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# Reactive Archey Target Design Team "Mimic"

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The University of Akron

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"Mimic"

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## Acknowledgments

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## Introduction

The project "Mimic" is an original concept that provides deer hunters with a platform to practice archery in a revolutionary way. By researching deer reaction times and instinctual responses as well as conducting over 35 customer interviews, it was found why many deer are wounded and missed with bow and arrow.

*Background:*

The term string jumping refers to a deer hearing the snap of a bowstring when fired and their reaction of beginning to drop, up to an astounding 12 inches, within a matter of .15 seconds. They collapse their front limbs and drop their chest to the ground. The act of ducking is not a reaction meant to dodge the arrow. The deer are spring loading their legs in preparation of bounding forward to run away. However, as a result of this, a plurality of hunters will either miss their intended target or end up wounding the deer. This product aims to assist hunters in practicing for this string jumping scenario.

There are many different styles of archery targets on the market but none of these targets react to the shot of a bow as a deer does. Hunters simply aim at a stationary target and practice shooting at a series of concentric circles or decoy deer chest cavities. Mimic aims to revolutionize the way hunters improve their lethality and ethical killing through realistic response and movement. Different options for our mechanical design and electrical sensors have been explored to determine the best overall product design.

*Product Definition:*

The final production model must be manufactured and successfully drop a target approximately ten inches as a result of a bow shot. The sound of the bow shot will be picked up by a sound sensor and trigger wireless communication to the target and release a gravity drop of the target. This entire process must occur within quick succession matching the reactions of a deer at about a tenth to two-tenths of a second. The target will then reset itself which will be done by a rotating lever arm. This lever arm will reset the target back to its initial position in time for the hunter to aim in and take their successive shot. If successful, the system will allow hunters to improve their marksmanship and minimize missed or wounded deer that result in lost time, money, and resources.

## Market Research

Market research is particularly important when developing new products from a start up like method. Customer interviews and research allow better understanding of the problem and identify new business opportunities. It also helps to directly target the interest of consumers and help to increase sales. To conduct the marketing research there needs to be a series of questions that would relate to the product and the consumer without telling the consumer what the product is. When conducting research for the reactive target we asked questions relating to the type of bow, lethality, problems they have had with hunting, how they practice shooting, and other leading questions that gave good insights to our value propositions.

Our team conducted 35 customer interviews including hunters, specialty shop owners, hunting department stores, archers, and target manufactures. It was gathered that having the target system use the bow’s volume was an important factor that we did not include in our initial decision matrix. Since not all bows are equal in their shot volume, having a system that filters how loud the shot is and will help the archer determine how big of a factor the snapping noise is to the deer. If an archer’s bow is made quiet enough, through adding silencers and other features, he/ she may be able to minimize the sound exposure to the deer. Our triggering system gives another value proposition of allowing the archer to be more aware of his or her sound output.

The market size was calculated using the top down method. We used rough round numbers based on preliminary findings from our customer interviews and basic internet research to narrow down to, what is thought to be, the total market size for this type of product. Starting with 300 million Americans we can immediately restrict this number down to the number of people who participate in outdoor activities. According to the US Department of the interior that number is about 100 million people (2). Out of those people about a third are hunters, which gives us 33 million. Out of those hunters about 40 percent are archers, narrowing us down to 13.2 million people. Even more particularly, this is a one per household item and often there are at least 2 hunters who would be using each target, thus cutting that number in half to 6.6 million. As a last narrowing measure, we can say from our customer interviews that about 50 percent owned bows that shot above 300 fps, which negates the effects of string jumping. This left us with a conservative total market size of about 3.3 million units that could be sold in the US market.

Additional information from our customer interviews pointed to the price point that they would be willing to pay for such a product. The conservative price that we would be wanting to sell this reactive target would be between 150 and 175 dollars. With no competitive reactive targets currently on the market, we have a potential market value of approximately 5 billion dollars.

## Planning

The planning phase for this project was significant and required in-depth team deliberation and communication. The Work Breakdown Structure in Appendix A, Figure 1 shows the course of action taken by the team to build the first Mimic prototype.

To go along with this work breakdown structure, we also created a timeline to help us plan out when we want to meet certain goals and how we will progress through the year. Refer to Appendix A, Figure 2 to see the Project timeline overview.

## Deer Biology Background

In order to fully understand how to mimic the reactions of a deer research needed to be conducted into the biology of deer. More specifically for this scenario it is necessary to look into the hearing abilities of deer and how they first react to the sound of a bow.  It turns out that deer’s hearing capabilities are relatively similar to human hearing capabilities. Their hearing frequency range is mostly the same as human hearing and like humans, deer hear best in moderate frequencies, 4,000-8,000 hertz (4). Deer vocalizations like bawls, bleats and grunts are all in this range. However, deer can detect sound at lower volume levels than humans can, primarily due to their large ear size.  Where deer excel is in detecting high-pitched sounds. While the upper end of human hearing is about 20,000 hertz, deer can hear frequencies to at least 30,000 hertz (4). Looking a deer’s ear, which can range from 5 to 6 inches from base to tip, demonstrates how they’re built to detect predator sounds (1). Their ears are uniquely shaped to gather a great deal of sound and to pinpoint where each sound is coming from. Without turning its head, a deer can rotate its ears to localize sound. Whitetails are wired to quickly distinguish between sounds that represent a threat and those that don't. This explains why deer run away after hearing two hunters whisper but stay put when they hear two squirrels playing.

Now that it is understood how deer can easily distinguish unique sounds like the firing of a bow, it is time to learn how they react to threatening sounds. When a deer reacts to immediate danger, their first response is almost always flight. When they go to run, the first thing they do is load their leg muscles resulting in them dropping at the acceleration of gravity around six to twelve inches. This allows them to accelerate forward to reach speeds of 30+mph within 3 bounding leaps (1). About eighty percent of the time a deer will react accordingly, ducking down to load their legs and dart the other way. Looking at multiple research attempts of pinning the reaction time of a deer it was found that an estimate of about 0.1 to 0.2 seconds from arrow release for a deer to start moving or loading, and 0.25 to 0.35 seconds for a deer to fully load their legs or complete the downward movement (3). So, in about 0.35 to 0.55 seconds from the time the arrow is fired, a deer can load-drop-then unload springing forward forcing the shot to land off mark.

Now that there is a clear understanding of the reactions of a deer, calculations can be done to determine how to properly match this projects mechanism reaction time to that of a deer. Refer to Figure 4 and Figure 5 on appendix A to view the detailing of all the constants and known values as well as the timing of the order of the events. An assumed deer reaction time of about 0.16 seconds was used because this is the part of the deer's reaction at which it first ducks down to load its legs. We set up a sample scenario in which more assumptions were made: the target was approximately thirty meters away, the bow used was producing an arrow speed of 100 meters per second and assumed that the target needed to drop ten inches or .254 meters. Also, factoring in for processing time of the system and motor reaction time. With these inputs it is possible to determine for three different types of signals how long quickly we could have our target drop at the initial firing of a bow.

Laying out the order of events it is possible to factor in all the items that would affect the overall duration of the deer ducking down and spring loading its legs. As seen in the figure it is found that all three of the signal types trialed will have the capability to complete the task of dropping the mechanism in a time that matches that of a deer. Now that these calculations are obtained, it is time to further evaluate the different design parameters that can be utilized to help mimic this sharp and quick movement of the deer.

## Conceptual Design

To achieve a goal of creating an archery target that would drop to mimic the reactions of a deer brought the thought of all the different ways to produce this design. The goal was to explore all the different possible ways of designing the product and going through each one to determine what was the best collective set of design parameters. The team's main goal was to create a target that could drop when shot at and reset itself in between shots. To do so an electromechanical system was created.

## Design Matrix

The product was broken down into three separate parts. These parts would include the sensor, signal, and mechanism used to create the design. Different methods were brainstormed for each part of the system and a series of weighted decision matrices were created to further evaluate each one. The weighted decision matrix for the sensor will be the first discussed.

Table 1: Weighted decision matrix for sensors

Sensors

| Sound | Criteria | WF | Score | Rating |
|---|---|---|---|---|
| | Reliability | 0.3 | 5 | 1.5 |
| | Cost | 0.35 | 10 | 3.5 |
| | Simplicity | 0.25 | 8 | 2 |
| | Size | 0.1 | 9 | 0.9 |
| | | | Total Score | 7.9 |

| Vibration | Criteria | WF | Score | Rating |
|---|---|---|---|---|
| | Reliability | 0.3 | 3 | 0.9 |
| | Cost | 0.35 | 10 | 3.5 |
| | Simplicity | 0.25 | 8 | 2 |
| | Size | 0.1 | 9 | 0.9 |
| | | | Total Score | 7.3 |

| Pressure | Criteria | WF | Score | Rating |
|---|---|---|---|---|
| | Reliability | 0.3 | 8 | 2.4 |
| | Cost | 0.35 | 7 | 2.45 |
| | Simplicity | 0.25 | 6 | 1.5 |
| | Size | 0.1 | 9 | 0.9 |
| | | | Total Score | 7.25 |

| Switch | Criteria | WF | Score | Rating |
|---|---|---|---|---|
| | Reliability | 0.3 | 10 | 3 |
| | Cost | 0.35 | 8 | 2.8 |
| | Simplicity | 0.25 | 7 | 1.75 |
| | Size | 0.1 | 9 | 0.9 |
| | | | Total Score | 8.45 |

| Tension | Criteria | WF | Score | Rating |
|---|---|---|---|---|
| | Reliability | 0.3 | 6 | 1.8 |
| | Cost | 0.35 | 8 | 2.8 |
| | Simplicity | 0.25 | 4 | 1 |
| | Size | 0.1 | 9 | 0.9 |
| | | | Total Score | 6.5 |

| Motion | Criteria | WF | Score | Rating |
|---|---|---|---|---|
| | Reliability | 0.3 | 4 | 1.2 |
| | Cost | 0.35 | 4 | 1.4 |
| | Simplicity | 0.25 | 5 | 1.25 |
| | Size | 0.1 | 7 | 0.7 |
| | | | Total Score | 4.55 |

From Table 1 six different types of sensors were explored. These six sensors were examined by four different criteria all with different weights depending on how important they were determined to be to the design. Then a score of one to ten was given for each one and a total score was determined for each type of sensor. The top contenders were the switch and sound methods.

The primary difference between the two was in the reliability category. The switch would be much more reliable since a mechanism could be set up on the bow that would be triggered as the bow was shot at the target. When dealing with sound there was a concerned that it would be difficult to develop a program that would only recognize the specific sound made by the firing of a bow. If the program triggered upon a decibel level being reached, there was concern that other noises such as the human voice or other natural sounds could trigger the activation of the program. The possibility of having a set range of frequency levels to produce from the firing of the bow to trigger the system was explored. It seemed like a good idea but the difficulty of producing such a program was concerning. Research was done to understand if this was a realistic idea. Ultimately it was decided that there was confidence in the fact that we could produce a unique program that would only be triggered by the firing of the bow. The realistic effect of the sound sensor also would have the added benefit of showing the archer if his bow even was too loud to bother worrying about string jumping. After consulting Dr. Nadkarni and discussing as a team we proceeded with the sound sensor.

The weighted decision matrix for the type of signal used in the design will now be examined. The signal used will serve as a means of communication between the sensor that is attached to the bow and the mechanical system. The sensor on the bow will detect the firing of the bow, and then communicate this to the mechanical system through a signal. Four different types of signals were evaluated with four different criteria as seen in the table below.

Table 2: Weighted Decision Matrix for Signal

| | | | | | Signal | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Infra Red | | | | | | Bluetooth | | | | |
| | Criteria | WF | Score | Rating | | | Criteria | | | Rating |
| | Speed | 0.15 | 10 | 1.5 | | | Speed | 0.15 | 10 | 1.5 |
| | Cost | 0.15 | 8 | 1.2 | | | Cost | 0.15 | 6 | 0.9 |
| | Range | 0.4 | 5 | 2 | | | Range | 0.4 | 3 | 1.2 |
| | Reliability | 0.3 | 7 | 2.1 | | | Reliability | 0.3 | 6 | 1.8 |
| | | | Total Score | 6.8 | | | | | Total Score | 5.4 |
| Highfrequency/Radio | | | | | | Sound | | | | |
| | Criteria | WF | Score | Rating | | | Criteria | WF | Score | Rating |
| | Speed | 0.15 | 8 | 1.2 | | | Speed | 0.15 | 10 | 1.5 |
| | Cost | 0.15 | 7 | 1.05 | | | Cost | 0.15 | 4 | 0.6 |
| | Range | 0.4 | 8 | 3.2 | | | Range | 0.4 | 6 | 2.4 |
| | Reliability | 0.3 | 7 | 2.1 | | | Reliability | 0.3 | 3 | 0.9 |
| | | | Total Score | 7.55 | | | | | Total Score | 5.4 |

The four signal types explored were Infrared, Bluetooth, high frequency/radio, and sound. High frequency/radio came out with the best score primarily because it scored consistently well in all four criteria. All the other signal types seemed to have a score of 5 or below in at least one of the criteria. The thing enjoyed the most about the High-frequency radio was that it scored the highest in both range and reliability. Both of these criteria were found very important to the design of the product and there was excitement with the potential that a High-frequency signal would have.

The last part of the project that was explored through the weighted decision matrix is the mechanical system. The purpose of the mechanical system is to mimic the string jump reaction of a deer. This was planned to be done by dropping a target approximately 10 inches vertically downward in a very short amount of time. The mechanical system will then also have to return the target back up to its original position a few seconds after the bow is fired. Five different types of systems were evaluated with 7 different types of criteria as seen in the table below.

Table 3: Weighted decision matrix for mechanical systems

| Rotational Leverarm | | | |
|---|---|---|---|
| Criteria | WF | Score | Rating |
| Simplicity | 0.15 | 9 | 1.35 |
| Cost | 0.15 | 8 | 1.2 |
| Mobility | 0.15 | 6 | 0.9 |
| Realistic effect | 0.175 | 9 | 1.575 |
| Reliability | 0.15 | 9 | 1.35 |
| Power Source | 0.1 | 7 | 0.7 |
| User friendly | 0.125 | 9 | 1.125 |
| | | Total Score | 8.2 |

| Air Spring | | | |
|---|---|---|---|
| Criteria | WF | Score | Rating |
| Simplicity | 0.15 | 3 | 0.45 |
| Cost | 0.15 | 5 | 0.75 |
| Mo bility | 0.15 | 8 | 1.2 |
| Realistic effect | 0.175 | 7 | 1.225 |
| Reliability | 0.15 | 6 | 0.9 |
| Power Source | 0.1 | 5 | 0.5 |
| User friendly | 0.125 | 7 | 0.875 |
| | | Total Score | 5.9 |

| Linear Actuator | | | |
|---|---|---|---|
| Criteria | WF | Score | Rating |
| Simplicity | 0.15 | 7 | 1.05 |
| Cost | 0.15 | 6 | 0.9 |
| Mobility | 0.15 | 10 | 1.5 |
| Realistic effect | 0.175 | 10 | 1.75 |
| Reliability | 0.15 | 10 | 1.5 |
| Power Source | 0.1 | 8 | 0.8 |
| User friendly | 0.125 | 10 | 1.25 |
| | | Total Score | 8.75 |

| Car Jack | | | |
|---|---|---|---|
| Criteria | WF | Score | Rating |
| Simplicity | 0.15 | 7 | 1.05 |
| Cost | 0.15 | 7 | 1.05 |
| Mobility | 0.15 | 7 | 1.05 |
| Realistic effect | 0.175 | 10 | 1.75 |
| Reliability | 0.15 | 10 | 1.5 |
| Power Source | 0.1 | 7 | 0.7 |
| User friendly | 0.125 | 9 | 1.125 |
| | | Total Score | 8.225 |

| Trap Door | | | |
|---|---|---|---|
| Criteria | WF | Score | Rating |
| Simplicity | 0.15 | 9 | 1.35 |
| Cost | 0.15 | 9 | 1.35 |
| Mobility | 0.15 | 3 | 0.45 |
| Realistic effect | 0.175 | 7 | 1.225 |
| Reliability | 0.15 | 9 | 1.35 |
| Power Source | 0.1 | 2 | 0.2 |
| User friendly | 0.125 | 4 | 0.5 |
| | | Total Score | 6.425 |

At the conclusion of this weighted decision matrix it was found that there were three stand out designs that had scored well enough to gain further consideration. After much consideration the decision was to go with a rotating lever arm that would raise a trap door, i.e. the platform on which the target would sit. A separate motor would actuate the trap door release. Albeit, the linear actuator would meet all the requirements of what is needed from the mechanical system, it would also be the most expensive option and required less engineering calculations and design for the team. The team received a ½” Impact Wrench from Stanley Black & Decker as a donation to power the rotating lever arm.

## Arduino Coding and Wiring

This project utilized Arduino computing power to autotomize the mechanical system. Arduino software uses C++ language and is relatively user-friendly. The following flowcharts will walk through how the code that was written operates and will highlight its failures and pitfalls.

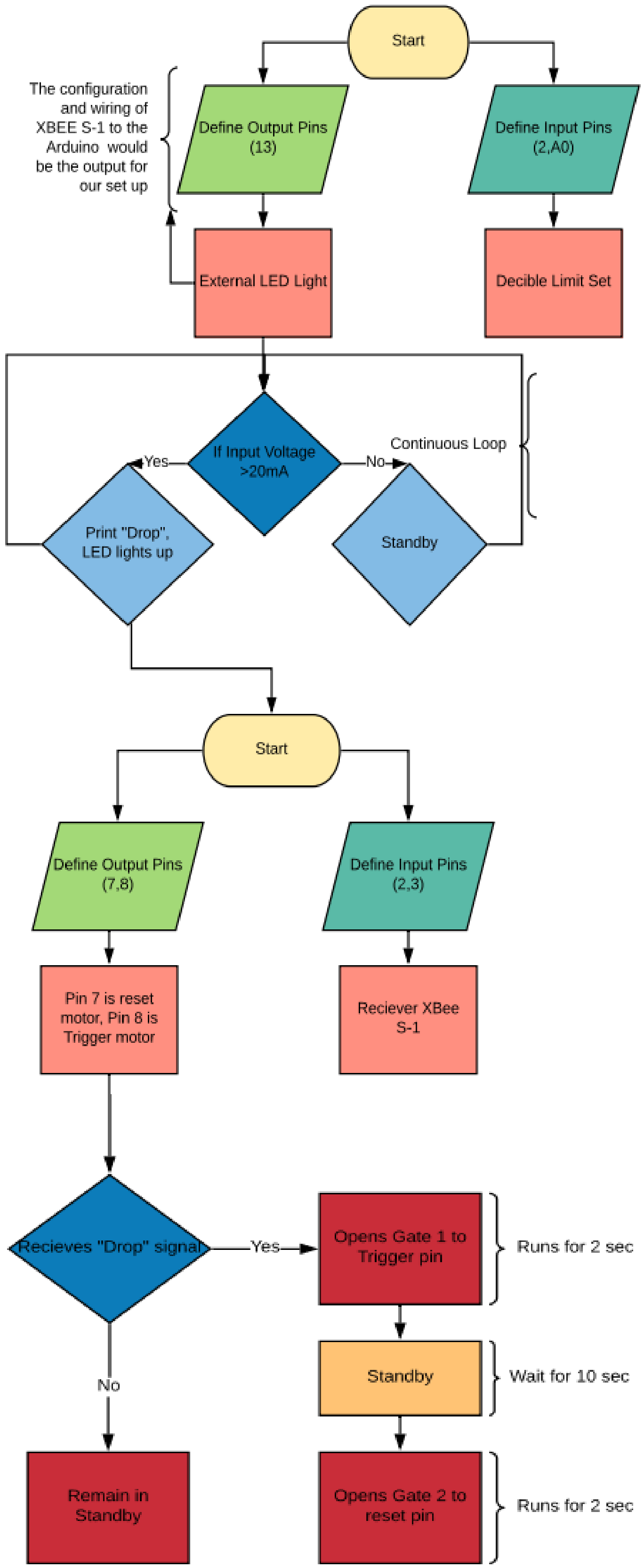



Figure 1: Logic of code flowchart

A Spark fun sound detector, model LM234, was used to listen and be the ear of our system. The analog input "A0" was utilized to allow more than the digital HIGH or LOW values, i.e. on or off.  This gives the ability to have a volume tolerance level that we can set based on bow shot volume data that was collected. The tolerance was set to 80 decibels which equates to 20 mA in the Arduino. The filter could be improved by adding a time component that would require the 80 decibels to only be maintained for .05 -.1 seconds before returning to the ambient sound level. This code also only outputs to an LED light, whereas the intention is to output to the XBEE S-1 to allow wireless communication with the target. Refer to Appendix C, Figure 1 to view the detailed code.

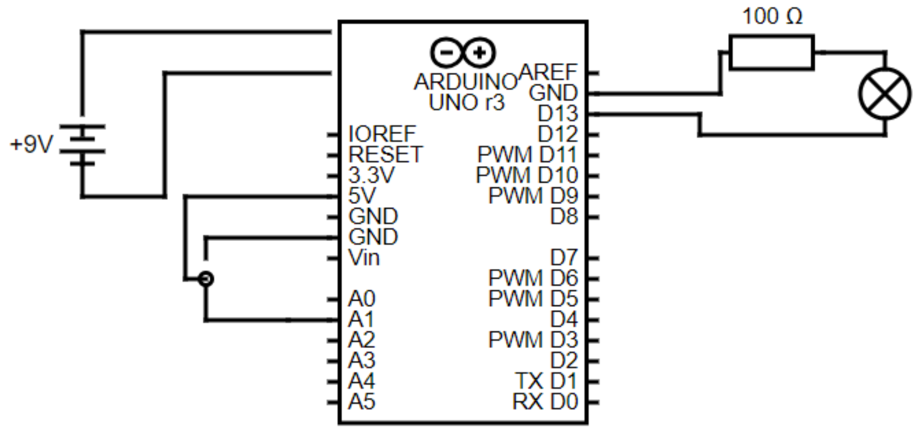



Figure 2: Schematic of Arduino

The second half of the code is what operates the reset and latching mechanisms. Two MOSFET's that act like a valve for the 12V power supply were used to control the motors without exposing the Arduino to the excessive voltage. Diodes were placed in parallel to these MOSFET's in order to avoid the accumulated back charge from the motors from burning the gates up. Below in Figure 2 is a showcase of the components used to filter the sounds of the ambient environment vs. the bow string, the communication from one X-Bee to the other, and the Arduino's for controlling the motors of the mechanical system.

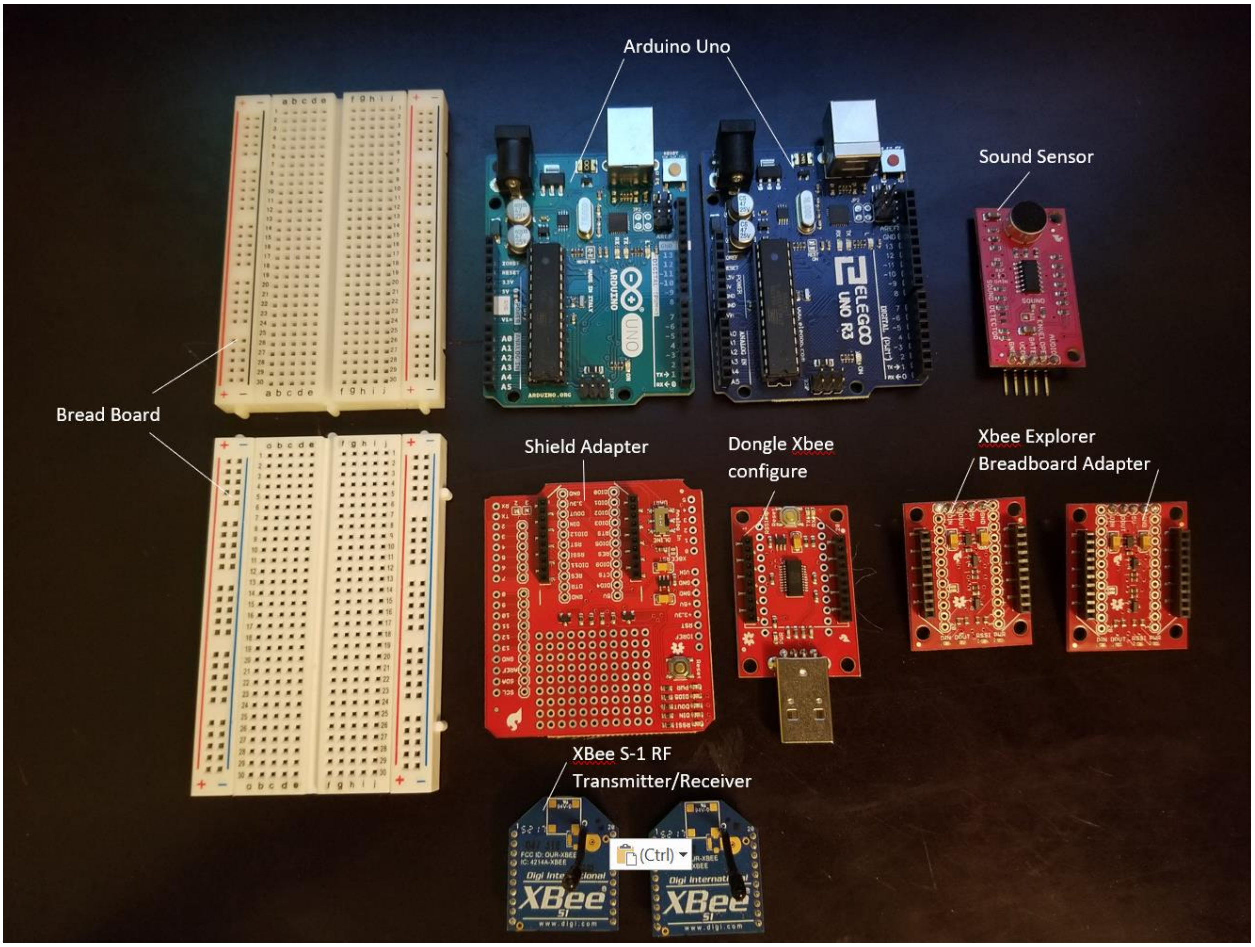



Figure 3: Electronic components used by the Mimic Archery Target

## Manufacturing Process

The manufacturing process began with simple sketches using pencil and paper. These sketches then evolved into SolidWorks drawings to show how the archery target would move in order to mimic a deer. Generic dimensions were used to keep the design simple and easy to follow. A Bill of Materials (BOM) was then created in Google Sheets to allow the team to collaborate and write down any items they believed needed to be purchased. Next the BOM was condensed to the necessary materials to achieve the design in the most economical fashion. Once the CAD design and the BOM were set a trip to the local hardware store was made to purchase materials. The Gantt Chart found in Appendix A highlights the steps taken by the team to accomplish the manufacturing process.

*Rotating Lever Arm:*

Once the decision matrix was completed and the team begin to research rotary-linear motion machines. Inspiration was taken from scotch and yoke mechanisms, piston cylinders, and slider-mechanism for the lever arm which would raise the platform to its starting height. After receiving the donated DEWALT ½" impact Wrench rated to deliver 400 ft-lbs. of torque the team designed a link that could connect the drive shaft of the wrench to the target platform in order to raise the platform. See Figure 3 below for a showcase of the parts used in the rotating lever arm design and Figure 4 for the linkage assembly.


Figure 4: Components of the rotating lever arm design for raising the target platform

Figure 5: Linkage system to raise the target system with impact wrench

Two black pipes of different diameters were slid over top of each other to allow the target platform to remain at its top resting position. The small metal link and the outer piston (larger black pipe) returned to the lower resting position to await the free fall of the target. Because a free-falling target would best mimic a string jumping deer it was imperative that the lever arm designed didn't obstruct the fall. For this reason, the two black pipes were designed to slide concentrically within each other. Two drawer extension slide tracks were also mounted onto the base of the target system to guide the free fall and reset of the system. The figure below shows the assembly of the small diameter pipe to the underside of the target platform to allow for pivoting during the raising of the target.

Figure 6: As the impact wrench turns the metal link in Figure 6

While the short link turns, it causes the outer piston (larger diameter pipe) to push the target up while sliding over the inner piston (smaller pipe.) The telescoping design and the sliding drawer tracks ensure that the platform is being guided into the correct latch position.

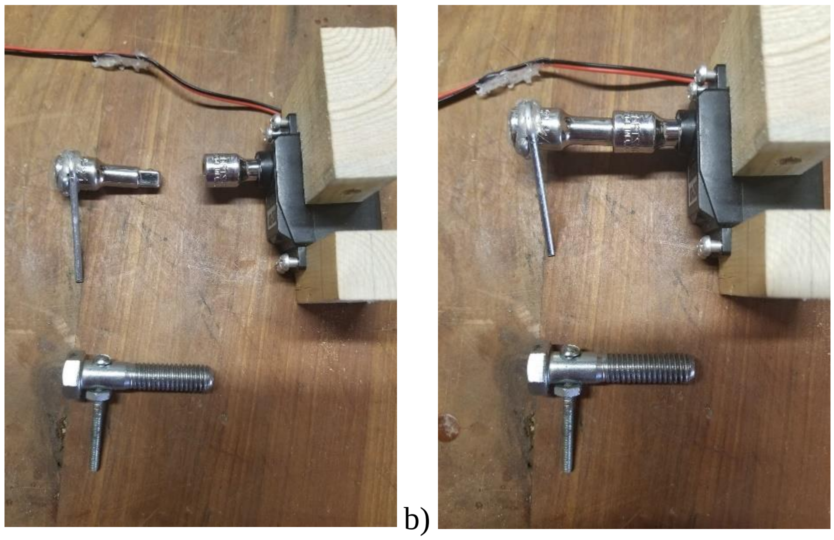
The team faced many setbacks throughout the course of the manufacturing process and had to make significant alterations to the design. For instance, the target frame and platform only took two days to complete; however, it was constantly being modified throughout the manufacturing process to accommodate the mechanical components. The frame was given additional supports with diagonal braces after feedback from team members and Dr. Nadkarni that the system would not withstand the repetitive dropping of the target. Shock absorption springs were added within the piston and along the rails to help increase the durability. Additionally, more wood was needed than expected to add the diagonal braces and supports for the impact wrench which raised and lowered the platform. Another setback was that the metal link that had been outsourced for welding was assembled backwards and could not be used because socket end could not be engaged by the square drive of the impact wrench. The link was disassembled and sent to BWX-Technologies and was professionally welded in the correct orientation. See the figure below for the correct assembly.

Figure 7: ½” Socket correctly mounted onto the ½” Impact Wrench drive shaft.

Once the team corrected the backwards metal link issue it was time the test the impact wrench’s motor strength against the load of the platform. Surprisingly, the impact wrench failed to lift the platform. Partially due to the large load placed on the motor to lift platform and the fact that the impact wrench would begin to use its impacting mechanism to lift the platform. The impact mechanism managed to raise the platform slightly until it faced the largest amount of torque, at this point it began to use its impacting mechanism to achieve its max torque output of 400 ft-lbs. In between impacts the target would lower slightly and cause large vibrations in the system. The split second of time in between impacts was enough that the target could not be raised further but instead stalled out at that height. The team was then faced with the decision to redesign the entire system to lift the platform or sacrifice the drop height of the platform for functionality. The team decided to try shortening the metal link lever arm from 5 inches to 2.5 inches. This would cut the torque experienced by the impact wrench in half. Again, the impact wrench could not deliver enough continuous torque to raise the platform consistently. The link was then shortened to 1.5 inches resulting in a maximum drop height of 3 inches. The impact wrench was able to supply enough torque to raise the platform under these conditions.

Torque calculations were computed with a significant factor of safety, such as assuming a target weight of 50 pounds and a lever arm length of 6 inches. Under these conditions the total torque on the impact wrench would be 25 ft-lbs. The DEWALT ½" Impact Wrench is rated to deliver 400 ft-lbs. of torque so in theory it should have worked effortlessly. It was unanticipated that in between the impacts in which max torque is produced the platform would jump up and down and essentially vibrate at one position due to the non-continuous application of force. The shorter linkage design was successful because the required torque never broke the threshold for the impacting mechanism to run.

In order to deflect the trigger of the DEWALT ½" Impact Wrench a small shaft was fixed to a 12V motor controlled by the Arduino. As the small motor runs it presses the trigger and turns on the drill. A mistake was made when assembling the motor and too much Loctite was applied to the assembly and fixed the output shaft. A second, more reliable design was created that could be disassembled with ease using a simple set of sockets rather than a bolt. See Figure 7 a) and 7 b) below to see the modified changes.



a) b)

Figure 8: a) The optimized design is shown as the top version of the design. The threaded bolt was the previous design that was unsuccessful. b) The design is shown in its assembled fashion.

*Platform Release:*

The platform mechanism underwent multiple design iterations. Initially, a simple solenoid design to release the target platform was investigated. This design was promising in theory because it could achieve a compact linear motion to release the platform. Unfortunately, in practice the solenoids were inadequate because they required a constant current supply to be engaged (holding up the platform) and caused overheating issues in MOSFET’s.  Additionally, they were not strong enough to overcome the friction that the weight of the target and platform applied while in its set position. The team found inspiration from a simple spring-loaded door knob and assembled one to the rear side of the target platform. See Figure 8 below for the assembled door knob on the frame.

Figure 9: The door knob assembly mounted onto the frame which latches the platform in its starting position and releases the target when a signal is received from the Arduino

The door knob design was successful at holding the platform in its starting position and could easily be operated manually. The challenging part of the design was to automate the turning of the door knob using a motor controlled by an Arduino. A small 12V motor was salvaged from a small compressor and redesigned to turn the doorknob. The team knew that the motor operated quickly and designed a torque multiplier gearbox to transfer that speed into torque. A 16-tooth gear was press fitted onto the output shaft of the motor and meshed with a 64-tooth gear to produce a torque multiplier of 4. The torque was further multiplied by placing a chain and sprocket in series with 64 tooth gear. A bicycle donated to the team by the Boss family provided the team with the necessary components for the chain and sprocket design. The small sprocket had 10 teeth and the large sprocket, which was fixed to the door knob, had 48 teeth. This resulted in a 4.8 torque multiplier between the two sprockets. The overall torque multiplier from the output shaft to the door knob was 19.2 (4*4.8=19.2). In other others words the output shaft would need to spin 19.2 times to cause the door to knob the spin once. Although it is important to keep in mind that the door knob only needed to make 1/4th of a revolution to release the latch. Therefore, only 4.8 revolutions of the output shaft are required to release the latch, thus dropping the platform. The final chain and sprocket design (Figure +++) required some brainstorming and multiple failed attempts to create a combination that would maintain taught and provide the necessary torque on demand. A brainstorming session was conducted, and a few ideas were thrown about such as; a rubber belt and pulley system, mounting a steel cable to the door knob to be pulled by the motor, or even meshing gears directly onto the door knob. The team disregarded the rubber belt idea for fear of slippage and the steel cable idea due to mounting troubles onto the preexisting door knob hardware. A large meshed gear on the doorknob was also disregarded for cost reasons and weight. This led the team to the chain and sprocket design. Shown in Figure 10 is an initial attempt that was made with a sprocket torque multiplier value of just 2.8. It proved to be unsuccessful without preloading the door knob with some extra momentum. The largest sprocket available was then used. The issue with preloading the door knob with extra momentum was that it took extra time to release the platform and would require the motor to spin in both directions, a task which is feasible with the addition of a motor controller to the electronic system. This route was not pursued due to costs and short timelines. In further prototyping this could be a possibility.

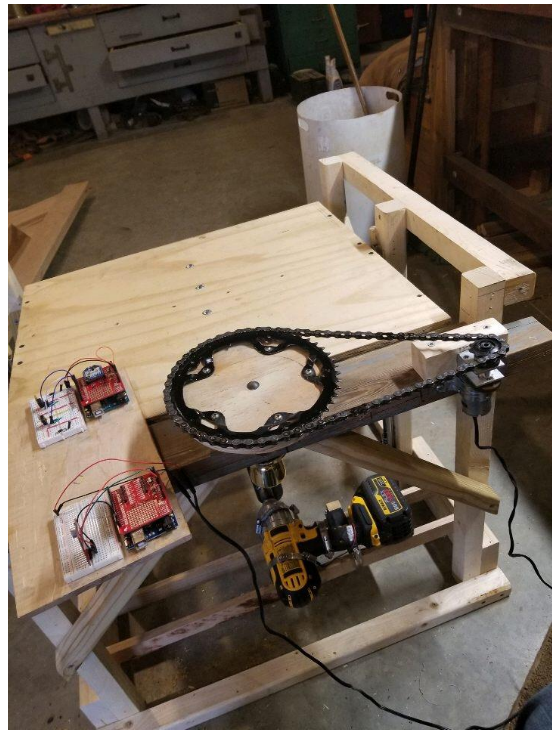
a)  b) 

Figure 10: a) The motor and torque multiplier of 4 gearbox. b) The final chain and sprocket design with a sprocket torque multiplier of 4.8 and overall torque multiplier of 19.2

Figure 11: Intermediate design with sprocket torque multiplier of only 2.8 and overall torque multiplier of 11.2 (Unsuccessful design)

## Improvements on the Design

The Mimic Archery Target shows significant room for improvement across a wide variety of design aspects. From a mechanical standpoint the impact wrench needs to be replaced by a motor that can deliver a constant amount of torque greater than 25 ft-lb. This modification would allow the target to drop the goal height of ten inches.  Exploring the linear actuator design that was looked at in the brainstorming phase could prove to be a superior reset mechanism. The platform release design should also be redesigned with more robust, stable brackets and fixtures. Slippage occurred between the small sprocket and chain during the initial assembly and could be a reoccurring problem without proper adjustments in the chain tension. Additionally, the placement of the chain and sprocket are too large and would be in the path of the arrows while shooting at the target. This sprocket and chain mechanism ideally would be replaced with a stronger compact motor. Furthermore, the black pipes known as the inner and outer pistons have some play in them. Tightening this gap would provide another guide in the system to ensure a plumb drop of the target and guide the platform back to the reset position. Additional guarding ought to be added to protect the piston and other components from the arrows. The guarding would need to be forgiving enough to not damage the arrows and strong enough to protect the components upon impact. Using a dense foam with a rigid backing could meet this criterion. Weight was also an aspect that we would like to reduce. The goal would to have it be able to comfortable be carried by one average stature adult without significant physical effort. To do this, changing the dimensions to be more compact and using lighter materials would be incorporated into the next prototype.  The electronic components that were used have greater capabilities beyond what was being run through them. Fine tuning the necessary functions would reduce costs and increase profit margins.  While springs were utilized to absorb shock from the repetitive drops and increase durability, the current method requires sacrificing free fall drop height. If a 10-inch freefall is desired, the system needs to mechanically be able to fall further to allow the spring to be compressed and dissipate the kinetic energy. A torsion spring attached to the drive link could provide better shock absorption.

These improvements would bring us to a prototype we could bring forward to investors. With an infusion of financial support, the mimic platform could perfect the design and bring the product to market. Based on the success of the archery target, the Mimic brand could expand into other models on its platform.

## Final Conclusions

The Mimic prototype produced effectively satisfies the project proposal. It allows for deer hunters to effectively practice their aim and targeting of string jumping deer. With the support of market research this product evolved into a marketable product, that with further efforts, could be sold in a profitable business. The costs of the project were minimal. The design is straightforward and effective, accommodates an appropriate range of bow types, and is consistent with its functions. While we were not able to demonstrate the wireless communication and the limitations of the motor sizes kept the design constrained, the primary issues that were encountered could all be solved with better materials, outside expertise, and finances.

The future possibilities with this project are bright. With a broadened budget and more research, the technology of this design can be greatly updated and perfected. Moving forward this group will continue to strive in developing this product further and potentially reach a point where the product is finalized and available to an open market with high opportunity and low competition

# Citations

1. https://www.boone-crockett.org/bgRecords/records_FieldJudging_WTDeer.asp
2. https://www.doi.gov/pressreleases/new-5-year-report-shows-1016-million-americans-participated-hunting-fishing-wildlife
3. http://www.fullpotentialoutdoors.com/deer-reaction-time-jumping-string/
4. https://www.grandviewoutdoors.com/big-game-hunting/whitetail-deer/scientific-facts-about-how-deer-see-and-hear/

# **Appendix A:** Planning & Scheduling

Attachments include; Work Breakdown Structure of the Mimic Archery Target, Project Timeline, Project Gantt Chart, and Delay Calculations.

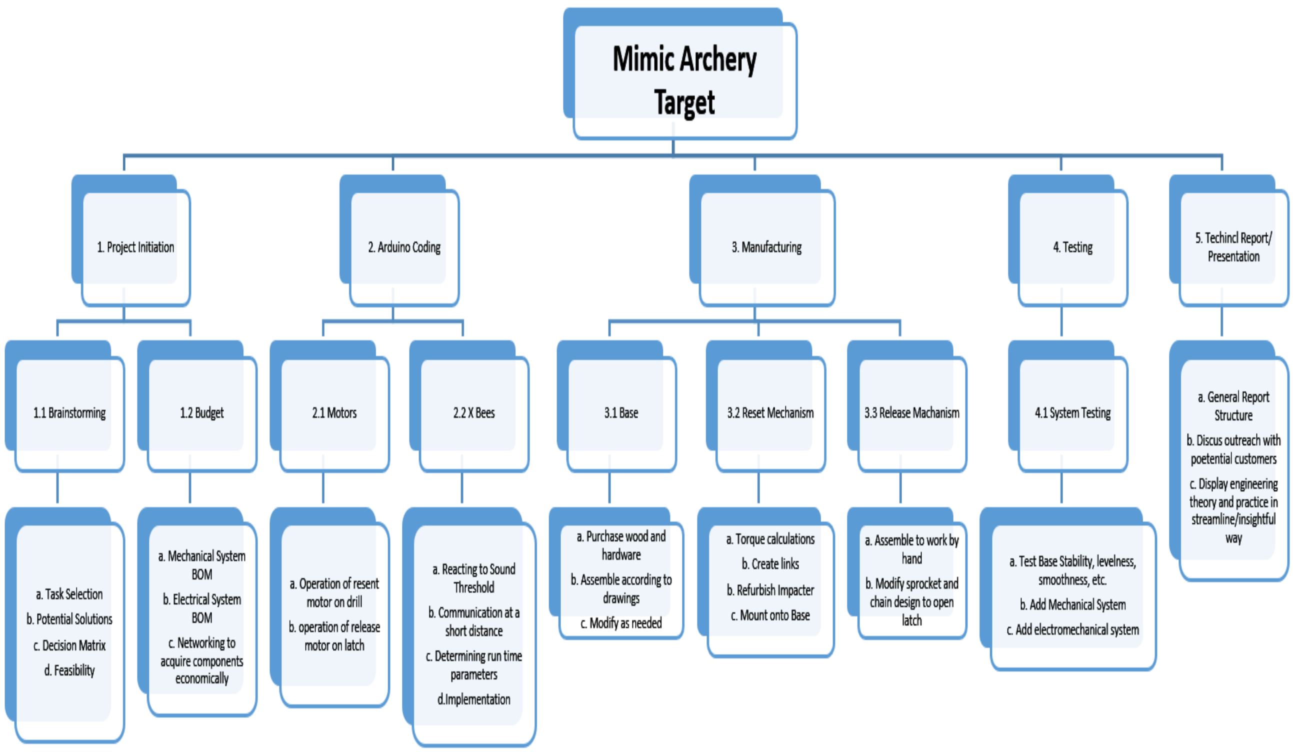



Figure 1, Planning layout of objectives and concepts

Senior Design Project

Mimic

| DATE | DESCRIPTION |
|---|---|
| 9/1/18 | Design Conceptualized |
| 9/25/18 | Design Proposed |
| 10/1/18 | Design Approval |
| 10/20/18 | Financing/Budgeting |
| 11/5/18 | Scheduling |
| 11/15/18 | Initial Design Embodiment |
| 12/5/18 | Material Collection |
| 1/14/19 | Coding/Programing |
| 2/10/19 | Trouble Shooting |
| 3/1/19 | Redesign Evaluation |
| 3/10/19 | Begin Report |
| 3/28/19 | Construction of Prototype |
| 4/1/19 | Submit Report for Readers |
| 4/5/19 | Gather Data |
| 4/18/19 | Fine Tune Report and Prototype |
| 4/26/19 | Working Prototype Presented |
| 4/26/19 | Report Submitted |

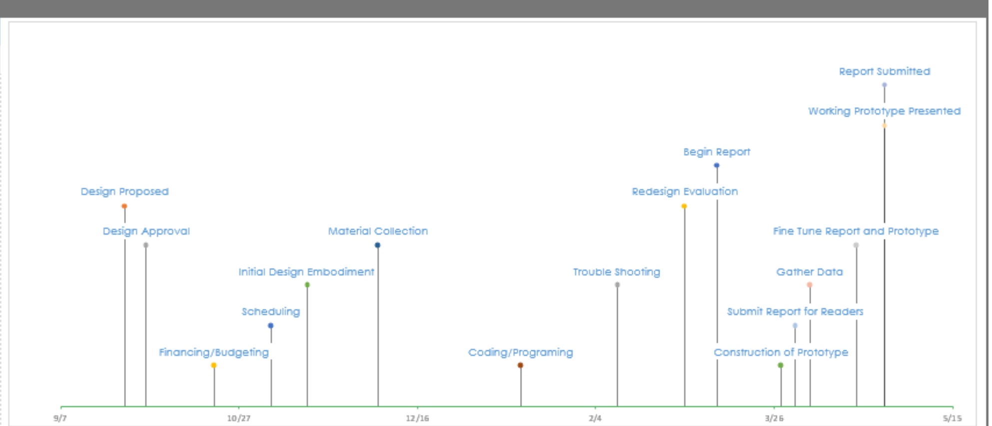


Figure 2, Project Timeline Overview

Senior Design Project

| Mimic | | | |
|---|---|---|---|
| START DATE | END DATE | DESCRIPTION | DURATION (days) |
| 9/1/18 | 9/25/18 | Design Conceptualized | 24 |
| 9/25/18 | 10/2/18 | Design Approval | 7 |
| 10/1/18 | 10/12/18 | Financing/Budgeting | 11 |
| 10/3/18 | 10/22/18 | Scheduling | 19 |
| 10/20/18 | 11/15/18 | Initial Design Embodiment | 25 |
| 11/1/18 | 12/5/18 | Material Collection | 34 |
| 11/20/18 | 2/10/19 | Coding/Programing | 80 |
| 12/3/18 | 1/29/19 | Trouble Shooting | 56 |
| 1/15/19 | 2/25/19 | Redesign Evaluation | 40 |
| 2/22/19 | 3/31/19 | Begin Report | 39 |
| 3/1/19 | 3/31/19 | Construction of Prototype | 30 |
| 4/1/19 | 4/8/19 | Submit Report for Readers | 7 |
| 4/8/19 | 4/20/19 | Gather Data | 12 |
| 4/10/19 | 4/23/19 | Fine Tune Report and Prototype | 13 |
| 4/20/19 | 4/26/19 | Working Prototype Presented | 6 |
| 4/23/19 | 4/26/19 | Report Submitted | 3 |

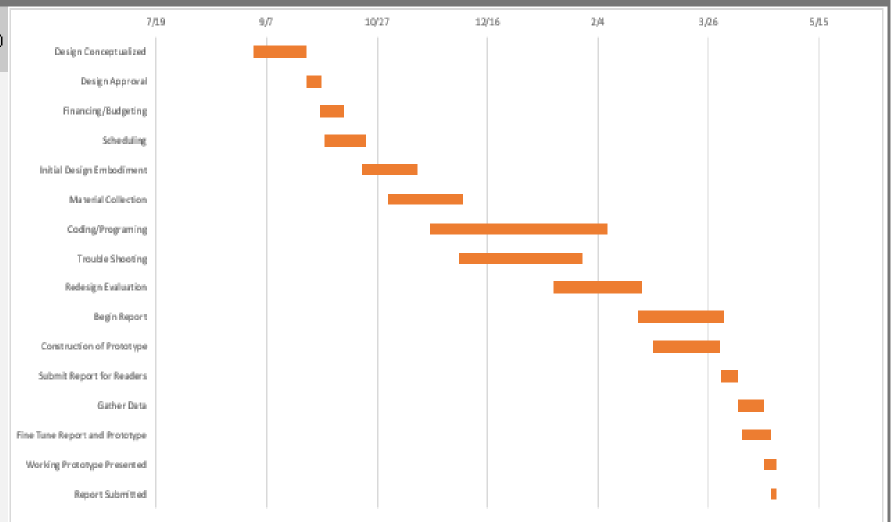



Figure 3, Project Gantt Chart Overview

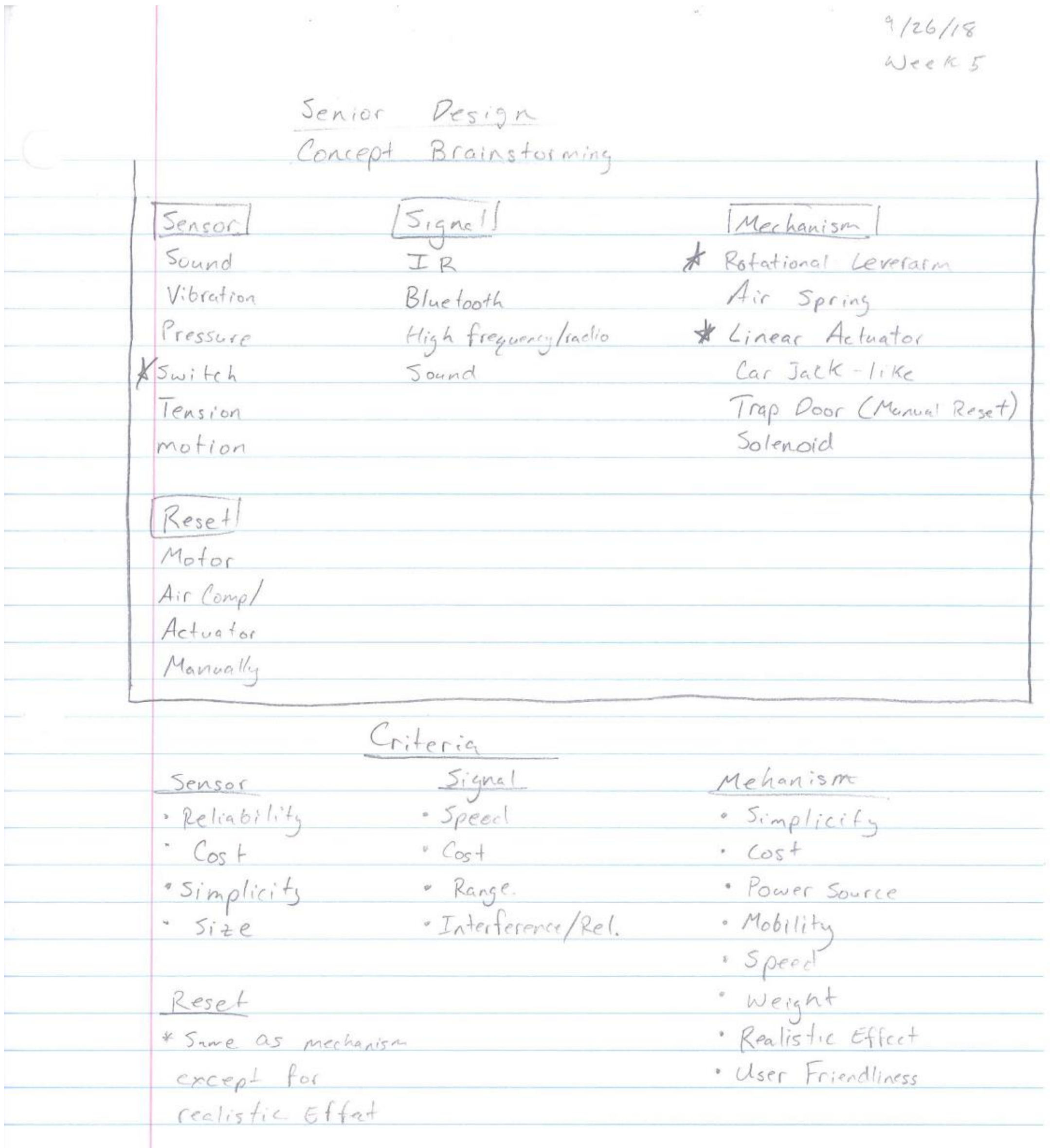
| Constants | Inputs | Calculated |
|---|---|---|
| **Speed of sound(m/s)** | **Target Distance (m)** | **Time for target to drop (s)** |
| 343 | 30 | 0.228 |
| **Speed of light (m/s)** | **Arrow speed (m/s)** | **Time for IR/RF signal to reach target (s)** |
| 299792458 | 100 | 1.00E-07 |
| **Deer Reaction time (s)** | **Sensor Distance (m)** | **Time for sound to reach target (s)** |
| 0.16 | 0.1 | 0.0875 |
| | **Drop Distance (m)** | **Time it takes arrow to reach target (s)** |
| | 0.254 | 0.3 |
| | **Processing time (s)** | **Time for sound to reach sensor (s)** |
| | 0.0001 | 0.000292 |
| | **Motor reaction time (s)** | |
| | 0.1 | |

Figure 4, Constants and Inputs for Deer Biology Calculations

| | | | Order of Events | | | | |
|---|---|---|---|---|---|---|---|
| Deer | | | | | | | |
| arrow sound | Sound travels to deer | Deer Reaction time (s) | | | Deer falls | | Duration (s) |
| | 0.0875 | 0.16 | | | 0.228 | | 0.4750 |
| senario 1 sound sensor on target | | | | | | | |
| arrow sound | Sound travels to target | Target processes the sound | Arduino engages mechanism | | Target falls | | |
| | 0.0875 | 0.0001 | 0.1 | | 0.228 | | 0.4151 |
| senario 2 using IR light | | | | | | | |
| arrow sound | Sensor processes sound | IR Signal travels to target | Target processes IR signal | Arduino engages mechanism | Target falls | | |
| | 0.0001 | 1.00E-07 | 0.0001 | 0.1 | 0.228 | | 0.327760848 |
| senario 3 using High frequency radio (RF) | | | | | | | |
| arrow sound | Sensor processes sound | Signal travels to target | Target processes IR signal | Arduino engages mechanism | Target falls | | |
| | 0.0001 | 1.00E-07 | 0.0001 | 0.1 | 0.228 | | 0.327760848 |

Figure 5, Overview of Reaction Time Calculations

# **Appendix B:** Manufacturing and Sketches



9/26/18
Week 5

Senior Design
Concept Brainstorming

| Sensor | Signal | Mechanism |
| --- | --- | --- |
| Sound | IR | * Rotational Leverarm |
| Vibration | Bluetooth | Air Spring |
| Pressure | High frequency/radio | * Linear Actuator |
| * Switch | Sound | Car Jack - like |
| Tension | | Trap Door (Manual Reset) |
| motion | | Solenoid |

Reset
Motor
Air Comp/
Actuator
Manually

Criteria

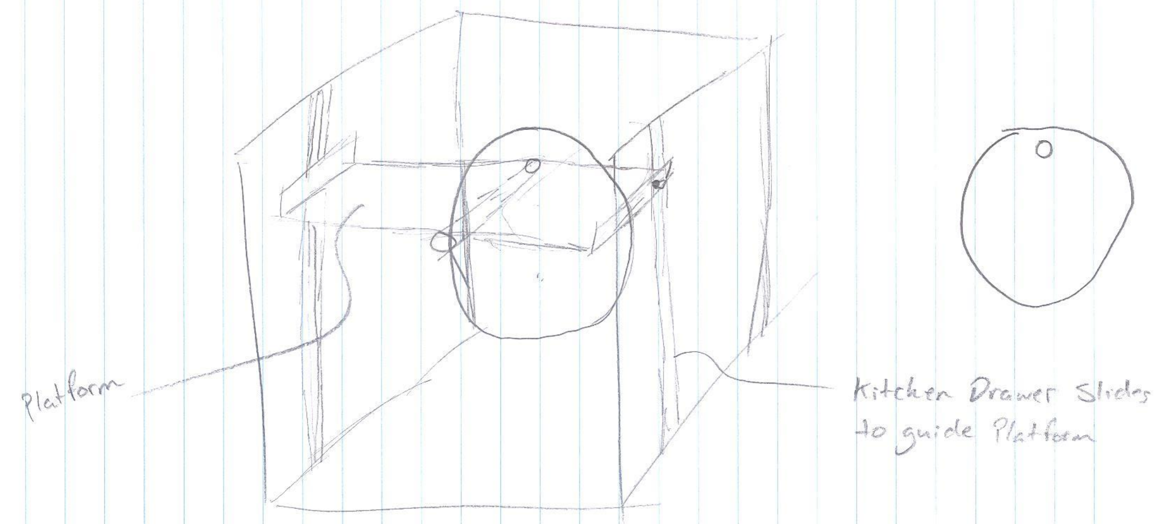
| Sensor | Signal | Mehanism |
| --- | --- | --- |
| • Reliability | • Speed | • Simplicity |
| • Cost | • Cost | • Cost |
| • Simplicity | • Range | • Power Source |
| • Size | • Interference/Rel. | • Mobility |
| | | • Speed |
| | | • Weight |
| | | • Realistic Effect |
| | | • User Friendliness |

Reset
* Same as mechanism except for realistic Effect

Basic Frame, Platform, and Slide Design

Austin Wied

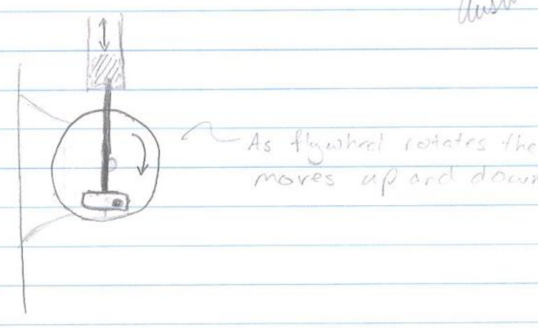
Austin Wied



10/11/18

Scotch Yoke Mechanism Under Target

Austin Merritt

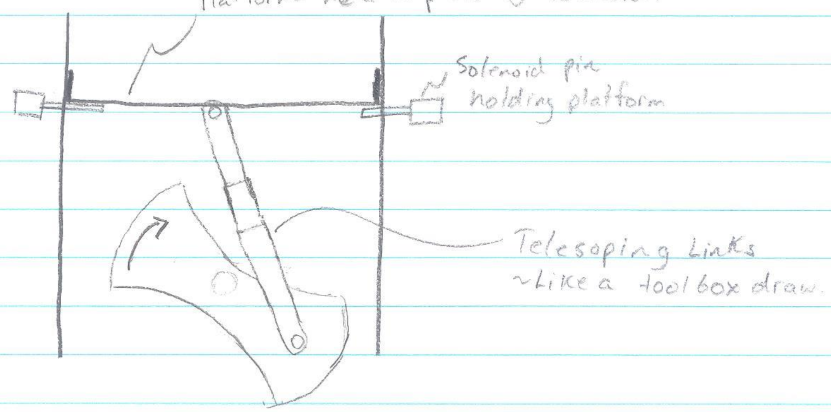



Pro: This mechanism could lift the target and release the target. Eliminating the need for expensive solenoids.

10/29/18

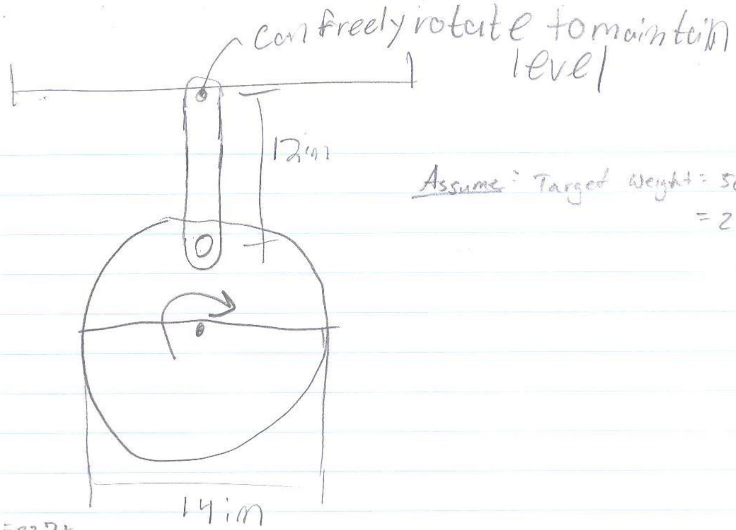
ME Design Project

Austin Wivell

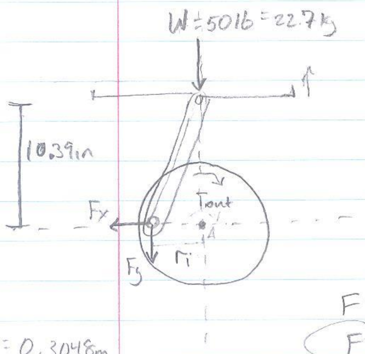



* In order to get needed Torque we must sacrifice motor speed. So it would be best in motor could return to lower Position to allow the target to simply freefall by releasing solenoid pin.

11/15/19




Assume: Target Weight = 50lb
= 22.7kg

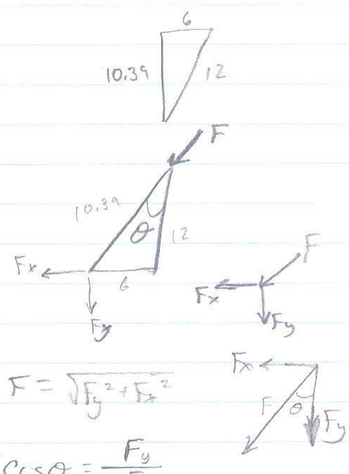



$\sum M_A = 0$

$T_{out} - F_y \times r_i = 0$

$T_{out} = F_y \times r_i$

$\boxed{T_{out} = F\cos\theta \times r_i}$




$F = mg = 22.7kg \times 9.81 m/s^2$

$F = 222.69N$

12in = 0.3048m

$T_{out} = 222.69N \cos(26.6°)(0.1524m)$

$\boxed{T_{out} = 30.35\ N\cdot m}$

$\sim 22.39\ ft\cdot lbs$

$F = \sqrt{F_y^2 + F_x^2}$

$\cos\theta = \frac{F_y}{F}$

$F_y = F\cos\theta$

$\sin\theta = \frac{F_x}{F}$

$F_x = F\sin\theta$

$\theta = \tan^{-1}\frac{6}{12}$

$\theta = 26.6°$

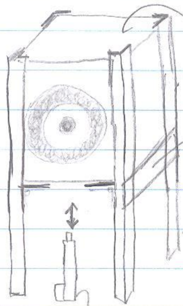
Torque Calculations
w/ 6" link and 50lb Target + Platform Weight.

10/11/14

Trap Door w/ Linear Actuator

Austin Wivell

(1)



Target

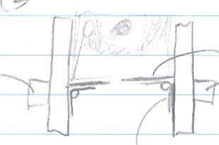
Latch Mechanism Plate (Solenoid operated)

Rails to guide target up/down

Linear Actuator. Resets Target after dropping.

Detailed View of Latch

(2)



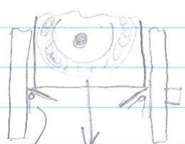
Solenoid

Latch closed (Holding target)

Solenoid Pin Extended (Holding target)

Torsion Spring (Strong enough to return plate but not hold the target)

(3)

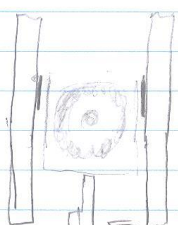


Solenoid Pin Retracted (Releases Target

Target begins to free fall

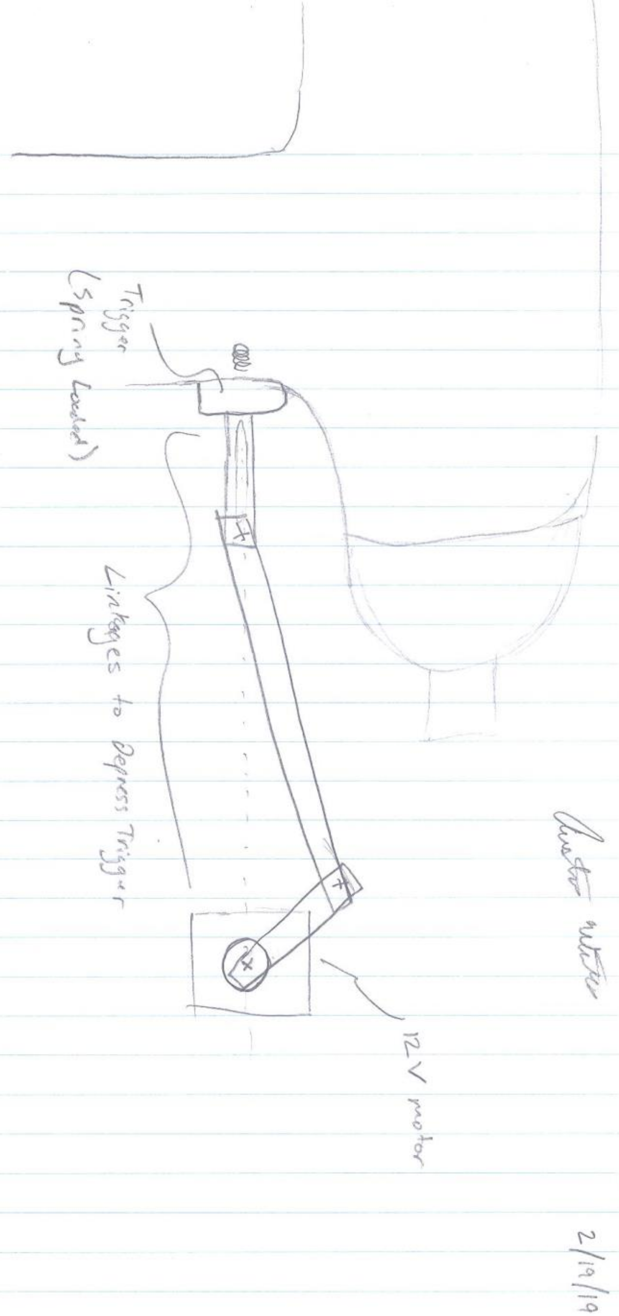
Springs begin to compress

(4)

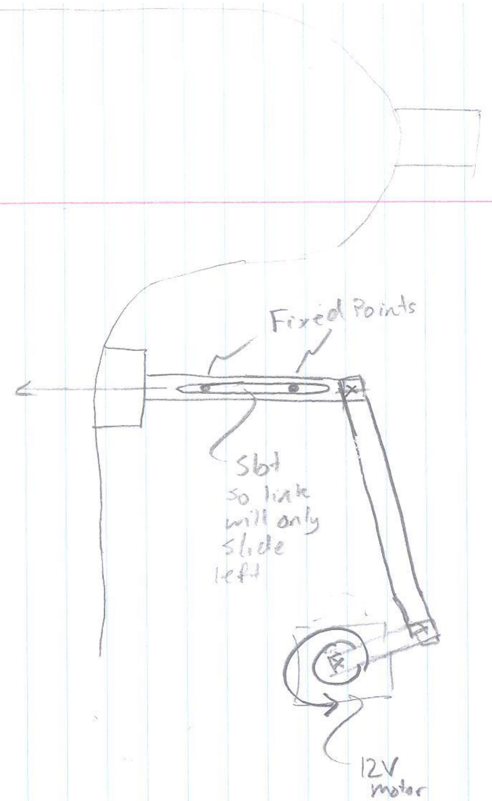


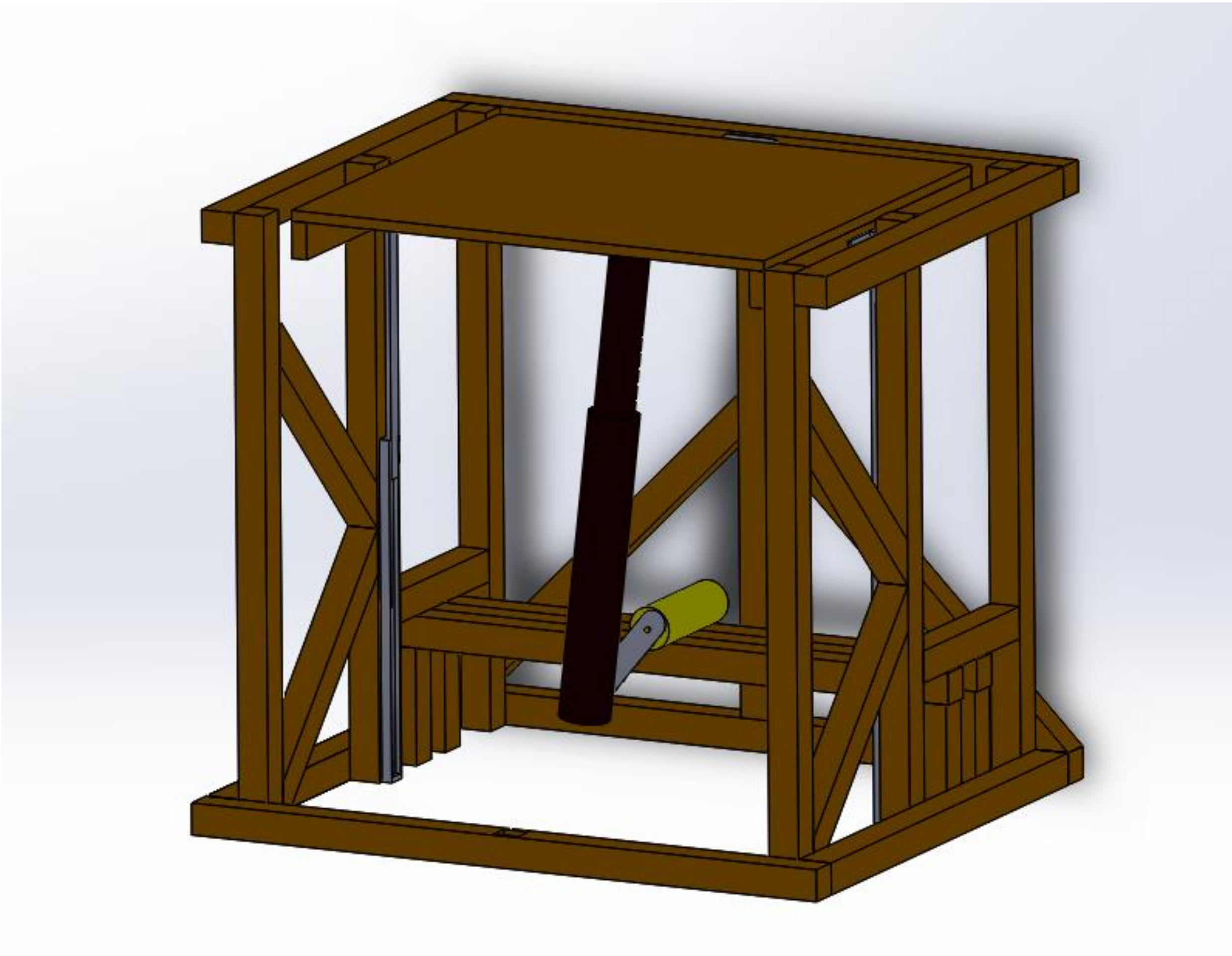
Target has fully fallen.

Linear Actuator ready to return target to position (1)

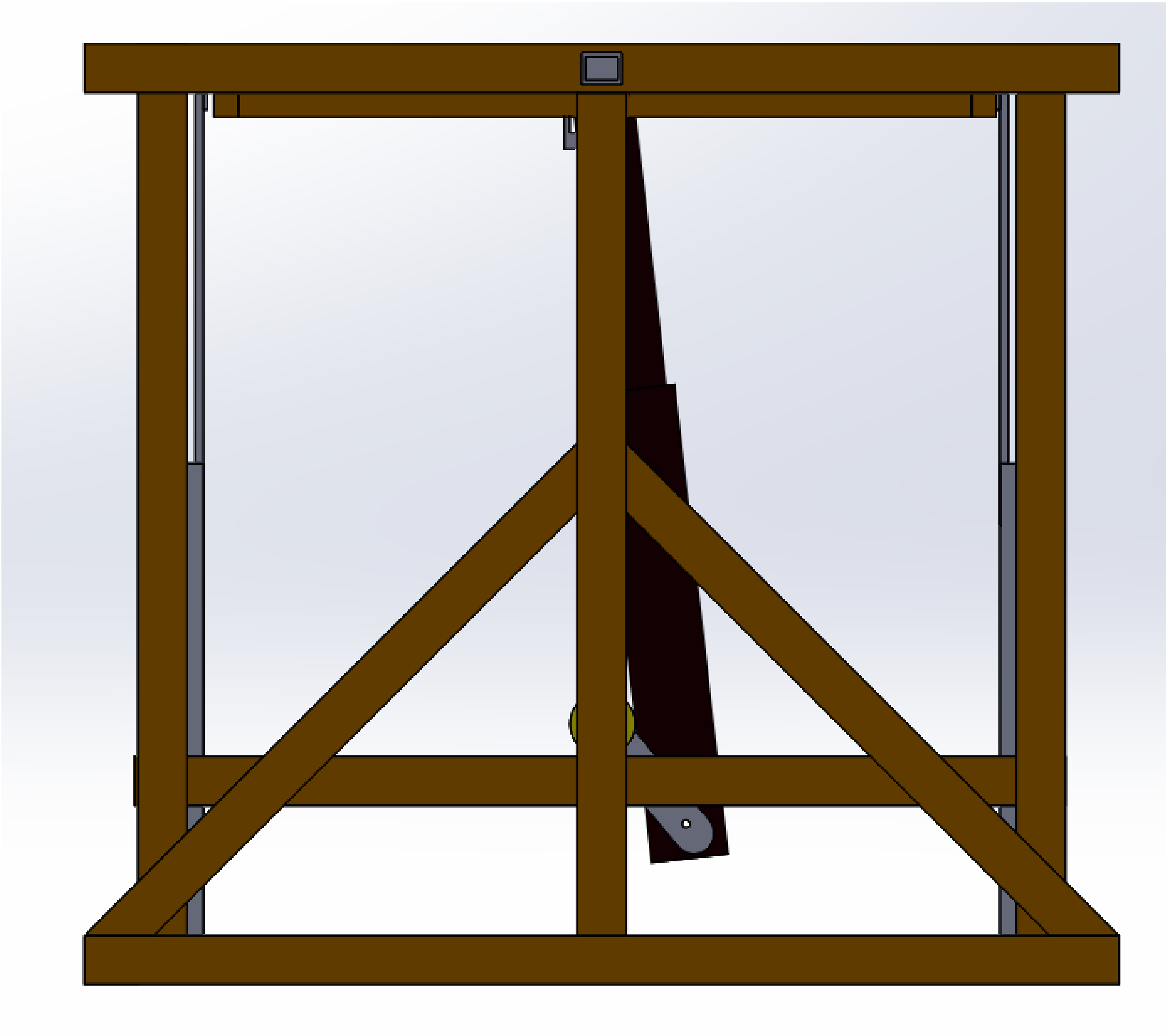

Trigger
(Spring Loaded)
Linkages to Depress Trigger
12V motor
2/19/19

Austin White 2/19/19





*Perspective view of Mimic Archery Target assembly in SolidWorks.*



*Rear view of Mimic Archery Target in SolidWorks.*

# **Appendix C:** Code

Figure 1: C++ Code written in ARDUINO for the demonstration Sound Sensor LED

```
#include <SoftwareSerial.h>
SoftwareSerial XBee(2, 3); // RX, TX double check the pins

int pReading;
const int gateDigitalSoundInput = 0;        // the Analog number of the Sparkfun sound
// the setup function runs once when you press reset or power the board
void setup() {
  XBee.begin(9600);
  Serial.begin(9600);
  pinMode(gateDigitalSoundInput, INPUT);
}

// the loop function runs over and over again forever
void loop() {
  pReading = analogRead(gateDigitalSoundInput);
  if(pReading > 40){ // if the sound detected is above a certain level
      XBee.write(pReading); // send signal on the XBee
      delay(100);                              // wait for a 0.1 second
  }

}
```

Figure 2: C++ Code written in ARDUINO for the wireless sound sensor

```
 // Define hardware connections
#define PIN_GATE_IN 2
#define IRQ_GATE_IN  0
#define PIN_LED_OUT 13
#define PIN_ANALOG_IN A0

// soundISR()


// This function is installed as an interrupt service routine for the pin
// change interrupt.  When digital input 2 changes state, this routine
// is called.
// It queries the state of that pin, and sets the onboard LED to reflect that
// pin's state.
void soundISR()
{
  int pin_val;

  pin_val = digitalRead(PIN_GATE_IN);
  digitalWrite(PIN_LED_OUT, pin_val);
}

void setup()
{
  Serial.begin(9600);

  //  Configure LED pin as output
  pinMode(PIN_LED_OUT, OUTPUT);

  // configure input to interrupt
  pinMode(PIN_GATE_IN, INPUT);
  attachInterrupt(IRQ_GATE_IN, soundISR, CHANGE);

  // Display status
  Serial.println("Initialized");
}

void loop()
{
  int value;

  // Check the envelope input
  value = analogRead(PIN_ANALOG_IN);

  // Convert envelope value into a message
  Serial.print("Status: ");
  if(value <= 2000) //equates to approx 80db

    Serial.println("Drop");


  // pause for .1 second
  delay(100);
}
```

Figure 3: C++ Code written in ARDUINO to run the Motors

```
#include <SoftwareSerial.h>
SoftwareSerial XBee(2, 3); // RX, TX double check the pins on the shield connection

const int resetPin = 7;// the number of the drill motor control pin
const int TriggerPin = 8;// the number of the latch motor control pin
// the setup function runs once when you press reset or power the board
void setup() {
  XBee.begin(9600);
  Serial.begin(9600);
  pinMode(resetPin, OUTPUT);
  pinMode(TriggerPin, OUTPUT);
}

// the loop function runs over and over again forever
void loop() {
  if (XBee.available())
  {                  // If data comes in from XBee,
    digitalWrite(resetPin, HIGH); // turn the motor on, to unpin the platform
    delay(10000);              // wait 10 seconds
    digitalWrite(TriggerPin,HIGH); // turn motor on to rest platform
    delay(2000);               // wait 2 seconds
    digitalWrite(resetPin,LOW); // turn the motor off,
    delay(2000);                      // wait 2 seconds
    digitalWrite(TriggerPin,LOW); // turn the motor off.
  }else{ // if no data comes in from XBee.
    digitalWrite(resetPin,LOW); // keep the motor off,
    digitalWrite(TriggerPin,LOW); // keep the motor off.
  }
}
```