the goal of the sorting station holds balls back while dispensing a single ball at a time. In order to determine the best design for this purpose, the team developed the following two possible designs to consider:

Hopper Design number one is simply a linkage system that translates rotational motion into linear back and forth motion. As shown in figure 11, the mechanism is a four-bar linkage system that includes a slider. A motor rotates the wheel and with each full rotation, the slider travels backwards the distance of the diameter of the wheel and then back into the original position. In its original position, the slider bar blocks the path of the balls and with each full rotation dispenses a single ball in the perpendicular direction of the ball’s entry. A disadvantage of this design is the possibility of balls jamming in this loading configuration.

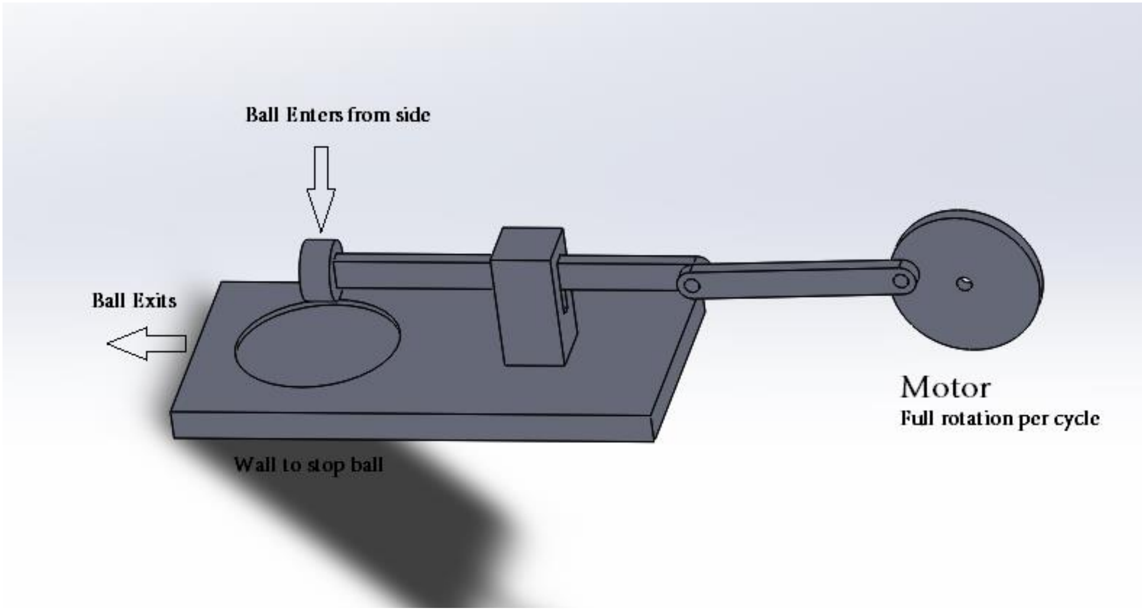


Figure 11: Four-bar Linkage System Design 1

Hopper Design number two, shown in figure 12, uses gravity to load the balls into position and utilizes a rotating mechanism to transfer a single ball into another path to the launcher. All the balls line up vertically in a tube with one ball resting in the 2.7" diameter hole cut into the rotating disk. The disk will rotate a certain degree counter clockwise where a hole is placed so that the single tennis ball is shifted from one pathway to another. The pathway will lead to the launcher, allowing the entertainment center to hold multiple balls and launching them one at a time. The rotating disk will rotate back after dispensing the tennis ball and receive the next single tennis ball in the path pushed by the weight of the tennis ball itself. Because the rotating disk will be the height of a standard tennis ball, only one ball can be moved at a time, making this design improbably to jam unless a different sized ball is used.

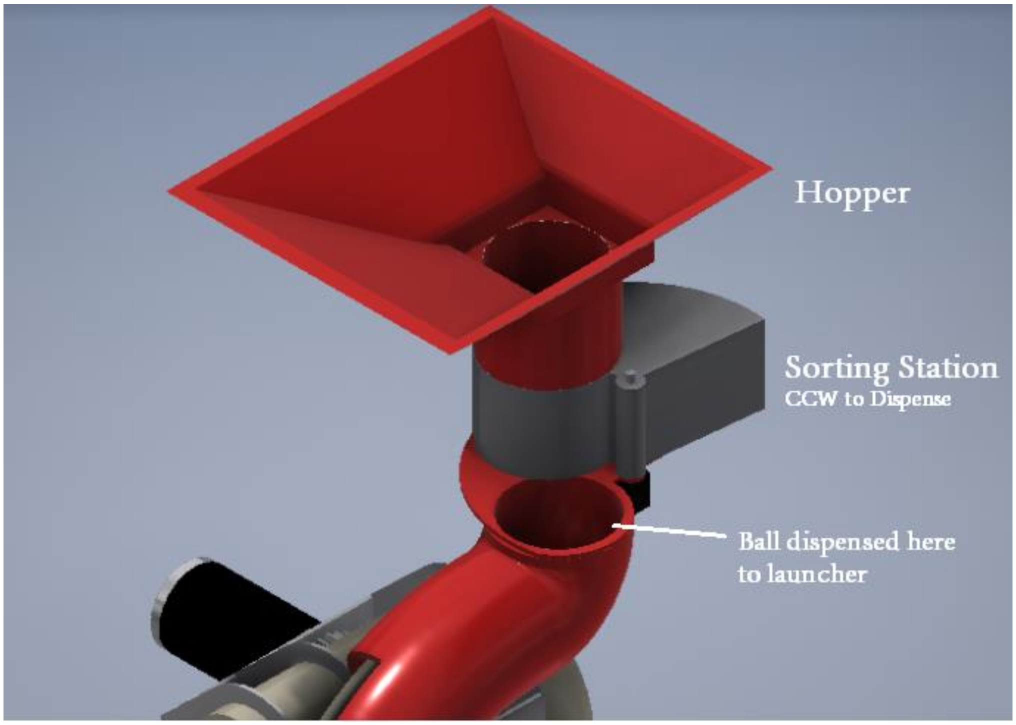


Figure 12: Hopper System Design 2

After considering the potential of the two designs, the team quickly determined that hopper design number two is more suited for the project because the sorting station needs to be completely enclosed and organized. The simplicity and efficiency of design number two was more appealing of the two designs. A major drawback of design one is that it would be more prone to jamming because the balls were more prone to shifting around whereas design number two guarantees a single tight pathway for the ball to travel. The four bar linkage system described as hopper design number one also requires full rotation while design two only requires rotation to a slight degree to deposit the ball. The parts for design number two is expected to mostly be 3D printed and will not need a very powerful motor. A sensor will be necessary to signal that there is a single ball in the rotating disk ready to be transported to the launcher. The entrance and exit pathways of the sorting station are expected to be made of 3D printed material as well. The team is confident that this design is the most efficient and effective method of feeding a single ball at a time.

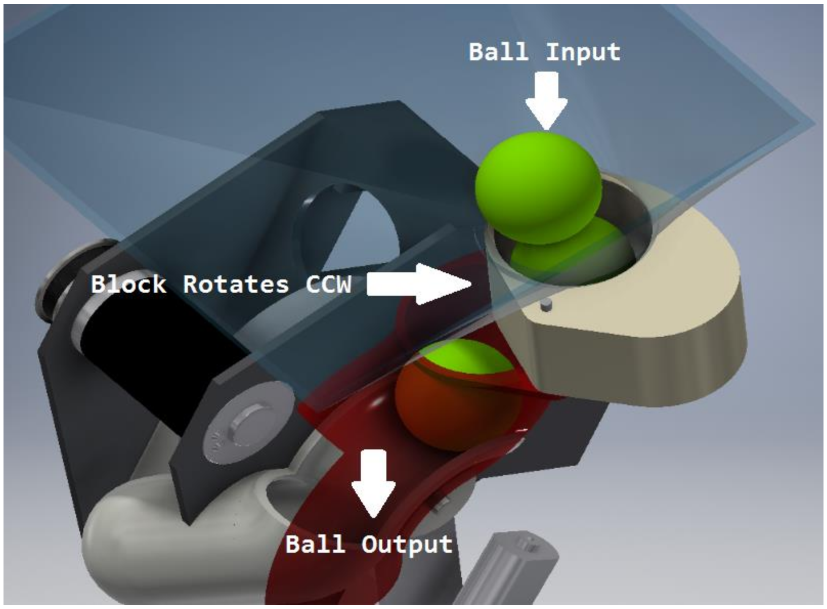


Figure 13: Hopper Demonstration

Elevation/ Angle of Launcher Design

The team felt that angle adjustment could be a feature that separates the product from other existing similar products. Being able to have the launcher randomly change its angles within constraints adds variation to keep the dog engaged. Achieving angle adjustment however presented an interesting challenge. The team devised a design where the launcher will be rotated by a motor on a worm gear that drives a belt attached to the axle holding the shooter. The team chose to use a worm gear for its non-back drivable property. While the plan is to try to have the launcher relatively balanced (possibly by using constant force springs), it is unlikely for the launcher to be perfectly balanced. The worm gear allows us to hold the launcher at a fixed angle without stalling the motor. The team is using a belt drive in order to position the motor lower on the device to increase stability. This concept is shown in figure 14.

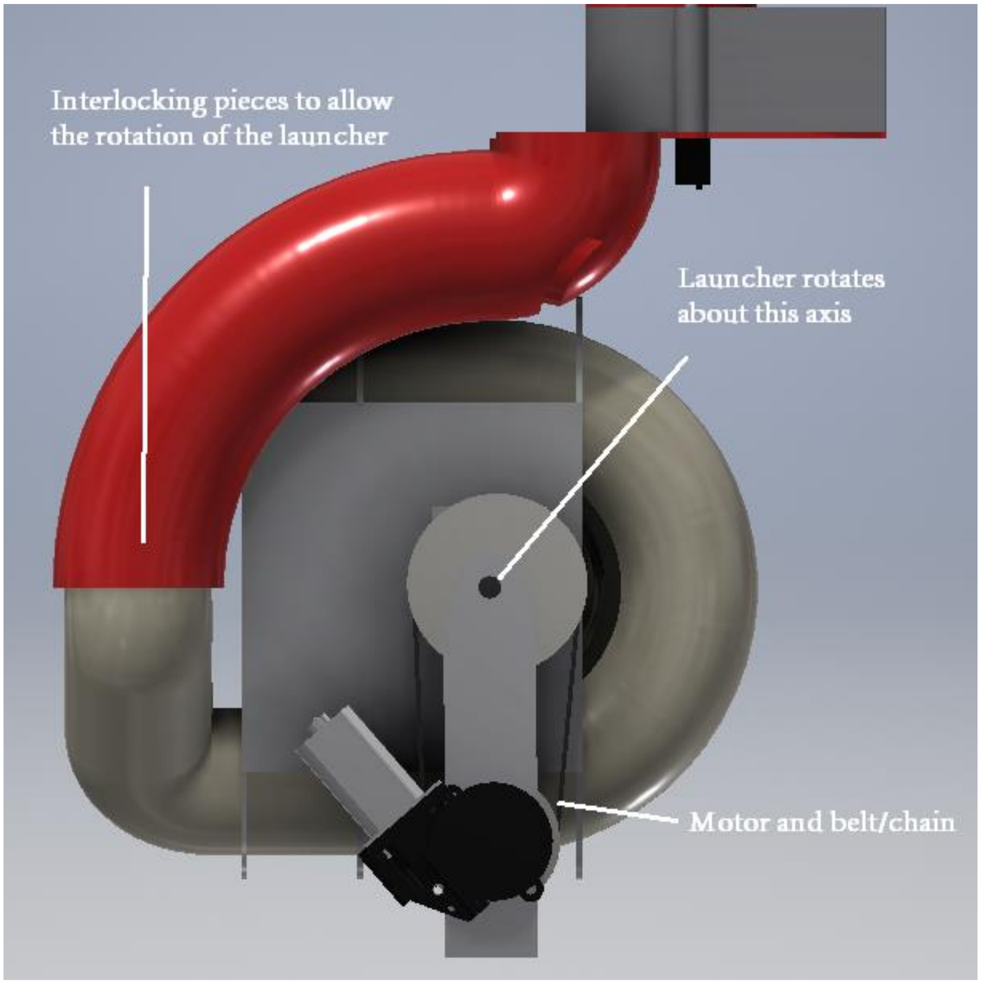


Figure 14: Launcher Angle Rotation Design

Ultimately, a new design for the angle adjuster was created as the previous design was not efficient and has structural risk because of the presence of a cantilever beam. The new design, while still using the same concept, is to fix a chain sprocket onto the launcher independent of the main shaft and fix the launcher to the housing frame via a chain. This is shown in figure 15. There will be a motor mounted to the chain that incorporates a worm gear so that the motor is not back drivable. This fixes the launcher into place and allows the mechanized adjustment of the angle of launch. This system does not require a tensioner because the chain length depends on exactly the amount of link necessary and can be adjusted using a chain breaker. This design save a lot of space and allows for a much simpler housing frame design. More importantly, using a chain and sprocket is a much more rigid and reliable design than the previous concept.

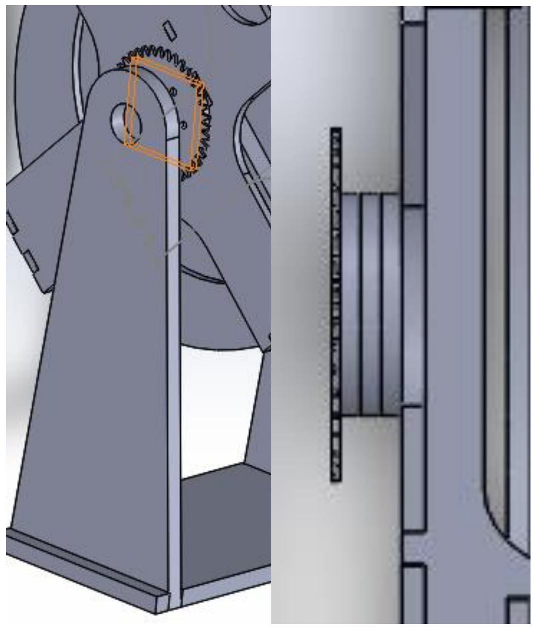


Figure 15: Angle Adjuster Design

Programming/ Electrical and Power Systems Design

The FIDO systems from the 2015 and 2016 teams both utilized a Raspberry Pi to run a code that would launch a tennis ball. The teams used interrupts in their code that allowed for safe interaction between the dog and device. The team used Raspberry Pi for their system since it has various pins to accommodate multiple subsystems and is Python user-friendly. The team used distance sensors with the Raspberry Pi to detect if an object or dog is in the ball's path. By measuring the distance between the sensor and the obstruction, the team can program the computer in such a way that the ball will not be launched when something is within a certain distance from the launcher. It can run on 5V-12V power which makes it a reasonable choice for a sensor since the system uses a 12 volt source.

A 12 volt drill battery is used to power the system since these cordless power tool batteries are reusable, portable and generally reliable. The team will be using various types of motors for the system. A 12 V CIM motor is used for the launcher since it is known to frequently be used on competitive robots in FIRST Robotics tournaments. A VEX voltage controller is used between the power source and the motor so that the power output can be regulated using the raspberry pi.

A servomotor is used for the feeding system because it gives precise movement under 180 degree. Other advantages include it being small, having large torque, internal control circuit, quiet at high speeds and high efficiency. It is a suitable motor coupled to a sensor for position feedback to the user. Servomotors are a higher performance alternative to other motors like the stepper motor since they operate in a closed loop rather than open loop. These motors can also operate in various different ranges.

The team used a motor already on the worm gear for angle adjustment because the worm gear is non-back drivable. This means that the system is not stalling the motor every time the shooter is in a position. The force of the motor will be on the teeth of the gear and held in place by the worm gear. This motor is used as part of a chain and sprocket system that will rotate the entire launcher and is definitely powerful enough to move the already well-balanced launcher with little torque necessary.

Housing Design

The FIDO system has to protect the electronic and mechanisms from weather, children and dogs. The housing of the project needs to be durable to withstand rain, winds, dirt, debris and other animals. The machine will need to be stable enough not to be tipped over or shifted because of obvious safety and mechanical reasons. The team considered all these conditions when deciding on housing design for FIDO 3.0.

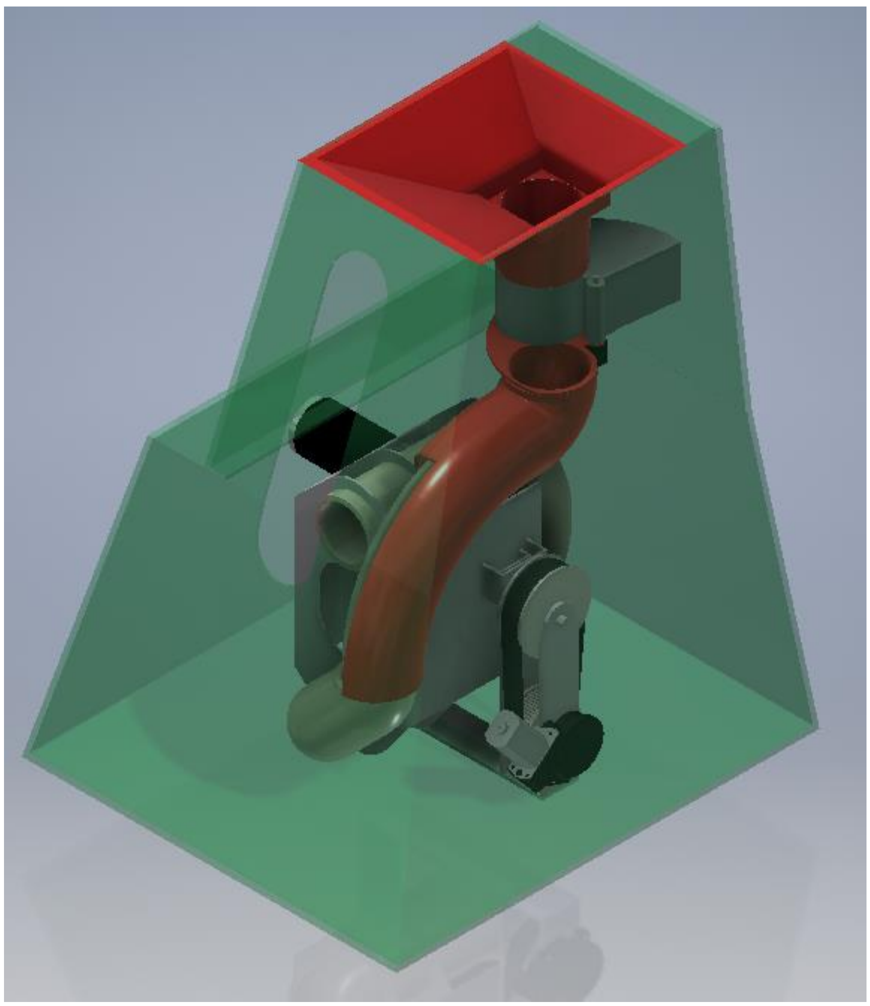


Figure 16: Housing Design

The team decided that the most practical approach to creating such a large housing structure is to laser cut panels and build the housing using finger joints. A rectangular housing that tapers on the top allows the design to efficiently conserve space and is practical when making adjustments to the design. The material of the housing must be rigid and structurally robust to be able to handle normal use. Because the housing must contain the entire weight of all the subsystems, an economic but reliable material for this application is a wood fiber composite, or Medium Density Fiber boards to be specific. The team decided to use this material above other materials such as acrylic because it was a much cheaper alternative without sacrificing and durability.

4-Construction, Assembly and Testing

In order to construct the device, the team incorporated various methods of fabrication, primarily milling and 3D Printing. Several team members became advanced users in order to use the unguarded machine tools. This advanced status gave the team access to the labs during after hours, allowing the team to work effectively throughout the fabrication stage. Several design changes were required as the product development progressed and the reasons behind each change will be described within the sections. The fabrication process is again split up into subsystem categories for consistency.

Final Design

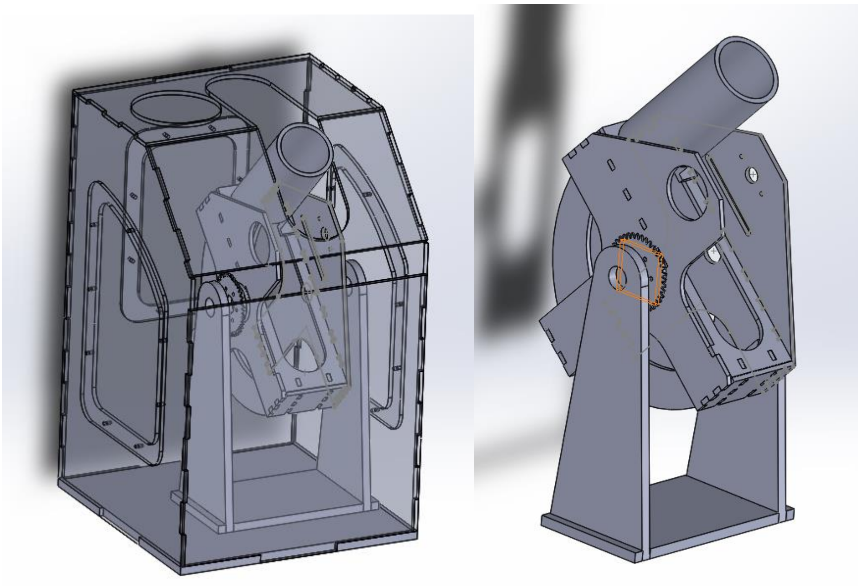


Figure 17: Final CAD of FIDO 3.0 System

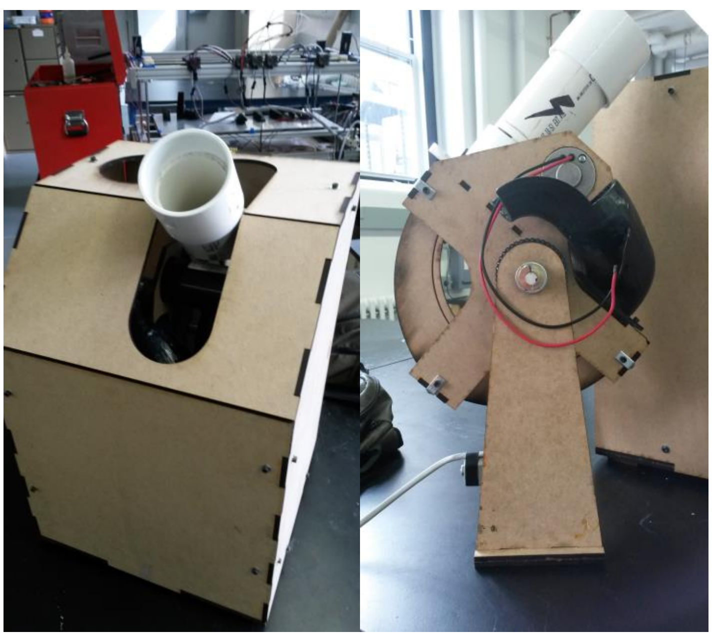


Figure 18: Actual FIDO System

Launcher

As described the design process, the team designed a launcher that accelerates the ball along a semicircular path to not only increase speed, but also create a backspin on the ball utilizing the Magnus force as an advantage. The launcher has several components that required a range of machinery to fabricate. The frame of the housing and rails were cut from Medium Density Fiber using a laser cutter. The wheel, which needed to have both mass and balance, was machined in the CNC mill. The lathe was used to create the rod tensioner for the drive train belt. All of these components are designed to fit together to create the launcher subsystem.

A 6-inch diameter disk of mild steel was used for the flywheel and milled on a HAAS XYZ CNC machine. Despite its relatively simple design, the wheel proved difficult to mill. It was difficult to clamp down because of the stock's circular profile. In order to successfully mill the wheel, two arcs matching the radius of the wheel were cut into aluminum clamps. These soft jaws would hold the circular piece of steel in place while the end mill smoothed out the edges and creates the shaft bore. The soft jaws were created using Esprit and then converted into NC code so that the MiniMill would read and complete the task. Once the soft jaws that held the cylindrical piece of mild steel was created, the wheel itself could be machined. Both sides of the wheel were machined so there were two separate operations which both slightly faced the surface area of the part in order to smooth out any inconsistencies.

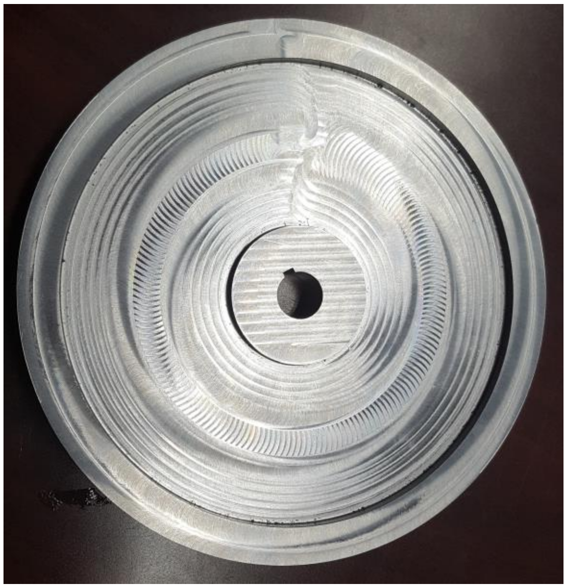


Figure 19: Machined and Keyed Wheel for Launcher System

After successfully milling out the wheel, the team then used a 1/8th inch broaching tool and the arbor press to create a keyhole in the center of the wheel. This allows the wheel to stay fixed to the keyed shaft during operations. The wheel is fixed axially using half-inch shaft collars, which also keeps the key within the keyed slot from slipping out. From initial tests, the team found the milled wheel to be much to smooth and precise and thus the ball kept slipping within the launcher. This created too much Magnus force resulting in vertical and even backward launches. To fix this issue, the team inverted a tooth belt and adhered it to the edge of the wheel created a toothed wheel with much more grip and even gave greater compression on the tennis ball. This improved the launch of the tennis ball significantly.

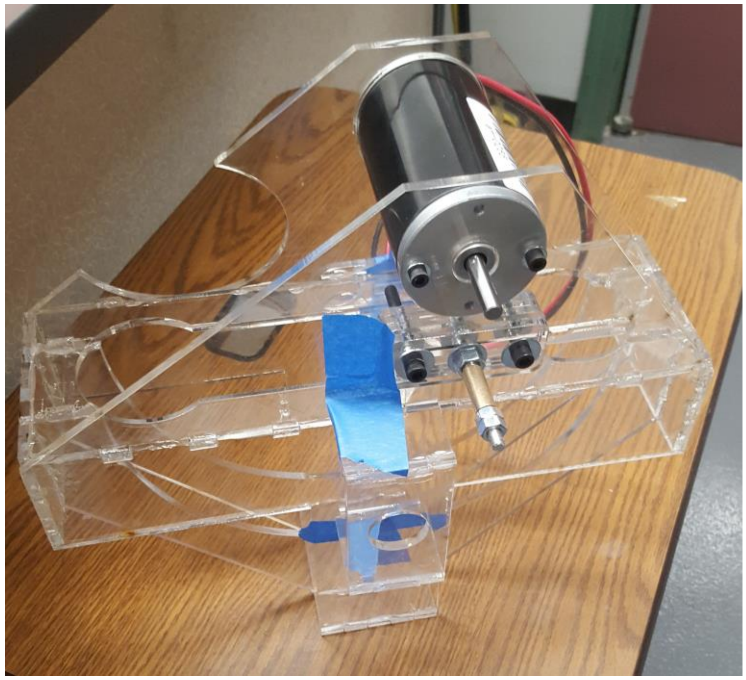


Figure 20: Acrylic Launcher Frame

The team used originally used acrylic panels to laser cut parts for the launcher. In order to accomplish this, the team designed the launcher frame on AutoCAD and then imported this file into a .DWG to work with the laser-cutting machine. One of the main challenges of working with acrylic was that it was not easily machined. This made it very difficult for the team to edit or modify any changes to the part once it was laser cut. During the early stages of the construction, the launcher had to be recut three times before all the parameters were correct. This was because the launcher frame is the center of the system and is the bridge that connects the majority of the components which is why it needed to be very precise. Ultimately the team decided to switch over to MDF board as it was as sturdy as acrylic but less likely to fail due to the vibration of the system.

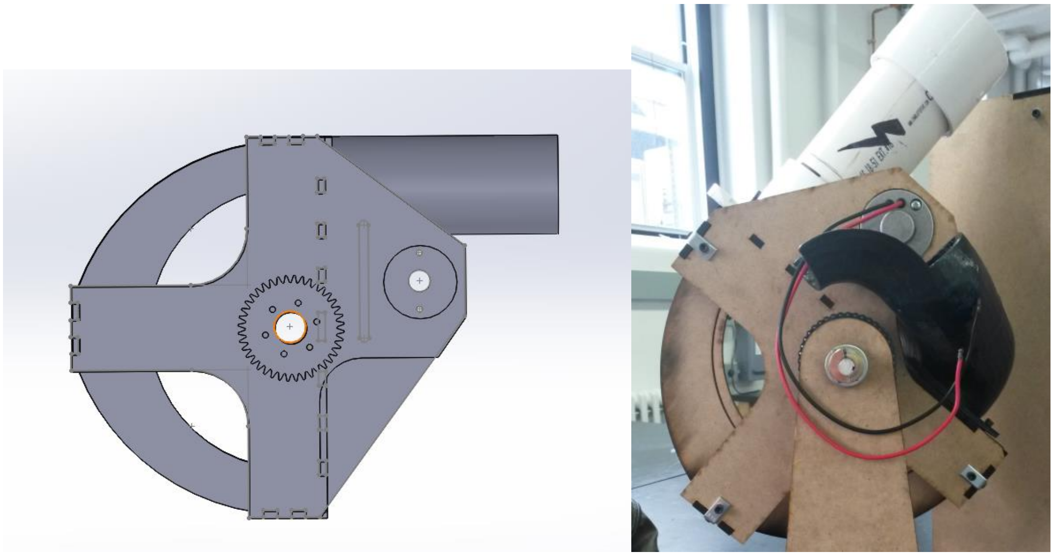


Figure 21: MDF Launcher

Replacing the acrylic frame with Medium Density Fiber (MDF) boards was a game changer to the structure and construction process of the launcher, frame and housing. The material was much easier to cut and only needed a single pass at 3 to 4 percent cutting speed. The ability to machine after laser cutting also saved a lot of material because the team were able to drill holes and create codifications to the panels. With acrylic, sanding and epoxy was necessary for assembly, which was messy, time-consuming, and permanent. MDF allowed the team to bolt panels for assembly and was easy to disassemble in case of any modifications.

For the main shaft of the launcher, a 12-inch long, ½-inch diameter keyed shaft was ordered with ⅛ inch key slots. To prevent axial movement of the launcher frame and wheel relative to the housing frame, ½-inch inner diameter shaft collars were purchased. ½ inch Bearings with raised edges were used to allow the shaft to free rotate in the housing frame. With the axial clearances and components completed, the team focused on the power drive train. A 24 tooth and 16 tooth drive train pulley was purchased to transfer rotational power from the CIM motor to the main shaft. Because the CIM motor output shaft diameter was .313 inches, an adapter was purchased to fit the sprocket's standard ½-inch bore. After a miscalculation on belt size, the correct belt size with the correct pitch length was purchased that just fit the sprockets.

A tensioner was fabricated to fit the specific needs since it was not readily available for purchase. The design was a rod with a sleeve bearing that is mounted in a slot to the side of the launcher frame with bolts and acrylic brackets that disperses the load of the tensioner. Using a 5/16" aluminum rod was turned down to ¼-inch diameter on the lathe to accept the "oil impregnated bronze bearing sleeve". The ends were threaded and nuts compressed the tensioner into place. This was an effective tensioner because it was adjustable and easy to remove.

Figure 22: Drive Train with Tensioner

The assembly of all launcher components fit with ease and even held with friction fit alone. L brackets were bolted and the launcher frame, wheel and shaft were assembled. Spacers and shaft collars held all the components in place and the axial clearance between components were all satisfactory. When testing the CIM motor in the launcher, the team had no trouble with the transfer of power from the CIM motor shaft to the main shaft via the drive train.

Hopper System

The team used the MakerBot Replicator 2X in the Washburn labs to 3D print the hopper tubes. It was originally planned to print two parts of the tube together as shown below. However, the print time for both parts would take over 16 hours which would cause complications in the long run. It was also hoped to print out three different aligning pins in order to keep the tube in place with the other part. However, it turned out the pins would be difficult to print. Another factor that made this design difficult to print was the use of PLA which caused the extruder nozzle to clog frequently. The 3D printers in Washburn needed a learning curve since there were many complications with the extruder and print itself. The team learned that often times you could just use the ABS in the shop for free. However, the team ended up purchasing its own since a lot of filament was used and the ABS supply was often low.

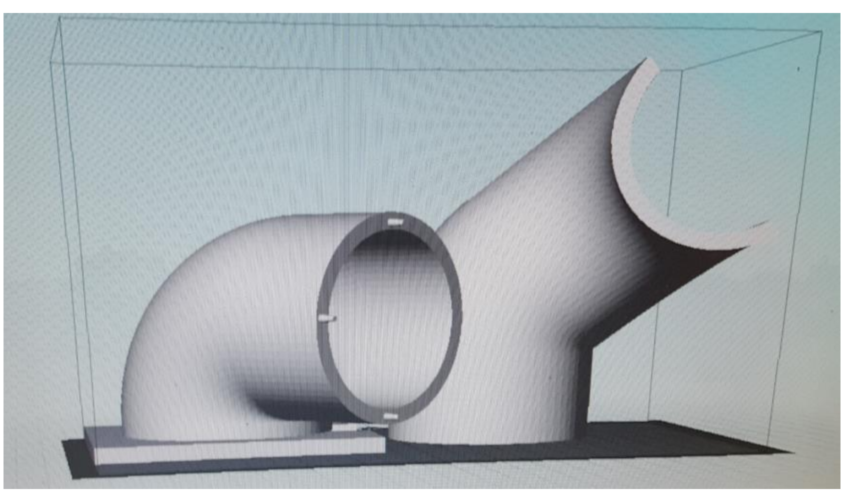


Figure 23: 3D Printer Model of Hopper

Instead of the initial design planned, the team came up with a tongue and groove connector which would act as aligning parts for the tube. Instead of combining the two parts, file was split in two in order to reduce print time. The team used Inventor and converted the file to a .STL file in order to be compatible with the MakerBot. In the end 1.75 mm ABS was used to print the hopper system tubes. The part pictured is the base and will be attached to the frame.

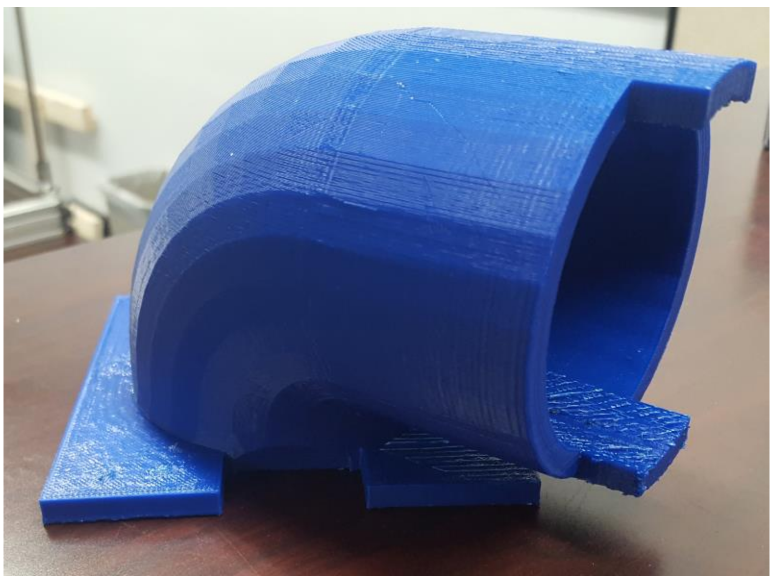


Figure 24: 3D Printed Hopper Base

Due to issues with the 3D printer in Washburn the team was forced to use a different 3D printer to complete the print. A relative of the team was used to finish the 3D prints. Due to slightly different specifications of the new printer as well as problems with print quality the 3D printed parts on the new printer required much sanding and filling. In order to fill many of the gaps between 3D parts the team used a slurry of acetone and abs. This allowed us to “glue” the parts together as well. By repeatedly sanding and then applying the slurry by paintbrush the team was able remove much of the stepping caused by the 3D printing process on the internals of the tubes. Once the parts were assembled, the team found the ball still snag on a few bumps inside the tube which lead to further sanding. After repeated examination of the tube, the team was able to fix all the problem areas.

Three bolts were used to attach the inner tube to the launcher frame. The outer tube is connected to the housing by way of a bracket the team laser cut. This bracket also holds the servomotor used to actuate the block. A funnel sits atop the block attached to the housing. Its purpose is to accept the ball from either a dog or human and direct the ball into the block. A push switch or micro switch is also mounted on the inner wall of the hopper to signal to the control system that there is a ball present in the hopper system ready for deployment.

Elevation/Angle of Launcher

As described in the design process, the angle of elevation system will compose of a chain sprocket, chain, and non back drivable motor mounted to the housing frame. The specific parts that are purchased is a 40 teeth chain sprocket, #35 chain, snow blower motor that has a built in worm gear internal, 16 tooth chain sprocket adapter for the motor, and its corresponding motor mounting bracket. The purchased 16 tooth sprocket and motor bracket are specific products designed to be coupled with the snow blower motor.

Figure 25: Angle Adjuster Drive Train with Snow Blower Motor

The 40 tooth sprocket is bolted onto the launcher with circular spacers cut from .25 inch MDF and stacked to position the chain sprocket in the correct axial distance. Everything was mounted with the launcher aimed at 45 degrees from the horizontal because the motor shaft is fixed unless powered. The motor bracket mount is mounted onto the housing frame and slots were drilled onto the mounting bolts so that sliding the bracket allowed us to have a minimal tensioning system. This system proved to be very robust and reliable compared to the initial design with minimal effect to the overall design and axial clearance calculations.

Housing and Frame Assembly

The team ultimately decided on MDF as the sole material of its launcher, frame and housing. The wood and glue composite of the Medium Density Fiber allowed the material to retain strength and rigidity but also the flexibility of wood. These properties are crucial because the material must be able to handle the weight of the heavy launcher components yet still be able to withstand the vibrations during operation.

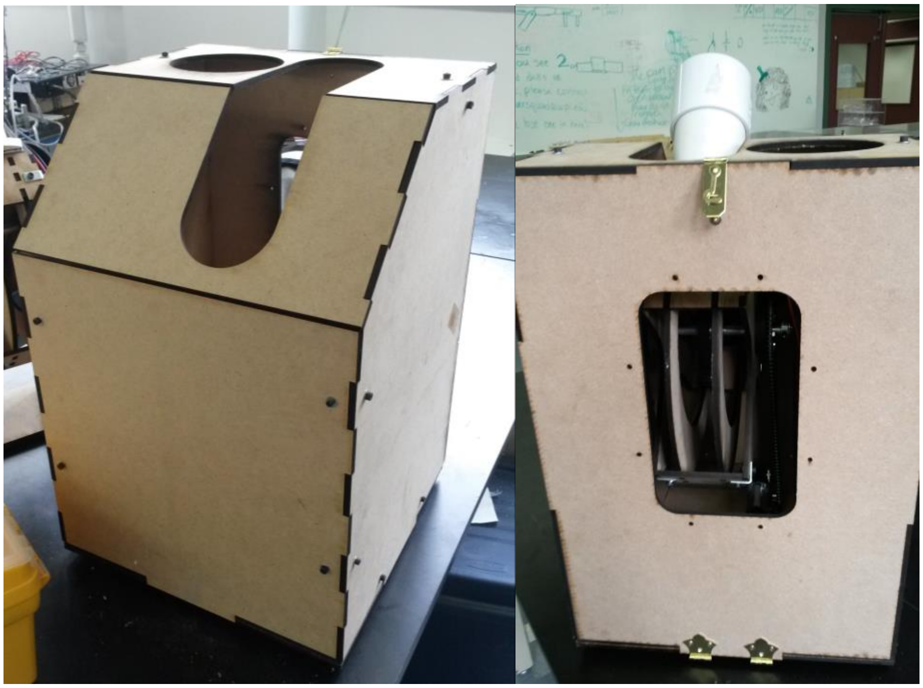


Figure 26: Housing

There are two major constructions that house the subsystems: The housing frame and the outer housing itself. The housing frame is the upright structure to hold up the launcher system, and that frame can be mounted onto the base of the outer housing. The housing frame was create separate of the housing because there was always a possibility of change to either the launcher or the housing, so it was easier to simply bolt the frame to the housing after accounting for all adjustments. The launcher mounted in the frame fits within the housing with minimal clearance to keep space efficient and the general housing profile appealing.

The housing composes of 7 panels, with some large enough to require the entire 18 inch by 24 inch maximum limit of the laser cutter. Base panels are two panels thick for additional support, and this was accomplished by scouring and wood gluing two quarter inch thick MDF together. The top of the housing consists of two panels, one with a 45-degree slant that designates the front of the housing and one with a horizontal panel for the installation of a hopper funnel. A slot for the launcher allows the angle adjuster to move freely and a hole allows for a hopper. Some windows were cut into the side panels to allow the viewing of internal mechanisms with acrylic panes bolted onto the opening. The back panel of the housing is different in that it has much larger interlocking finger joints to allow a hinge. This allows the team to bolt all panels for assembly and still access the internals via the hinged back panel.

Electrical Systems

To power the entire system a 12 V 3 amp hour Milwaukee drill battery and charger was used. The battery was salvaged from the previous FIDO projects. The previous teams modified the drill charger to have a ground and positive lead wires that came out of the charger base to be able to be connected to a breadboard. However, some modifications had to be made to the charger. FIDO 3.0 used larger motors that require more amperage and the current wires were too thin to support so much amperage. The casing from the charger was removed and the old positive and ground wires were removed. Thicker wires were soldered on to replace the thinner wires. The charger is still able to be plug into a two-prong wall plug to recharge itself.

Raspberry Pi

A Raspberry Pi 3 Model B was used to control the electronic system. A Raspberry Pi cobbler was used as a bridge from the Raspberry Pi to the electronics on a breadboard. The Raspberry Pi controls a servomotor, a CIM motor, Victor SP motor controller, an actuator motor, a relay and an ultrasonic sensor.

Servomotor

When a ball is inserted into the hopper, it does not go directly down the tube to be shot out of the system. There is a block preventing the ball from travelling down the tube. A Hi-Tec Deluxe Standard Servo was used to control the block. The motor operates at a five voltages so it does not need any kind of controller for the raspberry pi to control it. The servo has three lead wires that go to ground, to power and one that connects to the Raspberry Pi. The Raspberry Pi controls the servo to move 90 degrees and then reset back to its starting position.

CIM motor.

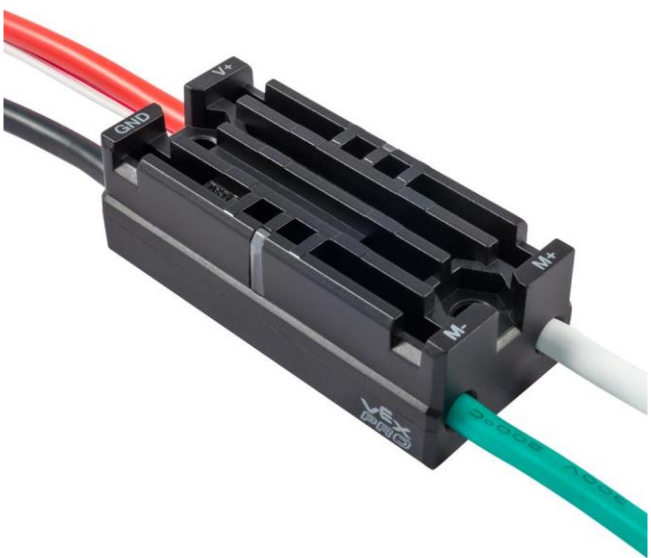


Figure 27: Vex Victor SP

To spin the steel wheel at a high speed, a large and powerful motor was needed. A Controlled Induction Motor, or a CIM motor, was used to control the wheel. This motor operates at twelve volts, which posed a problem because the Raspberry Pi operates at five volts and around twenty amps. A solution to this problem was to bring in a motor controller. A Victor SP motor controller was used as the controller. The Victor SP was circuit between the CIM motor and the Raspberry Pi. In Figure 27, the Victor SP was circuit between the CIM motor and the Raspberry Pi. The green wire is connected to ground of the CIM motor, and the white wire is connected to the power of the CIM motor. The black wire is connected to ground and the red wire is connected to the power of the battery. Not shown in Figure 27 are two lead wires coming out of the Victor SP, which connect to ground and to the Raspberry Pi. The Raspberry communicates with the Victor SP, which in turn communicates to the CIM motor.

Snow blower motor actuator motor

To rotate the entire system to provide a new angle of elevation, an actuator motor is used. The actuator motor will move the entire system to one rotation and then back. The actuator motor also operates at twelves, which means that this motor will need a controller too. A 4-Channel Optic-Isolated Relay was used as the controller for this motor. The five pins on the relay connect to the motor, the Raspberry Pi, power and ground.

Push switch

A couple of push switches are in the system to trigger when the system when something happened. There is a push switch in the hopper, which tell the Raspberry Pi that there is a ball waiting in the hopper, which starts the program to begin its loop of operations. There is also one push switch is triggered when the entire system is moved to its new angle position. This push switch notifies the motor to stop rotating the entire system. There is one at each angle position.

Sensor

An Ultrasonic Range Sensor is used to verify that the path of the ball is clear. This sensor is important because it can prevent injury to the dog or a child who might be standing in front of the machine. The sensor is placed in front of the machine where the ball will be shot out. This senor operates at a 5.0 V but is converted to a 3.3 V to not fry the Raspberry Pi. If the sensor senses a something in the balls path it will either tell the system to not let the ball be dispensed into the tube, or if the ball was already dispensed it will stop the motor.

Power System

A Raspberry Pi is used to control the electronic system. A Raspberry Pi cobbler is to connect to the electronics on a breadboard. The Raspberry Pi controls a servomotor, an ultrasonic sensor, a CIM motor, Victor SP motor controller, a relay and an actuator motor. A Victor SP motor controller is used to control the CIM motor and the relay controls the actuator motor. All these components are circuited together on a breadboard. A 12 V DC Milwaukee battery is used to power the entire system. A Milwaukee drill battery and battery charger was modified so that power output of the battery charger is through 14 gauge wires. To power the system for longer than five minutes, the battery has to be connected to a wall plug.

Program Codes

Servo Motor Code

In order to control the servomotor to dispense a tennis ball the output shaft needed to be control by sending it a python coded signal with a minimum pulse, maximum pulse and repetition rate. As the python coded signals changes, the angular position of the shaft also changes. The team controlled the servo by sending it electrical pulses through Pulse Width Modulation (PWM). The PWM module in the RPi.GPIO was used with a frequency of 50 Hz. The team sent pulses with a specific length by using the duty cycle which is the length over the period. Since the servo expects to see a pulse every 20 ms and the servo usually only turns in 90 degrees, the team calculated the turns for the servomotor. The team then moved it from its neutral 90 degrees and insert a time.sleep command to have a 1 second pause.

Ultrasonic Distance Sensor Code

For this project, the team used the HC-SR04 Ultrasonic Range sensor to measure the distance to prevent people and animals from being harmed when the ball is shooting out. This distance sensor emits a frequency that is in the ultrasound range. The sensor then is able to calculate the time it takes to reflect the ultrasound waves between the sensor and a solid object. The transmitters emit a high frequency which bounces off nearby objects; the return signal is then processed to calculate the time difference between the signal transmitted and received. The frequency is inaudible to the human ear and is accurate within short distances. The sensor has four pins: GND, ECHO, TRIG and Vcc. Through the code, the team sent an input signal to TRIG which triggers a pulse, the sensor then detects these waves and sends a 5V signal to the ECHO pin. Therefore, the python script measures pulse duration. Using 1 and 2 kΩ resistors, a few wires and the Raspberry Pi the team was able to set up the ultrasonic range sensor to function.

CIM Motor Code

A CIM motor was used to spin the steel wheel in the system. However to control the CIM motor a motor controller is needed. The Victor SP motor was used to as the controller. Programming the Victor SP was a bit of a challenge. The Victor SP is not normally pair with the Raspberry PI, which gave the team a bit of difficulty finding help online. The team later found out there is a very small range of frequencies that will make the motor rotate. One frequency range will move the wheel clockwise and another range of frequencies will rotate it counter-clockwise. Once the range was found, changing the speed of the wheel was easy.

Testing

The FIDO 3.0 has both adjustable power output and adjustable angle of elevation. Because of these features, this automatic launcher can be used both indoors and outdoors. The initial calculations were set for 30 feet of horizontal distance as the maximum for the launcher set at a 45 degree, but theory and the actual application of the system will differ. When testing the launcher with a direct 12-volt power source, the team achieved an estimated range of 10 to 15 feet in horizontal distance. It was also noted that from these initial testing, the Magnus effect of the tennis ball was prominent at lower speed. This means that an ideal launch angle would be lower than 45 degrees to account for the spin from Magnus force. It is also noted that it take 2-4 seconds for the motor to generate the maximum speed for the wheel.

Test 12V Source	Horizontal Distance
1	10.5 feet
2	12.5 feet
3	13 feet
4	12 feet
5	14.5 feet
Average	**12.5 feet**

These figures are initial tests and does not account for any bounce of the tennis ball. Often, dogs do not catch balls in midair but rather after the ball bounces and slow down. This is important in the design as the team also need to measure the distance the ball travels even after the ball touches the ground. As distance varies depending on the floor surface, whether it is hardwood or carpet, the team estimates an additional 10 to 20 feet after the ball hits the ground. This places the maximum launch to complete ball stop at around 35 feet on a hard floor surface using a tennis ball.

5-Conclusions and Recommendations

This senior-year project involved brain storming, designing, trouble shooting and fabricating a dog entertainment center. The team tested individual subsystems such as the launcher, hopper system, angle adjuster and housing verifying their performance. Coupling these components into an operational system resulted in a successful prototype. The design reduced moving parts compared to alternate systems that are more complex. The design efficiently used space within the housing. Overall, the mechanics of the FIDO 3.0 functioned as expected and was able launch a tennis ball that utilized the Magnus force as expected.

For the programing of the system, the team has successfully created working codes for each individual subsystem. Using the Raspberry Pi computer as the controls system, the team created a unified code so that the ball would be sensed in the hopper, checked for launch obstructions, power delivered to the launching motor with final feed of the ball into the launcher for the ball toss. This method has worked well, with the only safety concern being the horizontally mounted distance sensor. This sensor used had to be horizontally mounted created a blind spot above the launcher.

The team recommends several improvements that the FIDO 3.0 can undergo for the ideal dog entertainment system. A treat reward system is a good idea to implement because there us a learning curve for a dog to learn how to properly use the machine and this reward system can alleviate this possible frustration. The overall height of the launcher can be lower as well. The team noticed this design inefficiency. The angle adjuster motor is placed directly below the launcher, but can also be mounted to the side so that the launcher can be lowered 4 to 5 inches. Lowering this by removing that clearances can substantially impact the materials cost as it lowers the frame and housing.

Another possible improvement to the design is the slot for the launching tube. An ideal design would be to create a half circle top and have the launcher tube and shield rotate along a slot. The team's flexible cover blocks children from sticking their arms into the mechanism but is not as durable as a harder material. The team approves of the existing housing design, but recommends a waterproof silicone sealant between the finger joints and a polyurethane coating to make this build water resistant. Overall, the FIDO 3.0 functions as it was planned, fits the initial constraints, and has a certain appealing aesthetic charm, but is still not a complete product ready for manufacturing. To complete this product; the previously stated recommendations should improve the design and reliability of the FIDO Project.

6-References

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7-Appendix

Cost Analysis: Bill of Materials

When was it bought	Where it was bought	What was bought	How many were bought	Cost of one	Total cost
11/14/16	Amazon	Bread boards	1	$5.75	$5.75
11/14/16	Amazon	Tennis Balls	1 pk	$13.63	$13.63
11/14/16	Amazon	Raspberry Pi	1	$36.90	$36.90
11/14/16	Amazon	Pin-in Wires	1 pk	$11.99	$11.99
11/14/16	AndyMark	Cim Motor	1	$28.00	$28.99
11/14/16	AndyMark	Standard Servo	1	$11.00	$11.00
11/15/16	HomeDepot	Acrylic			$73.93
11/17/16	MSC Industrial Supply	Smaller Hub	1	$23.10	$23.10
11/17/16	MSC Industrial Supply	Bigger Hub	1	$44.83	$44.83
11/17/16	MSC Industrial Supply	Ft Long Shaft	1	$19.94	$19.94
11/17/16	MSC Industrial Supply	Radial Ball Bearing	2	$7.66	$15.32
11/17/16	MSC Industrial Supply	Shaft Collar 1/2" Bore Size	4	$6.88	$27.52
11/17/16	AndyMark	Key Adapter Shaft	1	$12.00	$12.00
11/22/16	Peterson Steel	Hunk of steel	1	$25.00	$25.00
11/22/16	Bando V- Belts	Belt	2	$8.40	$16.39
12/5/16	HomeDepot	Acrylic			$42.74
12/5/16	HomeDepot	Expoxy			$4.57
12/7/16	Grainger	Radial Ball Bearing	1	$12.08	$12.08
12/7/16	MSC Industrial Supply	Sleeve Bearing 1/4" inside	1	$1.31	$1.31
12/8/16	Grainger	Radial Ball Bearing	5	$12.08	$60.40
12/08/16	Amazon	ABS blue	1	$21.99	$21.99
12/12/16	HomeDepot	Plywood and Glue			$17.81
1/17/17	HomeDepot	Fiberbond and Acrylic			$30.59
1/18/17	Digikey	Solderable Bread board	3	$2.95	$8.85
1/18/17	Digikey	Ultrasonic Range Finder	1	$26.25	$26.25
1/18/17	Amazon	ABS blue	1	$26.99	$26.99
1/18/17	AndyMark	Machine Key	2	$0.50	$1.00
1/18/17	AndyMark	Machine Key	5	$0.70	$3.50

When was it bought	Where it was bought	What was bought	How many were bought	Cost of one	Total cost
1/23/17	AndyMark	Bracket	1	$9	$9.00
1/23/17	AndyMark	Roller Chain	1	$12	$12
1/23/17	AndyMark	Sprocket with Set Screws	1	$13	$13
1/23/17	AndyMark	Sprocket	1	$12	$12
1/23/17	AndyMark	Motor	1	$39	$39
	HomeDepot	Wood for Housing	6	$7.50	$45
1/23/17	AndyMark	Push Switch	5	$1.50	$7.50
1/23/17	AndyMark	Shaft collar	6	$5	$30
1/23/17	AndyMark	Motor Controller	1	$60	$60
3/17/17	Amazon	Relay Controller	1	$8.49	$8.49
3/17/17	Amazon	Switch	1 pck	$5.00	$5.00

HARDWARE SPECIFICATIONS IN SUBSYSTEMS

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	**Raspberry Pi 3 Model B** RASP-PI-3
	**2.5” CIM Motor** (am-0255)
	**8mm to 1/2" Key Shaft Adapter (am-0472)** **0.500 inch shaft with 1/8 inch keyway and 0.313 (8mm), 2mm keyed bore** **The bore of this adapter fits onto the 2.5" CIM Motor**
	**Hi-Tec Deluxe Standard Servo, model HS-422** (am-0010)

	**Power Drive - 16 Tooth, 1/2 Inch Inside x 1.88 Inch Outside Diameter, Hub and Flange Timing Belt Pulley** **1/2 Inch Belt Width, 1.91 Inch Pitch Diameter, 0.719 Inch Face Width, Aluminum**
	**Power Drive - 24 Tooth, 1/2 Inch Inside x 2.835 Inch Outside Diameter, Hub and Flange Timing Belt Pulley** **1/2 Inch Belt Width, 2.865 Inch Pitch Diameter, 3/4 Inch Face Width, Aluminum**
	WorkSmart - Belt Number 187L050, 3/8 Pitch, 50 Teeth, Section L Timing Belt 50 Teeth, Neoprene Rubber **Mfr Part #: 0187L050** **MSC Part #: 35394246**
	**Climax Metal Products - 1/2 Inch Bore Size, Yellow Zinc Coated, Steel, Two Piece Corrosion Resistant Clamping Shaft Collar** **1-1/8 Inch Outside Diameter, 13/32 Inch Wide**
	Flanged Radial Ball Bearing, Double Sealed, Flanged Bearing Type, 0.5000" Bore Dia., 1.1250" Outside Item# 1ZGE8 Mfr. Model# 1ZGE8
	Boston Gear - 1/4 Inch Inside x 0.377 Inch Outside Diameter, Oil Impregnated Bronze SAE-841 Sleeve Bearing 1 Inch Long **Mfr Part #: 34556** **MSC Part #: 06453229**

	**16 tooth, 25 series, DD bore (am-2282)** **S25-16HA-DD, 7075 Aluminum Sprocket, 25 Series, 16 tooth, DD Bore**
	**S35-40L Aluminum Sprocket** **40 Tooth sprocket for 35 chain**
	**#35 Single Strand-Riveted Roller Chain, 10' (am-0367)**
	**Snow Blower Motor (am-2235)** **Motor & gearbox combo from snow blower assembly**
	**Snow Blower Motor Bracket (am-2373)** **5052 aluminum**

Velocity - Distance Calculations:

Calculate the requred velocity of ball for it to reach the ideal distance

$distance_{ideal} := 35ft = 10.668m$

$\theta_{max\_distance} := 45°$

$g = 9.807\frac{m}{s^2}$

$V_{ball\_ideal} := \sqrt{\frac{distance_{ideal} \cdot g}{\sin(2 \cdot \theta_{max\_distance})}} = 10.228\frac{m}{s}$

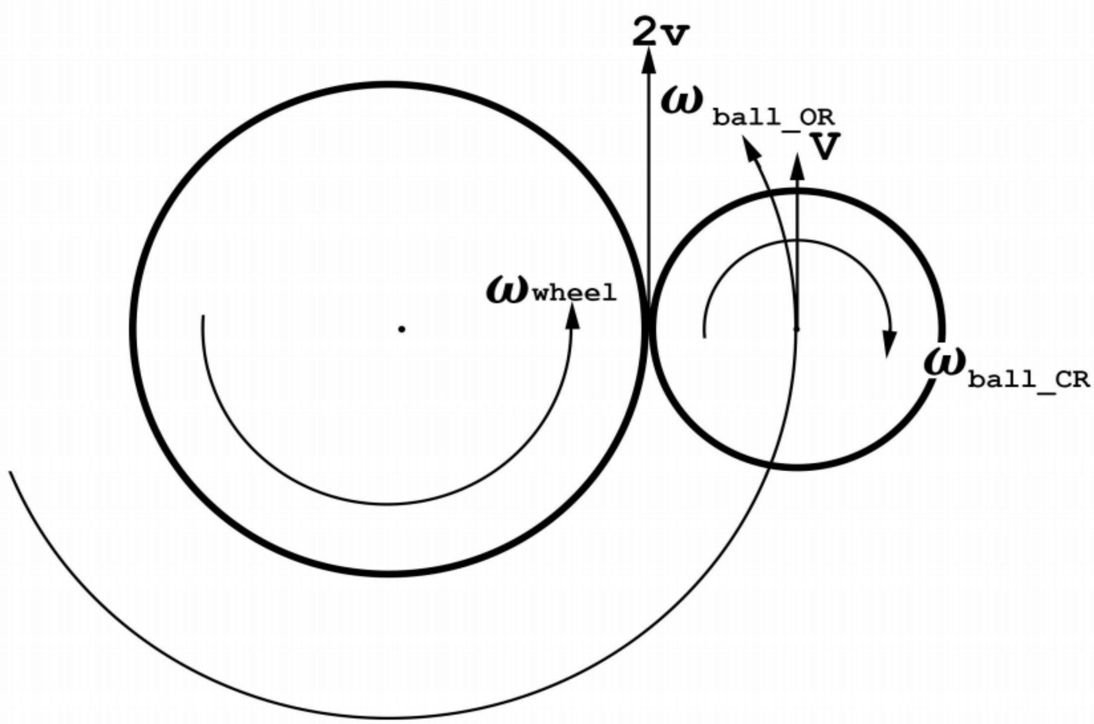
Power Calculations:

These numbers have been changed to be specific to our chosen motor

$T_{efficient} := .75N \cdot m$

$\omega_{efficient} := 285rpm = 29.845\frac{1}{s}$

$Power := T_{efficient} \cdot \omega_{efficient} = 22.384W$



Momentum Balance:

$J = \Sigma I_i \omega_i$

Start by looking at the formulas for moments of inertia

$I_{cylinder} = \frac{1}{2} mr^2$ this is the wheel

$I_{orbital\_mass} = mr^2$ the is the ball around the wheel

$I_{hollow\_sphere} = \frac{2}{5} mr^2$ this is the ball rotaiting around it's center axis

Values for our ball and wheel:

$m_{ball} := 2.6oz = 0.163 lb$

$weight_{wheel} := 1lbf$

$V_{ball\_ideal} = 10.228 \frac{m}{s}$

$V_{wheel} := 2 \cdot V_{ball\_ideal} = 20.457 \frac{m}{s}$

$r_{ball} := 1.35in$

$r_{wheel} := 3in = 0.076m$

$m_{wheel} := \frac{weight_{wheel}}{g} = 0.454kg$

Now calculate the ideal exit values for the system:

$\omega_{ball\_ideal\_OR} := \frac{V_{ball\_ideal}}{r_{wheel} + r_{ball}} = 92.572 \frac{1}{s}$ OR: Orbital Rotaion

$\omega_{ball\_ideal\_CR} := \frac{2 \cdot V_{ball\_ideal}}{r_{ball}} = 596.574 \frac{1}{s}$ CR: Center Rotational

$\omega_{wheel\_ideal} := \frac{2 \cdot V_{ball\_ideal}}{r_{wheel}} = 268.458 \frac{1}{s}$

When we initally did our calculations we realized that the motor did not have enough power to spin the wheel and the ball back up to speed after contact with the ball in the time constraints required. As a result we have to increase our inital speed so the motor slows down to the "right" speed.

$\omega_{wheel} := 320 \cdot \frac{1}{s}$ This value is a guess of the higher speed required to have the correct exit velocity

Calculating all other velocitys based on this "guessed" velocity:

$V_{wheel\_actual} := \omega_{wheel} \cdot r_{wheel} = 24.384 \frac{m}{s}$

$$\omega_{ball} := \frac{V_{wheel\_actual}}{r_{ball}} = 711.111\,\frac{1}{s}$$

calculating moments of inertia:

$$I_{wheel} := \frac{1}{2} m_{wheel} \cdot r_{wheel}^{\ 2} = 1.317 \times 10^{-3}\,m^2 \cdot kg$$

$$I_{ball\_OR} := m_{ball}\left(r_{wheel} + r_{ball}\right)^2 = 8.998 \times 10^{-4}\,m^2 \cdot kg$$

$$I_{ball\_CR} := \frac{2}{5} m_{ball} \cdot r_{ball}^{\ 2} = 3.467 \times 10^{-5}\,m^2 \cdot kg$$

calculating initial angular momentum:

$$J_1 := I_{wheel} \cdot \omega_{wheel} = 0.421\,\frac{m^2 \cdot kg}{s}$$

calculating the change in angular momentum after the ball has been added assuming no torque

$$J_{contact} = J_1 = I_{wheel} \cdot \omega_{wheel} + I_{ball\_OR} \cdot \omega_{ball\_OR} - I_{ball\_CR} \cdot \omega_{ball\_CR}$$

calculating the resulting velocitys for the wheel and ball

$$\omega_{wheel} = \frac{2V_{ball\_contact}}{r_{wheel}} \qquad \omega_{ball\_OR} = \frac{2V_{ball\_contact}}{r_{ball}} \qquad \omega_{ball\_CR} = \frac{V_{ball\_contact}}{r_{ball} + r_{wheel}}$$

$$V_{ball\_contact} := \frac{J_1}{\dfrac{2I_{wheel}}{r_{wheel}} + \dfrac{2I_{ball\_OR}}{r_{ball}} - \dfrac{2I_{ball\_CR}}{r_{ball} + r_{wheel}}} = 4.876\,\frac{m}{s}$$

$$\omega_{wheel\_contact} := \frac{2 \cdot V_{ball\_contact}}{r_{wheel}} = 127.984\,\frac{1}{s}$$

now calculating the angular momentum using the ideal values

$$J_{ideal} := I_{wheel}\,\omega_{wheel\_ideal} + I_{ball\_OR} \cdot \omega_{ball\_ideal\_OR} - I_{ball\_CR} \cdot \omega_{ball\_ideal\_CR} = 0.416\,\frac{m^2 \cdot kg}{s}$$

finding the required change in momentum

$$\Delta J := J_{ideal} - J_1 = -5.256 \times 10^{-3}\,\frac{m^2 \cdot kg}{s}$$

The tenis ball is in contact with the wheel for half a rotation. This allows for us to calculate our time constraint. Because the wheel is undergoing constant (non-zero) acceleration (from the torque of the motor) it's velocity is changing linearly. As a result we can use average velocity and still find the exact time.

$$t_{rotation} := \frac{1}{2\cdot\left(\frac{\omega_{wheel\_contact} + \omega_{wheel}}{2}\right)} = 2.232 \times 10^{-3}\,s$$

Torque is change in angular momentum over time:

$$T_{motor} := \frac{\Delta J}{t_{rotation}} = -2.354\cdot N\cdot m$$

compare that to the max torque the motor can output given its power constraint

$$T_{Motor\_Max} := \frac{Power}{\omega_{wheel}} = 0.07\cdot N\cdot m$$

now using mathcad to solve for the actually required inital velocity

$$\omega_{wheel\_exact} := 320\cdot\frac{1}{s}$$ Initial Guess for mathcad

Given

$$\frac{J_{ideal} - I_{wheel}\cdot\omega_{wheel\_exact}}{t_{rotation}} = \frac{Power}{\omega_{wheel\_exact}}$$ Equation for mathcad to solve

$$Find(\omega_{wheel\_exact}) = 315.889\,\frac{1}{s}$$ Mathcads anwser

now again but with 55% power efficency

$$\omega_{wheel\_not\_efficient} := 320\cdot\frac{1}{s}$$ Initial Guess for mathcad

Given

$$\frac{J_{ideal} - I_{wheel}\cdot\omega_{wheel\_not\_efficient}}{t_{rotation}} = \frac{Power\cdot .55}{\omega_{wheel\_not\_efficient}}$$

$$Find(\omega_{wheel\_not\_efficient}) = 315.943\,\frac{1}{s}$$

Calculate time in between shots:

Now calculate the required change in momentum from wheel after shooting to wheel ready to shoot again

$J_i := I_{wheel} \cdot \omega_{wheel\_ideal}$

$J_f := I_{wheel} \cdot \omega_{wheel\_not\_efficient}$

$$\Delta J_{if} := J_f - J_i = 0.068 \, \frac{m^2 \cdot kg}{s}$$

Given motor power calculate how much time is required

$$t_{between\_shots} := \frac{\Delta J_{if} \cdot \omega_{wheel\_not\_efficient}}{Power} = 0.97 \, s$$

Gear ratio:

Calculate the ideal gear ratio to have the motor opperate at peak efficency

$$R_{gear} = \frac{\omega_{in}}{\omega_{out}}$$

$$R_{gear} := \frac{\omega_{efficient}}{\omega_{wheel\_not\_efficient}} = 0.093$$ approximately a 9:10 gear ratio

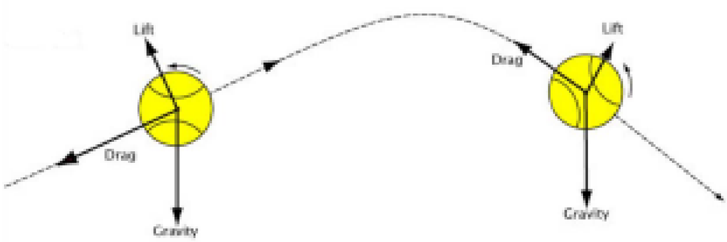
Flight path of Tennis Ball:

Key Equations:

$F_D = 0.5\ C_D \cdot \rho \cdot A \cdot v^2$ Drag force

$F_L = 0.5\ C_L \cdot \rho \cdot A \cdot v^2$ Lift force

$F_g = m \cdot g$ Force of gravity



$\Sigma F = F_D + F_L + F_g = ma$

$\Sigma F_x = F_D - F_L + ma = 0$

$\Sigma F_y = F_D - F_L + F_g + ma = 0$

Values:

$\rho := 1.21\ \frac{kg}{m^3}$ Density of air

$diameter := 66\ mm$ Diameter of tennis ball

$m_{ball} := .058\ kg$ Mass of ball

$F_g := m_{ball} \cdot g = 0.569\ N$ Force of Gravity

$t_{total} := 4\ s$ total time calculated

$A := \pi \cdot \frac{diameter^2}{4} = 0.003\ m^2$ Area

$C_D := 0.507$ Coeficent of drag

$C_L := 1.5$ coeficent of lift

$v_0 := 10.22\ \frac{m}{s}$ $\theta_0 := 45\ °$ Inital Conditions

$v_{0x} := v_0 \cdot \cos(\theta_0)$ $v_{0y} := v_0 \cdot \sin(\theta_0)$

$$k_x := \left((0.5)\ C_D\ \rho\ A - \frac{0.5\ C_L\ \rho\ A \cdot \cos\left(\theta_0 + \frac{\pi}{2}\right)}{\cos(\theta_0)} \right) \qquad k_y := \left(0.5\ C_D\ \rho\ A - \frac{0.5\ C_L\ \rho\ A \cdot \sin\left(\theta_0 + \frac{\pi}{2}\right)}{\sin(\theta_0)} \right)$$

$t := 0\ s, .001\ s .. t_{total}$

$x'(0\ s) = v_{0x}$ $x(0\ s) = 0\ m$ $y'(0\ s) = v_{0y}$ $y(0\ s) = 0\ m$

$m_{ball}\ x''(t) + k_x\ x'(t)^2 = 0$

$m_{ball}\ y''(t) + F_g + k_y\ x'(t)^2 = 0$

$\begin{bmatrix} x \\ y \end{bmatrix} := \text{odesolve}\left(\begin{bmatrix} x(t) \\ y(t) \end{bmatrix}, t_{total} \right)$

$t := 2\ s$

$y'(t) = 0$

$t_{max} := \text{find}(t) = 0.848\ s$

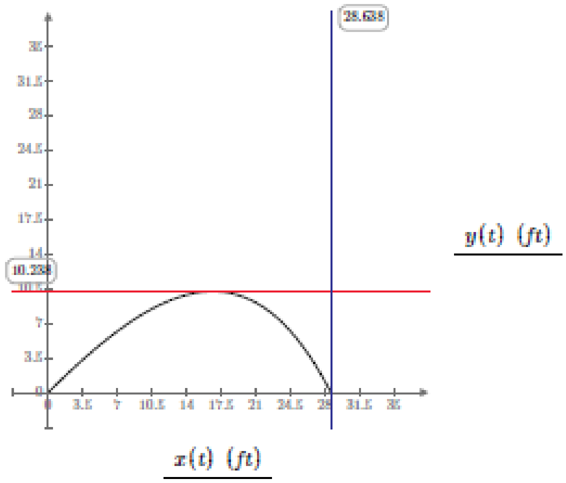
$t := 2\ s$

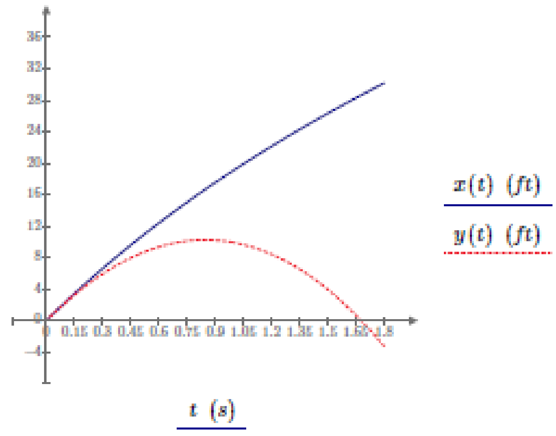
$y(t) = 0$

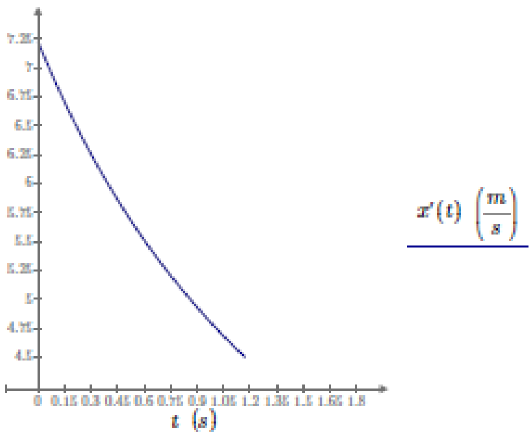
$t_{final} := \text{find}(t) = 1.678\ s$

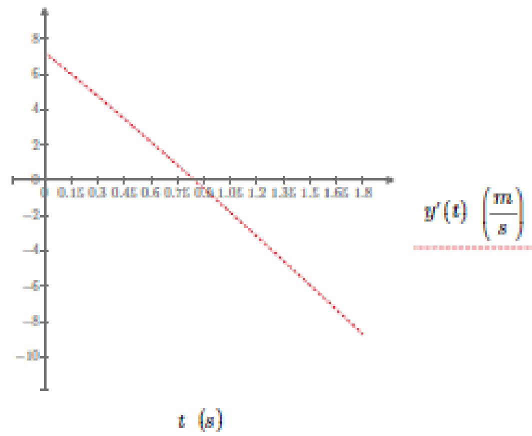
$Distance\_thrown := x(t_{final}) = 28.638\ ft$

$Max\_height := y(t_{max}) = 10.238\ ft$

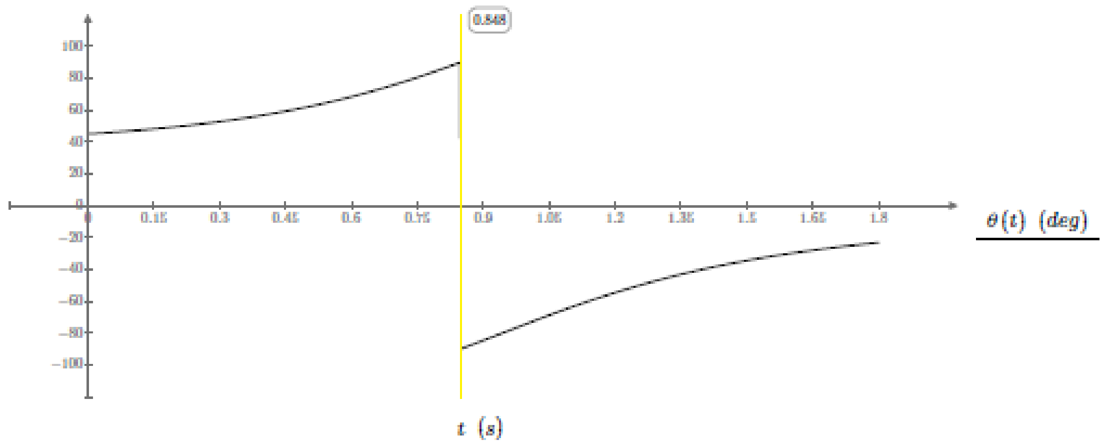








$$\theta(t) := \operatorname{atan}\left(\frac{x'(t)}{y'(t)}\right)$$



Power Calculations for Snow Blower Motor

$weight_{CIM} := 2.82\ lbf$

$d_{motor\_to\_axle} := 4.861\ in$

$Sprocket_{Driven} := 40$

$Sprocket_{Drive} := 16$

$N := \frac{Sprocket_{Driven}}{Sprocket_{Drive}} = 2.5$

$Power_{max} := 30\ W$

$\tau_{stall} := 70\ in \cdot lbf$

$\omega_{stall} := \frac{30\ W}{70\ in \cdot lbf} = 3.793\ \frac{1}{s}$

$\omega_{free} := 100 \cdot \frac{1}{s}$

$\tau_{free} := \frac{30\ W}{100 \cdot \frac{1}{s}} = 2.655\ in \cdot lbf$

$Stall\_Current := 24\ amp$

$Stall\_Voltage := \frac{30\ W}{24\ amp} = 1.25\ V$

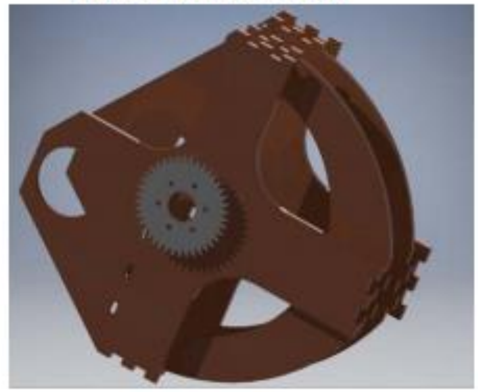
$Free\_Current := 5\ amp$

$Free\_Voltage := \frac{30\ W}{5\ amp} = 6\ V$

$Current := 5\ amp, 5.1\ amp .. 24\ amp$

$Volts(Current) := \frac{Power_{max}}{Current}$

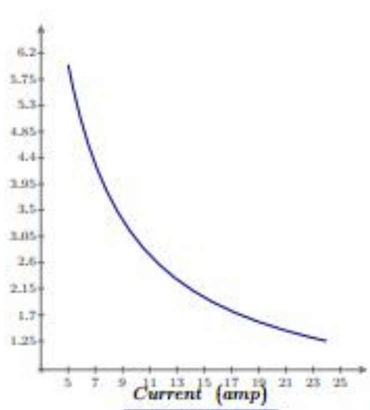
Revised launcher design

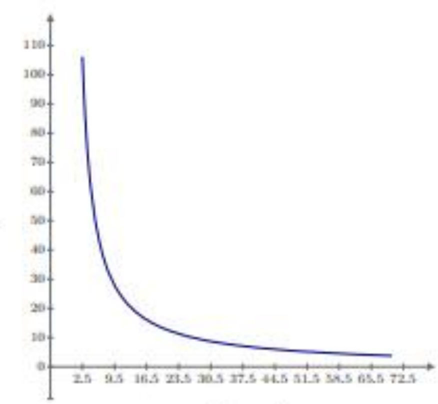


Snow Blower Motor (on worm gear)

$\tau := 2.5\ in \cdot lbf, 2.75\ in \cdot lbf .. 70\ in \cdot lbf$

$\omega(\tau) := \frac{Power_{max}}{\tau}$





$\tau_{required} := weight_{CIM} \cdot d_{motor\_to\_axle} \cdot 1.6 = 21.933\ in \cdot lbf$ $\tau_{gears} := \frac{\tau_{required}}{N} = 8.773\ in \cdot lbf$

$\omega(\tau_{gears}) = 30.265\ \frac{1}{s}$ Our motor is more than powerful enough.

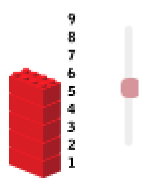
What is your dog's breed?

What is your dog's approximate weight and age?

What is the size of your dog?

- ◯ Small
- ◯ Medium
- ◯ Large

How trainable is your dog? (9 being the best)



Is your dog capable of playing fetch?

- ◯ Definitely yes
- ◯ Probably yes
- ◯ Might or might not
- ◯ Probably not
- ◯ Definitely not

What is your dog's favorite item to fetch?

- ☐ Ball
- ☐ Frisbee
- ☐ Stick
- ☐ Other Option

If you were away, would you want your pet to have an entertainment center? (Not taking into account the cost)

- ○ Yes
- ○ Maybe
- ○ No

If this were configured to what you wanted, what other activities would you want to entertain your dog?

Which features of a dog entertainment center would be of interest to you? (10 being the best)

0 1 2 3 4 5 6 7 8 9 10

Doggie Treat Reward System

Adjustable range and angles

Portability

Safety Features

Be able to record your voice

How much would you willing to pay for a product like this?

- $50-$100
- $100-$200
- Greater than $200

>>

Python Code

FIDOServo.py (code used to control servo motor for hopper system)

```
import RPi.GPIO as GPIO
from time import sleep
import time
GPIO.setmode(GPIO.BCM)
GPIO.setwarnings(False)

GPIO.setup(18,GPIO.OUT)
p = GPIO.PWM(18,50)
p.start(7.5)

try:
    while True:
        p.ChangeDutyCycle(7.5)
        time.sleep(1)

        p.ChangeDutyCycle(2.5)
        time.sleep(1)

        #turn 180 degrees
        #p.ChangeDutyCycle(12.5)
        #time.sleep(1)
except KeyboardInterrupt:
    p.stop()
    GPIO.cleanup()
```

UltraSonicSensor2017.py (code used for the Ultra Sonic Sensor to check if the area is clear)

```
import RPi.GPIO as GPIO
import time
GPIO.setmode(GPIO.BCM)

TRIG = 23
ECHO = 24

print "Distance Measurement In Progress..."

GPIO.setup(TRIG,GPIO.OUT)
GPIO.setup(ECHO,GPIO.IN)
```

```
GPIO.output(TRIG, False)
print "Waiting For Sensor To Settle"
time.sleep(2)

GPIO.output(TRIG, True)
time.sleep(0.0001)
GPIO.output(TRIG, False)

while GPIO.input(ECHO)==0:
  pulse_start = time.time()

while GPIO.input(ECHO)==1:
  pulse_end = time.time()

##while GPIO.input(ECHO)==0:
##  pulse_start = time.time()
##
##while GPIO.input(ECHO)==1:
##  pulse_end = time.time()

#insert while loop to pause at certain distance
#while (distance > 100 cm)
#print "end"
#use as interrupt sensor maybe half that distance
# ignore type item?

pulse_duration = pulse_end - pulse_start

distance = pulse_duration * 17150

distance = round(distance, 2)

print "Distance:",distance,"cm"

GPIO.cleanup()
```

Whatever.py (code for CIM Motor to Launch)

```
import RPi.GPIO as GPIO
from time import sleep
GPIO.setmode(GPIO.BCM)
mode = GPIO.getmode()
# PIN NUMBER ASSOCIATED WITH MOTORS
```

```
Motor1E = 23


GPIO.setup(Motor1E,GPIO.OUT)
GPIO.output(Motor1E, GPIO.LOW)
ok=input("Are you ready")


print "Turning motor on"
for x in range(0,1000):
   GPIO.output(Motor1E, GPIO.HIGH)
   sleep(1.3/1000)
   GPIO.output(Motor1E, GPIO.LOW)
   sleep(1.9/1000)
   print x
ok=input("end whenever")

GPIO.cleanup()
```

MainProg.py (Program that combines all previous code into one section)

```
import RPi.GPIO as GPIO
import time
GPIO.setmode(GPIO.BCM)
GPIO.setwarnings(False)

TRIG = 23
ECHO = 24

print "Distance Measurement In Progress..."

GPIO.setup(TRIG,GPIO.OUT)
GPIO.setup(ECHO,GPIO.IN)

GPIO.output(TRIG, False)
print "Waiting For Sensor To Settle"
time.sleep(2)

GPIO.output(TRIG, True)
time.sleep(0.0001)
GPIO.output(TRIG, False)
```

```
while GPIO.input(ECHO)==0:
  pulse_start = time.time()

while GPIO.input(ECHO)==1:
  pulse_end = time.time()

pulse_duration = pulse_end - pulse_start

distance = pulse_duration * 17150

distance = round(distance, 2)

print "Distance:",distance,"cm"


exec('FIDOServo.py')


exec('whatever.py')

GPIO.cleanup()
```