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**Design and Implementation of an Automatic Let-Down System for an Archery Draw Board**

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ENGR 491 – Senior Design  
Spring 2022

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## **ACKNOWLEDGEMENTS**

In this section, I would like to acknowledge several people who helped greatly in making this project possible:

Dr. Paul Kuban for running the USI engineering department and making everything the engineering department does possible.

Mrs. Jamie Curry for making all kinds of arrangements, managing many of the duties of the engineering department, and generally making everyone's lives much easier in the engineering department.

Dr. Julian Davis for advising me on this project and devoting a tremendous amount of time and effort to helping me make this project possible.

Dr. Glen Kissel and Dr. Todd Nelson for reviewing this project and providing very helpful advice.

## **ABSTRACT**

The objective of this project was to design, test, and implement an improved archery draw board system. An archery draw board is a device that allows the user to draw and analyze characteristics of a compound bow. The bow is placed in the device and a winch mechanism is used to draw the bow string for analysis of bow parameters such as cam alignment, cam timing, and draw weight. Analysis of these parameters can allow the user to tune the performance of the bow. A new feature, the Automatic Let-Down System, was designed, tested, and implemented to achieve this goal. The design objectives for the Automatic Let-Down System were to improve the ease of use, speed, and safety of the draw board. The system allows the bow string to safely come to rest from full draw at a reduced speed without manipulation by the user. This improves upon current draw board designs that require the user to manually turn the handle of the winch to return the bow to a state of rest. The device was successfully designed, implemented, and tested with the design objectives in mind.

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# **DESIGN AND IMPLEMENTATION OF AN AUTOMATIC LET DOWN SYSTEM FOR AN ARCHERY DRAW BOARD**

## **1 INTRODUCTION**

The scope of this project covers the design, implementation, and testing of an Automatic Let-Down system for an archery draw board. A draw board was also built to serve as a base for implementation and testing of the automatic let-down system. Although the automatic let-down system was the focus of this project, it is important to distinguish that the base draw board was an important aspect as well. The draw board served as the test bed for the automatic let-down feature, and it was crucial that it was assembled in a way that kept implementation of the Automatic Let-Down System in mind. If this feature was implemented in an actual device to be marketed to consumers, the draw board would have to be designed around the implementation of the feature. It would likely not be a simple addition to an existing device. In summary of this distinction: the goal of this project is to create an improved draw board design through the design and implementation of a draw board with an Automatic Let-Down System. Design emphasis was placed on the automatic let-down system rather than the draw board as a whole because draw boards already exist and the one that was built for this project closely resembles commercially available devices to some degree.

After determining the makeup of the draw board, the automatic let-down system was designed. All the design for this project was done in a way that would be simple to implement using components that could be purchased. This eliminated a lot of analysis that would have been required if components were being designed and fabricated. The automatic let-down system was designed with specific design objectives in mind. Safety was one of the primary concerns when designing this device because of the potentially dangerous nature of drawing and releasing a compound bow. Multiple concepts were considered for the automatic let-down system and a final concept was selected after weighing the pros and cons of each concept. The most important factor in choosing a concept was meeting all the design objectives. An image of the finished device can be seen in Figure 1, and a subsystem breakdown of the device can be seen in Figure 2.



Figure 1.1: Completed Device

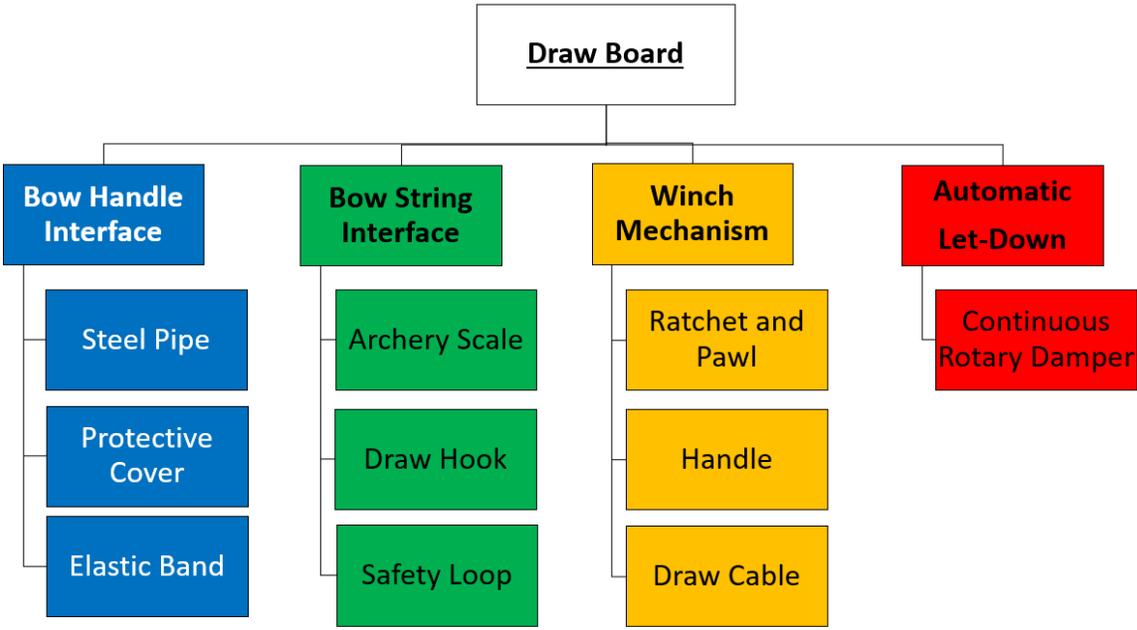


Figure 1.2: Subsystem Breakdown

## 2 BACKGROUND

This section will serve to help the reader understand the basics of a draw board, a compound bow, and the automatic let-down system.

### 2.1 DRAW BOARD DESCRIPTION

The core of this project is a device known as a draw board. This is a device used to analyze parameters of a compound bow. This analysis can help the user to tune the performance of the compound bow. In order to understand the purpose of a draw board, some key components of compound bows and draw boards will be described in the following subsections 2.1.1 and 2.1.2. An example of a commercially available draw board can be seen in Figure 2.1 which was sourced from [1].

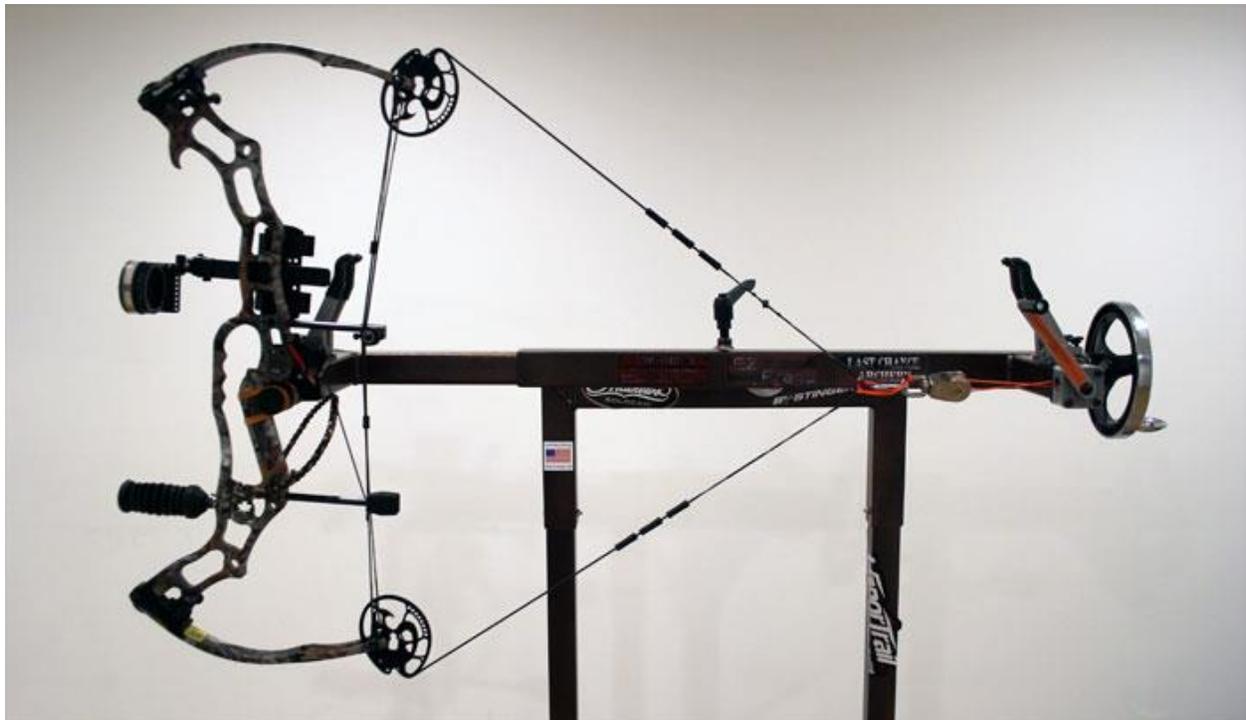
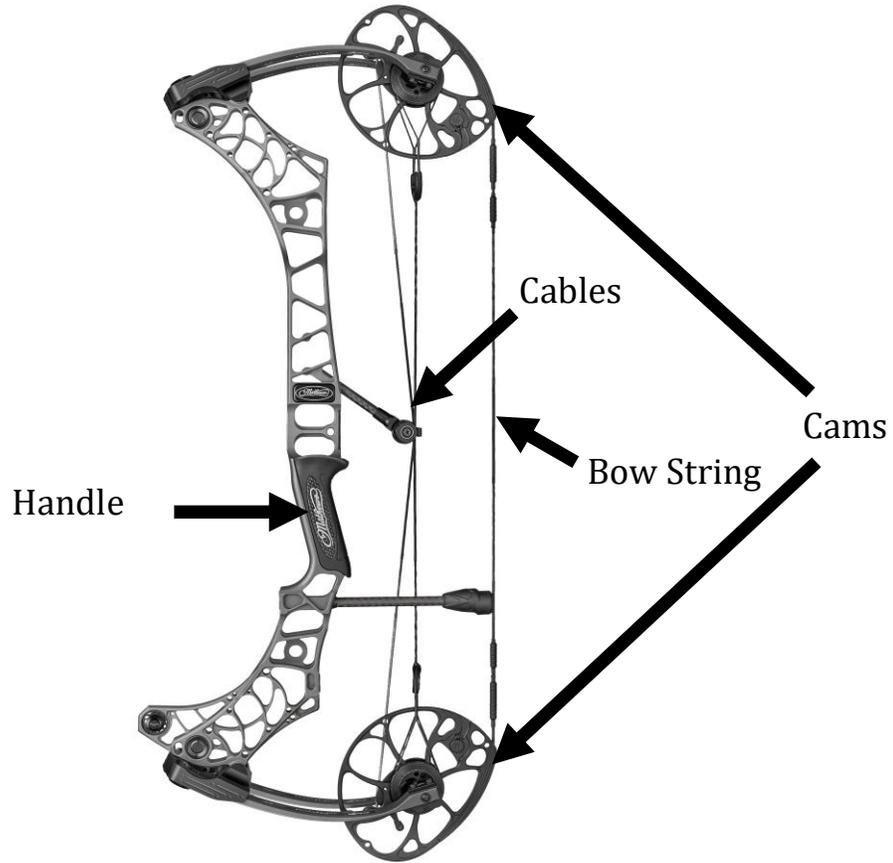


Figure 2.1: Last Chance Archery Draw Board

### ***2.1.1 Compound Bow Description***

A compound bow is a modern device used for archery. Compound bows are an evolution in design from a traditional bow like a longbow or recurve bow, which are basically flexible sticks with strings attached. A compound bow is much more complex than a more traditional bow. The only similarities are flexible limbs, a string, and the fact that they are used to propel arrows. Compound bows use rotating cams in conjunction with cables and flexible limbs to store potential energy when the bow string is drawn and release that potential energy into the arrow when the bow string is released. It is important to understand two dimensions of compound bows that will be used in this project; these dimensions being the draw length and let-down length. Draw length is defined as the distance measured from 1.75 inches in front of the deepest point on the bow handle to the bow string at full draw. This dimension is listed on commercially available bows so that the user can choose the correct draw-length bow to fit their body. The let-down length is a term that I have defined as the distance that the bow string travels between the point of rest and full draw. This value was necessary for the design of the automatic let-down system. An image of a modern compound bow with labeled components can be seen in Figure 2.1 which was sourced from [2].



**Figure 2.1: Compound Bow**

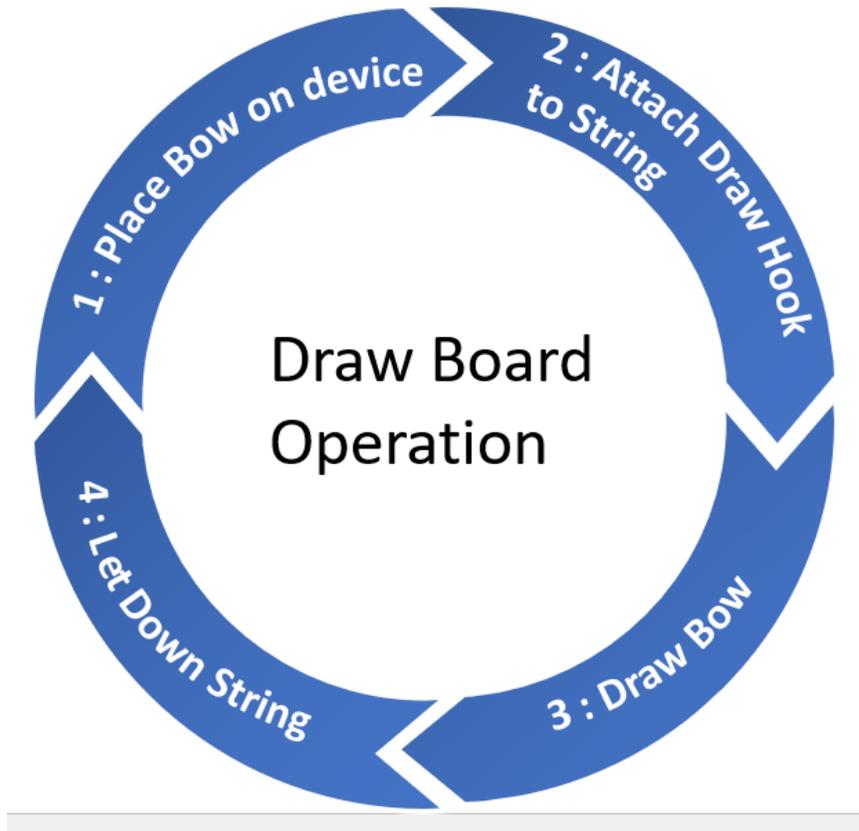
The cams and cables on compound bows are what sets them apart from more traditional bows. The bow string is attached to the cams, so the cams begin to rotate as the user begins to draw the bow string. Each cam is connected to one bow limb via an axle that the cam rotates around and connected to the other bow limb via a cable. As the user places tension on the bow string, that tension is transferred through the cams to the cables. The cables place tension on the flexible bow limbs. This causes the limbs to flex inward as the cams are rotated by the tension of the bow string. These limbs are typically made of fiberglass, and they are where the potential energy of the bow is stored. As the user pulls the bow string back to full draw, the cams reach a point in rotational position at the end of the draw cycle where their geometry greatly reduces the tension needed to hold back the bow string. This means that the user can hold the bow string at full draw with much less force than the force that was required to get the string to that position. This is one of the main advantages of a compound bow over a traditional bow. The user can

hold the bow at full draw for much longer than they would be able to hold an equivalent draw weight traditional bow at full draw. A modern compound bow can typically be held at full draw with a force equivalent to only 15-20% of the peak draw weight.

While compound bows have great advantages over traditional bows, the complexity of a compound bow means that there are certain components that must be tuned for the bow to perform properly. These parameters are draw weight, cam alignment, and cam timing. The draw weight of a bow is the maximum force required to bring the bow string to full draw. Cam alignment is a term that describes how the cams are aligned horizontally. Perfect cam alignments means that both cams rotate exactly in line with one another throughout the entire draw cycle of the bow. Cam timing is a term that defines the rotational position of each cam at any point in the draw cycle of the bow. Perfect cam timing means each cam should have an equivalent angular position to the other cam at all points in the draw cycle. Each of these parameters plays a role in the performance of a compound bow. If any of these are off from what they are expected to be, the bow will not propel the arrow as straight and as consistently as possible. These parameters can be adjusted by adjusting the components of a compound bow. Cams can be moved left or right to correct cam alignment and cable lengths can be adjusted to correct cam timing. Draw weight can be adjusted by adding or reducing tension on the bow limbs. These parameters can be extremely difficult or impossible to analyze without the aid of a device like a draw board.

### ***2.1.2 Draw Board Purpose***

The core of this project is a device known as a draw board. This is a device used to analyze parameters of a compound bow. This analysis can help the user to tune the performance of the compound bow. A draw board is essentially a device that allows the user to draw and let down a compound bow without holding the bow by hand. This is useful because it allows the user to analyze the draw cycle of the bow from a perspective that would be impossible if the user had to manually draw the bow while holding it. The user can stand to the side of the bow and look closely at the limbs and cams of the bow as it is being drawn. This is important because it allows the user to see things like cam alignment and cam timing. Some draw boards can also include a scale that measures the draw weight of the bow. All these parameters can be useful for tuning the bow to shoot arrows as straight and consistently as possible. A concept of operations for a typical draw board can be seen in Figure 2.2.



**Figure 2.2: Draw Board Concept of Operations**

## **2.2 CURRENT DRAW BOARD DESIGNS**

There are several draw boards available on the commercial market currently. These devices all operate similarly to each other. The user places the bow handle on the device, attaches the draw hook to the bow string, draws the bow string by turning the winch handle, and lets down the bow string by turning the winch handle in the opposite direction.

### **2.2.1 Last Chance Archery Draw Board**

The Last Chance Archery draw board is a draw board designed to be mounted to a Last Chance Archery bow press. A bow press is a device used to apply pressure to the limbs of the bow to flex them and hold them in place to a point where the user can remove the string and cables of the bow due to the tension being removed from the strings and cables. Last Chance Archery designed their draw board to be mounted to their bow press simply as a measure to save space and allow users to purchase just the critical draw board components without having to purchase a base for the device if they already own a Last Chance Archery bow press. The way in

which this draw board is mounted is largely irrelevant for the purposes of this project as it is just the main components and functionality of the draw board that were assessed for the research portion of this project.

The Last Chance Archery draw board functions as outlined in the concept of operations detailed in figure 2.2. The user must manually draw and let down the bow by operating a winch mechanism. This draw board utilizes a synthetic rope as a draw cable and does not include a device of any kind for measuring draw weight. An image of the Last Chance Archery draw board main components can be seen in Figure 2.3, which was sourced from [3].



**Figure 2.3: Last Chance Archery Draw Board**

### ***2.2.2 Archerydezin Draw Board***

Similarly to the Last Chance Archery draw board, the Archerydezin draw board components are also designed to be mounted to a commercially available bow press. This device is very similar to the Last Chance Archery draw board, but it uses a nylon strap for a draw cable rather than a synthetic rope. Functionality of this device follows the concept of operations outlined in figure 2.2. An image of the Archerydezin draw board components can be seen in Figure 2.4, which was sourced from [4].



**Figure 2.4: Archerydeign Draw Board**

### ***2.2.3 Hammer Hanger Bow Draw Winch***

The Hammer Hanger Bow Draw Winch is slightly different from the previous two devices because it is not designed to be mounted to a bow press. It is, however, designed to be mounted onto a table or work bench. This draw board utilizes a simple winch mechanism similarly to the other draw board designs and follows the same concept of operations outlined in figure 2.2. A nylon strap is used for the draw cable in this device. An image of the Hammer Hanger Bow Draw Winch can be seen in Figure 2.5, which was sourced from [5].



**Figure 2.5: Hammer Hanger Bow Draw Winch**

### ***2.3 AUTOMATIC LET-DOWN SYSTEM DESCRIPTION***

The automatic let-down system is an attempt to modify and improve the use of a draw board. This system is a component for a draw board that will allow the bow string to be let down safely from full draw without manipulation by the user. Letting down the bow string at a reduced speed is essential. Releasing a bow from full draw with no resistance to absorb the potential energy being released can lead to the limbs of the bow shattering. This occurs because the potential energy stored in the limbs is transformed into kinetic energy upon release of the bow string from full draw. Much of this energy is typically transferred to the arrow upon firing the bow, but if an arrow or some other form of resistance is not present, all of the energy is absorbed by the bow itself. Releasing the string from full draw without firing an arrow is called dry firing. Dry firing a bow can cause permanent damage and potentially injure the user. The automatic let-down system would absorb energy during the let-down process by providing resistance to the force of the bow, which would prevent damage to the bow and injury to the user. In most draw board designs; the user must manually let down the bow string by turning the winch handle of the device. An automatic let-down system does not exist on any commercially available draw board currently. This would remove a step of draw board operation because the user would no longer have to manually let down the bow string by turning the winch handle after drawing the bow. This system could reduce the time needed to use the device and improve the safety of the device in some cases. Multiple possible concepts were considered when designing this system. These concepts will be described in the design section following.

### **3 DESIGN**

There are two aspects to the design of this project: the requirements of the draw board and the design of the automatic let-down system. While the draw board was not necessarily designed, components were selected for it based on some requirements that were set in place. The draw board had to be built in a way such that it was adaptable and capable of meeting requirements. This way the draw board could serve as a base for the design and implementation of the automatic let-down system which is the focus of this project. It is, however, important to consider the requirements of the draw board as well because it is directly related to how the automatic let-down system was implemented and tested.

#### ***3.1 DRAW BOARD REQUIREMENTS***

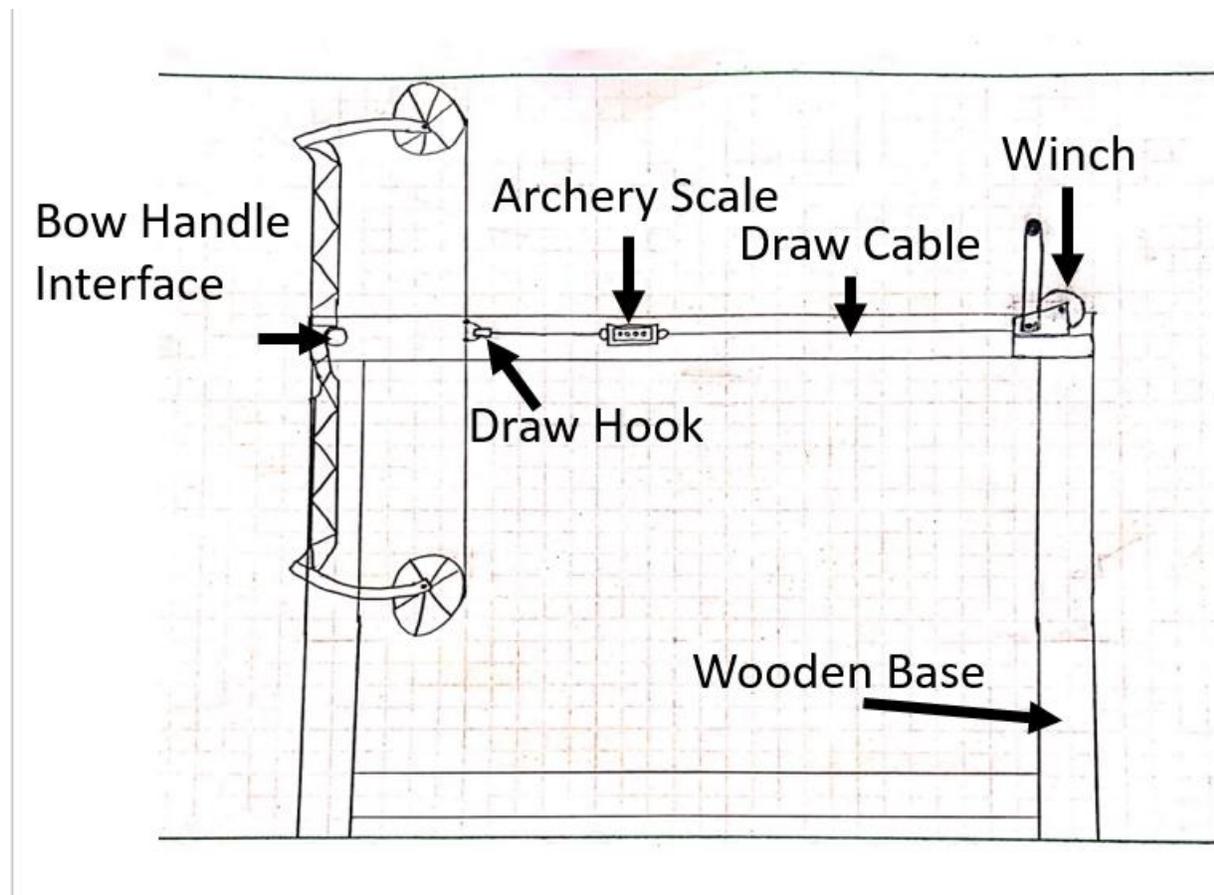
Components were selected for the draw board build based on some requirements so that it could be compared reasonably to draw boards that are commercially available. These requirements were:

- The device must be capable of drawing a bow with a 100-pound maximum draw weight
- The device must be capable of drawing a bow with a 36-inch maximum draw length
- The device must be capable of drawing a bow in under five seconds
- The device must be capable of measuring and displaying draw force
- The device must allow for the addition of an automatic let-down system

These requirements allow the device to be used with any commercially available compound bow. Compound bows are not available with a draw weight higher than 100 pounds or a draw length longer than 36 inches. This means that the device could be used with any commercially available compound bow. Draw force measuring capability was necessary because draw force is one of the important factors in tuning the performance of a bow as mentioned previously. Capability to draw the bow in under five seconds was a value that was set as an estimate after assessing some videos of commercial draw boards in use. Under five seconds was essentially an educated guess at a slight reduction in draw time when compared to the draw time of commercially available draw boards. It was determined from initial winch testing that the winch handle could be turned at an angular velocity of 2.21 rev/s while drawing the bow. This angular velocity was used to make an educated guess at the average draw time of a commercially available draw board. This was done by analyzing a video of a Last Chance Archery draw board

in use [6]. It could be seen from the video that the user had to turn the winch handle about 14 revolutions to reach full draw. It was assumed that the user could theoretically turn the winch handle of the device at the same angular velocity that was found in initial draw testing. Based on this assumption, it was determined that a last chance archery draw board should have a draw time of about 6.3 seconds. This validates the five second maximum draw time parameter that was the goal for the draw board being built for this project.

Once these requirements were set, a sketch of the device was created. Components were selected from McMaster-Carr that could meet the requirements of the device theoretically. A sketch of the draw board design can be seen in Figure 3.1.



**Figure 3.1: Draw Board Sketch**

The base of this device could be built from wood that was already available. All other components could be purchased and attached to the base.

### ***3.2 AUTOMATIC LET-DOWN SYSTEM DESIGN***

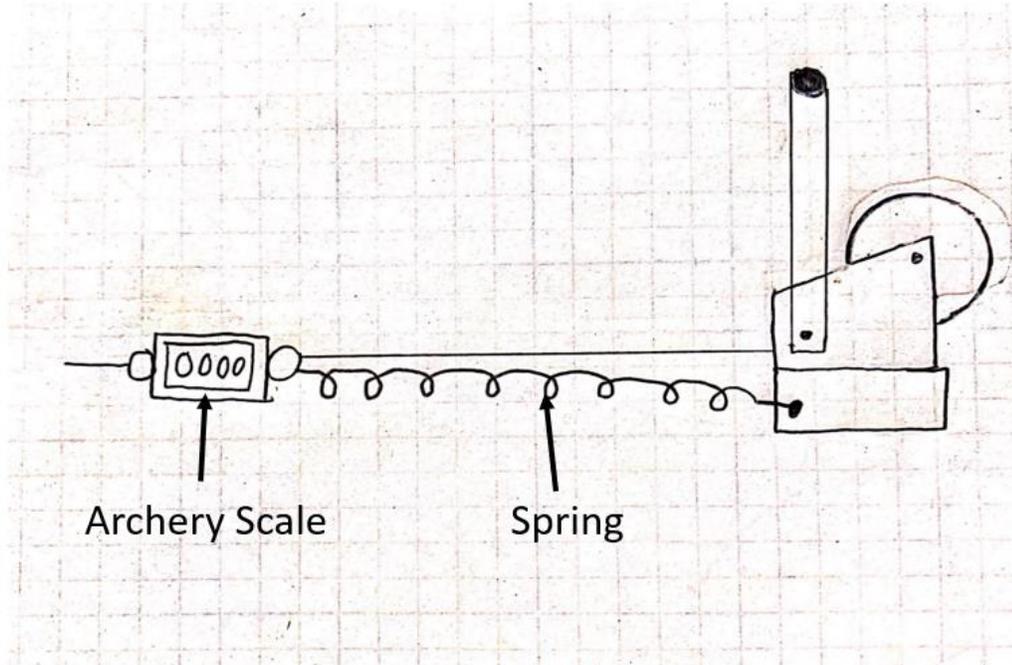
The design of the Automatic Let-Down System was the primary focus of this project. This system is the key to improving the operation of the draw board. The automatic let-down system was designed with some design objectives in mind. These design objectives were:

- The system must be capable of safely letting down the bow string in over one second and under five seconds
- The user must be able to attach the draw hook to the bow string without applying a force greater than 20 pounds to pull out the draw cable
- The device must be capable of safely letting down the bow string over a maximum let-down distance of 28.25 inches

The maximum let-down time was set at under five seconds because the maximum draw time was set at five seconds. In order for the automatic let-down system to add value to the device in terms of time saving, the user must be able to let down the bow faster than they could manually let down the bow with the winch handle. Theoretically, the time required to manually let down the bow should be equivalent to the time required to draw the bow. The second objective value was set somewhat arbitrarily. It seemed reasonable that the user should not have to apply a force greater than 20 pounds to the draw cable in order to attach it to the bow string. This value was set in an attempt to ensure that the device would improve the user experience when using the draw board. This is important to consider because the automatic let-down system fundamentally must apply some form of force or resistance upon extraction of the draw cable in order to reduce the speed of let-down of the bow string. The value set by the third objective is determined based on a bow with a 36-inch draw length and a 6-inch brace height, which is the maximum dimension bow that was already defined in the requirements of the draw board. In addition to these design objectives, designing a system that was as simple as possible was desirable. Simple in this case indicating a low number of additional components. Three Automatic Let-Down System design concepts were created and considered.

### 3.3 *AUTOMATIC LET-DOWN CONCEPT 1: LINEAR SPRING SYSTEM*

The first Automatic Let-Down System concept is designed to make the system as simple as possible. In this design, the force of the bow would be counteracted directly by the force of a linear spring. A sketch of the Linear Spring System can be seen in Figure 3.2.



**Figure 3.2: Automatic Let-Down Linear Spring System**

In this concept, a spring is attached to the base of the draw board on one end and to the bow string interface on the other end. This creates a system where the spring would apply force in the opposite direction of the force of the bow string. This concept would be ideal if it could accomplish the design objectives because of the simplicity of this concept. This would only require the addition of one component to the draw board, that being the spring.

This concept has great positives, but there is one issue that makes this concept unusable. One of the design objectives would be impossible to meet with this concept. The user must be able to pull out and attach the draw hook to the bow string without applying a force greater than 20 pounds. This would not be possible with this concept because the spring constant would be too low to provide sufficient resistance to the bow string during the let-down process. Equation 1 was used to determine the maximum possible spring constant that could be used such that the

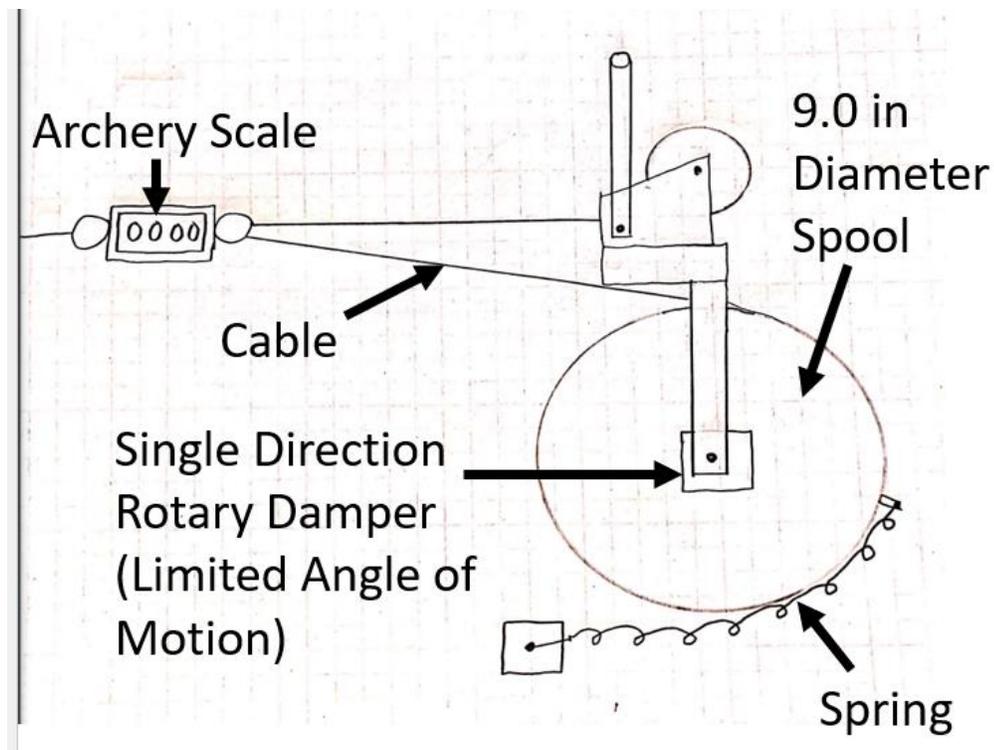
user would not have to apply more than 20 pounds of force to stretch the spring 28.25 inches, as this is the maximum let-down distance of the device.

$$\text{Equation 1: } F=kx$$

The maximum spring constant that could be used for this concept is 0.708 lb/in. The issue with this spring should be abundantly clear without further analysis due to the fact that at a maximum it would only produce 20 pounds of resistance, but this issue is made more apparent when considering the draw force curve of a compound bow. As a compound bow is drawn, the draw force typically increases throughout the draw process until the end of the draw cycle when the cams fully rotate and decrease the draw force by 60-90%. This is important because this indicates that the maximum draw force of the bow is occurring somewhere in the first few inches of the let-down cycle. This is the point at which the spring would produce very little force to resist the force of the bow. This makes it clear that the maximum strength spring that could be used in this concept would not apply sufficient resistance to reduce the speed of the bow string to a safe level during the let-down cycle.

### ***3.4 AUTOMATIC LET-DOWN CONCEPT 2: SECONDARY ROTATIONAL SYSTEM***

In this concept, a combination of components is used to apply resistance to the bow string during the let-down cycle. These components are a single direction rotational damper, A spool large enough to limit rotational motion to under 360 degrees, a linear spring, and a cable to attach the outer edge of the spool to the bow string interface. A sketch of this concept can be seen in Figure 3.3.



**Figure 3.3: Automatic Let-Down Secondary Rotational System**

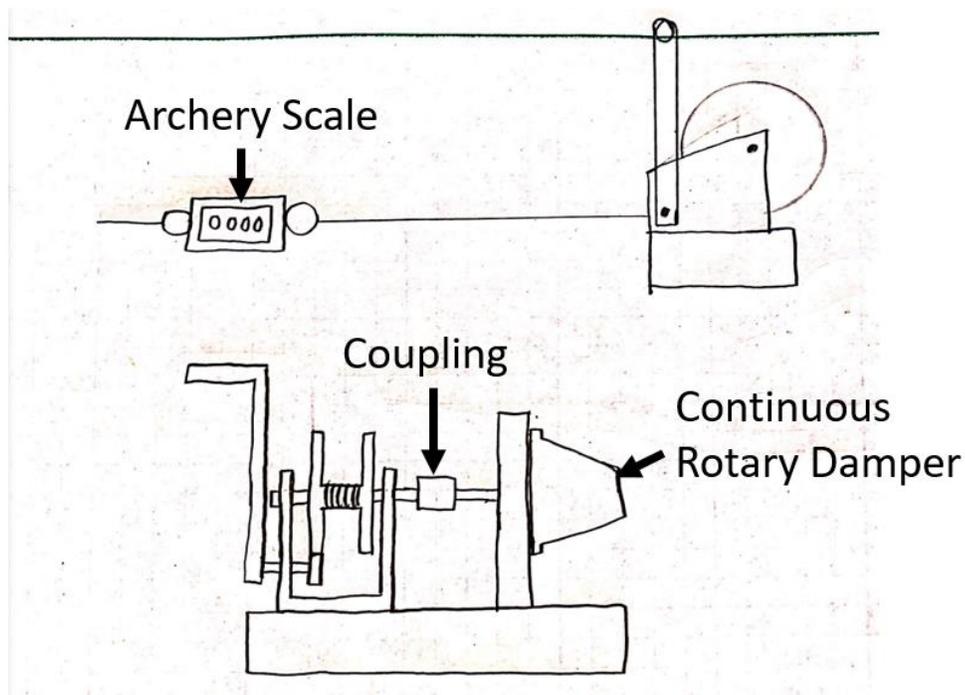
The purpose of the rotational damper is to resist force proportional to velocity of the bow string. This is accomplished by converting the linear motion of the bow string into rotational motion of the spool which is coupled to the damper in this concept. The damper in this concept reduces the velocity of the bow string, thus increasing let-down time theoretically to over one second. The purpose of the large spool is to limit rotational motion to under 360 degrees. This is necessary due to the single direction rotational damper having a limited angle of motion. This is done simply by choosing a spool with a circumference equal to the maximum let-down length that the device is being designed around, which is 28.25 inches. This means the spool would need to be nine inches in diameter. The purpose of the spring in this concept is simply to rotate the spool and draw in the cable as the bow is being drawn such that the cable attached to the spool will be fully retracted upon the bow reaching full draw. This is essential because the let-down system must be in this fully retracted position before the bow can be automatically let-down by this concept.

This concept accomplishes the design objectives by using correct values for the spring constant, damping coefficient, and moment of inertia of the spool. This concept would require

the addition of 4 components to the draw board. This would be relatively difficult to analyze and implement due to this complexity, as well as most likely being more expensive than the other concepts.

### **3.5 AUTOMATIC LET-DOWN CONCEPT 3: INCORPORATED DAMPING SYSTEM**

This concept combines the damping aspect from the Secondary Rotational System concept with greater simplicity present in the Linear Spring concept. The idea of this concept was to use a continuous rotational damper coupled directly to the winch mechanism to resist the force of the bow string during the let-down process. A sketch of this concept can be seen in Figure 3.4.



**Figure 3.4: Automatic Let-Down Incorporated Damping System**

The linear motion of the bow string is related directly to the rotational motion of the winch shaft. This means that the rotational damper coupled to the winch shaft applies damping to the linear velocity of the bow string. This could theoretically reduce the velocity of the bow string such that the let-down time would fall between one and five seconds if a suitable damper is used. Theoretically the user would not have to apply a force greater than 20 pounds to the draw cord to attach the draw hook to the bow string in this concept. The let-down length is

irrelevant in this concept due to the use of a continuous rotational damper with unlimited angle of motion. This means that this concept could meet all the design objectives without being overly complex. This concept would only add one additional component to the device, that being the rotational damper.

### **3.6 *SELECTED CONCEPT***

Concept 3, the incorporated damping system, was selected for the purposes of this project. This concept was selected because it was the concept that was the simplest while meeting all the design objectives. One issue with this concept is how rotational dampers are listed online. Rotational dampers that can be ordered are typically designated by maximum torque rating rather than damping coefficient rating. This means that a damper could be chosen such that its maximum torque rating would not be exceeded, but this does not necessarily mean anything with regards to the damping coefficient of the available dampers. This means that testing needed to be done with available dampers in order to determine if they could work as desired for the purposes of this project.

## 4 IMPLEMENTATION

All components for the device were purchased at the same time. As such, the draw board components and a rotational damper were ordered at the same time for implementation of the project. All components were ordered from McMaster-Carr aside from the archery scale, which was ordered from Lancaster Archery Supply. All purchased components can be seen in Appendix A. The winch was chosen because it was the lowest maximum force rated winch available from McMaster-Carr at a maximum force rating of 600 pounds and a gear ratio of 1:3.2. The draw cord was chosen simply because it was the correct diameter steel cable to work with the winch that was chosen. The archery scale was chosen because it had interfacing points that would attach easily to the device and it was rated for a maximum force of 110 pounds, which exceeds the maximum force of 100 pounds that the device was being designed around. The first damper was chosen because it was the highest available maximum torque rating rotational damper available from McMaster-Carr. Equation 2 was used to determine that the winch shaft must be no larger than 0.672 inches in diameter for the maximum torque rating of the damper to not be exceeded. The damper had a maximum torque rating of 33.6 inch pounds, and the maximum draw force of the bow is 100 pounds, as previously stated.

$$\text{Equation 2: } T=(F)(r)$$

The damper also had an extended shaft that would be easy to couple to the shaft of the winch mechanism in theory. The winch shaft diameter was not given in the specifications at the time of ordering, so it was assumed that the winch shaft might be close to 0.672 inches in diameter, meaning that the highest maximum torque rating damper might be necessary in order for the maximum torque rating of the damper to not be exceeded. Listed damping coefficients could have been useful in determining the best damper to order, but these values were not listed, so maximum torque rating had to be used as a metric for determining the most appropriate damper for the design.

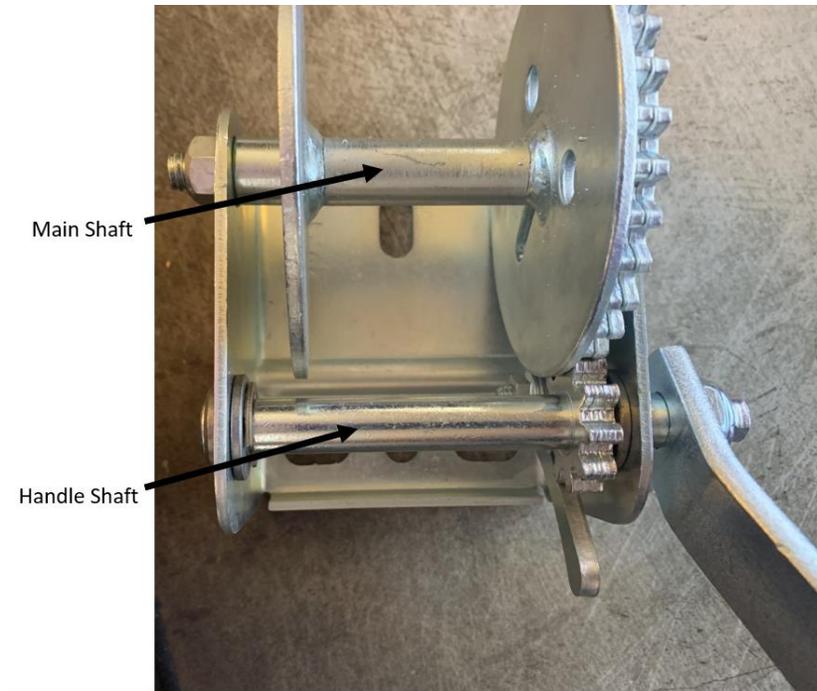
### ***4.1 DRAW BOARD IMPLEMENTATION***

Implementation of the draw board was relatively simple. The base was fabricated from wood that was available and held together by screws. Images of the draw board implementation can be seen in appendix D. These images provide dimensions as well. The 54-inch length was determined by adding the 36-inch maximum draw length, 13.5-inch bow string interface length,

and 4-inch winch base length. This number comes out to 53.5 inches. I decided to add an extra ½ inch because it functionally takes nothing away from the device and provides extra leeway for tolerance issues. The 48-inch height was determined based on personal ergonomics. While this height seemed appropriate for my own use of the device, that height might not necessarily be suitable for every individual. The steel pipe was cut to a length of 6 inches and press-fit into a 2-inch-deep hole that was drilled into the base and glued in place to serve as the bow handle interface. The base was significantly reinforced around the area where the winch mechanism would be attached, and the winch mechanism was attached to the base with ¼ inch bolts.

#### ***4.2 AUTOMATIC LET-DOWN SYSTEM IMPLEMENTATION***

The implementation of the automatic let-down system into the draw board was theoretically simple, the rotational damper simply had to be coupled to the main shaft of the winch and mounted into the base of the draw board. The original design intention could not be accomplished due to the winch mechanism design being different than originally anticipated. Originally it was assumed that the main shaft of the winch was a solid rotating shaft, meaning it would be relatively simple to couple the damper to the end of the rotating solid shaft via a coupling. Upon receiving the winch, it was discovered that this was not the case. The main shaft of the winch was a sort of sleeve that rotates around a stationary bolt. The winch mechanism can be seen in Figure 4.1.



**Figure 4.1: Winch Mechanism**

The main shaft being a sleeve meant that there was no rotating shaft to couple the damper to. This means that the damper had to be coupled to the motion of the winch in a different way than originally planned. As can be seen in figure 4.1, the handle shaft of the winch is a solid shaft. This means that the damper could be coupled to it instead of the main shaft. It was determined that coupling the damper to the handle shaft would be the best solution. This was done by drilling a hole slightly larger than the damper shaft into the end of the handle shaft of the winch so that the damper shaft could be inserted into the hole. Two holes were then drilled and tapped into the handle shaft perpendicular to the first hole so that two set screws could be inserted and tightened against the flat side of the damper shaft to secure it in place. This meant that the damper could be coupled directly to the motion of the handle shaft of the winch. An image of this attachment can be seen in Figure 4.2.



**Figure 4.2: damper attachment**

The damper being attached to the handle shaft rather than the main shaft caused some values to be different than originally designed for. The 1:3.2 gear ratio of the winch mechanism means that the handle shaft experiences 3.2 times less torque than the main shaft. This means that 3.2 times less torque is acting on the damper than in the original design concept. This could potentially cause issues as will be outlined in testing.

## 5 TESTING

### 5.1 FIRST ITERATION TESTING

Initial testing was done upon assembly of the device. An available test bow was used for the device testing. This bow had a draw weight of 75 pounds and a draw length of 29 inches. The test bow was placed onto the device, the draw hook was attached to the bow string, and the winch handle was used to draw the bow. Upon reaching full draw, the winch mechanism was unlocked, and the handle was released to initiate the automatic let-down cycle of the device. Upon releasing of the winch handle, the bow string remained stationary in a position of full draw. This meant that there was too much static friction within the system for the torque generated by the force of the bow to overcome. This resulted in a non-functional automatic let-down system. It was necessary to manually let down the bow string by rotating the winch handle counterclockwise.

The rotary damper was removed at this point and data was collected to determine the average time required to draw the bow. This data can be seen in Table 5.1.

**Table 5.1: First Iteration Draw Time**

<b>Trial Number</b>	<b>Draw Time (s)</b>
1	16.3
2	16.7
3	14.6
4	15.9
Average	15.9

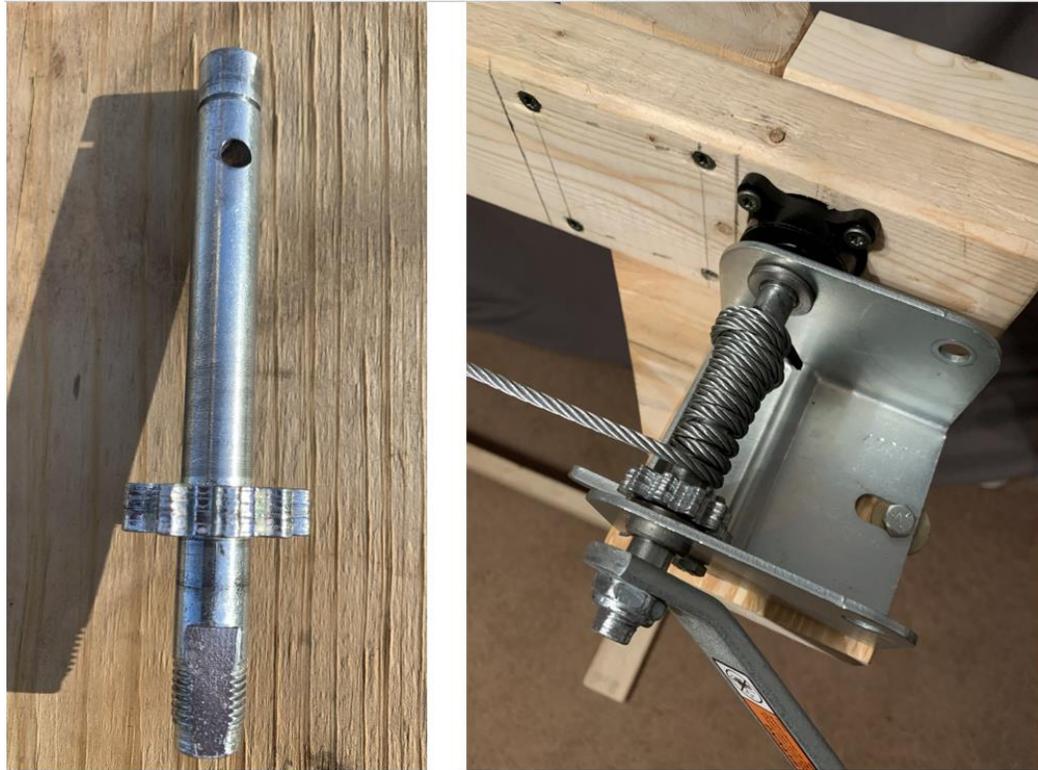
An average draw time of 15.9 seconds was achieved with this iteration of the device. This was much longer than the goal draw time of under five seconds. It was concluded from this first iteration testing that modifications were needed both to the winch mechanism and the automatic let-down system in order to meet the design objectives. Assessment was done to determine suitable winch modifications that could achieve a draw time under five seconds. It

was theorized that achieving a 1:1 gear ratio would be possible simply by eliminating the main shaft of the winch and attaching the draw cable to the handle shaft of the winch directly. Dividing the draw time of 15.9 seconds by the original gear ratio of 3.2 gives a general idea of a draw time that could possibly be achieved by making this modification. This yielded a result of 4.97 seconds, which would meet the design objective of achieving a draw time under five seconds in theory.

Three other available dampers were also purchased from McMaster-Carr in the same style as the original damper. These dampers were all listed as having a lower maximum torque rating than the original damper, so they could theoretically require less torque to overcome the static friction present in the damper. Upon testing each of these dampers, it was determined that they had the same issue as the original damper and there was too much static friction in the system to allow the force of the bow to initiate the automatic let-down cycle. No additional data could be gathered from any of the three dampers because none of them allowed for a functional automatic let-down system.

## ***5.2 SECOND ITERATION TESTING***

The second iteration of the draw board included modifications both to the winch mechanism and the automatic let-down system. As mentioned previously, the winch was modified such that the main shaft was removed, and the handle shaft was modified to accept the attachment of the draw cable. A hole was drilled through the handle shaft so that the draw cable could be placed through the hole, thus creating a method of winding the draw cable onto the handle shaft of the winch directly. This modification can be seen in Figure 5.1.



**Figure 5.1: Modified Winch**

This modification achieved a 1:1 winch gear ratio without having to purchase a different winch mechanism. In theory this gear ratio would allow for a draw time of under five seconds based on the draw time determined from the first iteration testing. In addition to reducing draw time, this configuration also increases torque on the damper by 3.2 times what it was experiencing in the first iteration due to the change from a 1:3.2 gear ratio to a 1:1 gear ratio. This means that the torque on the handle shaft could now be great enough to overcome the static friction of some of the dampers.

With the winch mechanism modified, the device was reassembled, and each damper was tested in the device. The device functioned as planned with the two lowest maximum torque rated dampers, but the static friction was still too high for a functional automatic let-down with the two highest maximum torque rated dampers. Data was collected for draw time, let-down time, and force required to extract the draw cable. Time data was collected simply by starting and stopping a stopwatch at the beginning and end of the draw and let-down cycle. This method is not necessarily extremely precise for determining exact draw and let-down times, but a high degree of precision is not necessarily needed for the assessment of the validity of this device.

Force required to extract the draw cable was measured by extracting the draw cable through applying force directly to the archery scale which was attached directly to the draw cable. The archery cable would then display the maximum force applied in extracting the draw cable. Data regarding draw time, let-down time, and force required to extract the draw cable can be seen in Table 5.2.

**Table 5.2: Second Iteration Testing Data**

<b>Damper</b>	<b>Draw Time (s)</b>	<b>Let-Down Time (s)</b>	<b>Force to Pull Out Draw Cable (lb)</b>
1 (5.3 in-lb)	4.4	1.5	17
2 (10.6 in-lb)	5.1	2.1	30
3 (21.2 in-lb)	6.9	N/A	42

As can be seen in the testing data, the lowest maximum torque rated damper allowed the device to achieve all the design objectives outlined. This was the only damper that fulfilled all design objectives due to the second damper requiring more than 20 pounds of force to extract the draw cable. The lowest maximum torque rated damper was selected for the final build of the device due to it allowing the device to meet all the design objectives.

## 6 OBJECTIVE EVALUATION

The objective of this project was to improve upon archery draw board designs through the design and implementation of an automatic let-down system. Design objectives were put in place and ultimately all design objectives were accomplished for this project.

### *6.1 DRAW BOARD REQUIREMENTS*

The draw board requirements were as follows:

- The device must be capable of drawing a 100-pound draw weight bow
- The device must be capable of drawing a 36-inch maximum draw length bow
- The device must be capable of drawing a bow in five seconds or less
- The device must be capable of measuring and displaying draw force

The final device achieved a draw time of 4.4 seconds with a 75-pound draw weight bow. The device is capable of drawing a 36-inch draw length bow due simply to the dimensions of the device, no testing is needed for this parameter. The device is capable of measuring and displaying draw force via the archery scale.

With regards to the test bow, the device was able to accomplish all the design objectives. That being said, the test bow has a draw weight of 75 pounds. This means that a bow with maximum parameters was not tested. All of the components of the device are capable of withstanding the force generated by a 100-pound draw weight bow, so theoretically the device could draw a 100-pound draw weight bow, and it can be assumed that the draw time could be under five seconds for such a bow due to the fact that force required to turn the winch handle did not seem to be a limiting factor in draw time of the bow to a certain degree. Angular velocity seemed to be the limiting factor when determining draw time. This means that theoretically the device should be capable of drawing a 100-pound draw weight bow in five seconds or less, but this cannot be stated with certainty without actual testing of a 100-pound draw weight bow.

## ***6.2 AUTOMATIC LET-DOWN SYSTEM DESIGN OBJECTIVES***

The automatic let-down system design objectives were as follows:

- The system must be capable of safely letting down the bow string in over one second and under five seconds
- The user must be able to attach the draw hook to the bow string without applying a force greater than 20 pounds to pull out the draw cable
- The device must be capable of safely letting down the bow string over a maximum let-down distance of 28.25 inches

The final build of the device was able to accomplish all these design objectives. A let-down time of 1.5 seconds was achieved. A force of 17 pounds was required to extract the draw cable for attachment of the draw hook to the bow string. The let-down distance objective was achieved due to the automatic let-down system consisting of a continuous rotary damper with unlimited angle of motion. This means that the let-down distance is equal in length to the maximum distance that the draw board could draw back a bow string. All the design objectives were met for the automatic let-down system.

## ***6.3 VALUE OF THIS PROJECT***

The goal of this project was to improve upon current draw board designs by designing and implementing a system to decrease time needed to use the device and increase safety of the device in some designs. The ultimate result is a draw board design that requires approximately six seconds less time to draw and let down a bow than a commercially available draw board. To an individual who occasionally uses a draw board, this time saving is most likely insignificant. To a professional who tunes several bows every day, perhaps this time saving could be significant. Ultimately this project is a proof of concept that something like this could be implemented, and it could reduce time needed to use a draw board.

## **7 CONCLUSIONS AND RECOMMENDATIONS**

### ***7.1 CURRENT PROGRESS***

The result of this project is a functional draw board with a functional automatic let-down system. The device meets all requirements and design objectives that were set in place. The result of this is a draw board that requires less time to use than commercially available options due to a decrease in draw time and let-down time of the device.

### ***7.2 FUTURE RECOMMENDATIONS***

While the device is fully functional and meets all the requirements that were set in place, there are some considerations for improvement of the device. The device has never been tested using a bow with a 100-pound draw weight, nor has the device been tested with a bow having a very low draw weight. Only the 75-pound draw weight bow was tested for this project. Valuable data could be collected using various draw weight bows to determine the validity of the design being used with a wide range of different bows. As of right now, testing data is limited only to one bow.

Another consideration is the implementation of the automatic let-down system. Due to the motion of the Automatic Let-Down System being linked directly to the motion of the winch mechanism, the winch handle is coupled to the rotation of the winch shaft during let-down. This means that the winch handle rotates quickly during the let-down cycle of the device. There could be some potential danger in allowing the winch handle to rotate quickly in this way due to the possibility of the winch handle hitting someone during this rotation. It also causes some undesirable oscillation in the device due to the mass of the handle rotating. This means that the device could be improved significantly by designing a system in which the winch handle is not coupled to the motion of the shaft during let-down of the bow.

## REFERENCES

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## **APPENDIX**

Appendix A: System Components

Appendix B: Preliminary Project Schedule

Appendix C: Bill of Materials

Appendix D: Additional Implementation Images

## APPENDIX A: SYSTEM COMPONENTS



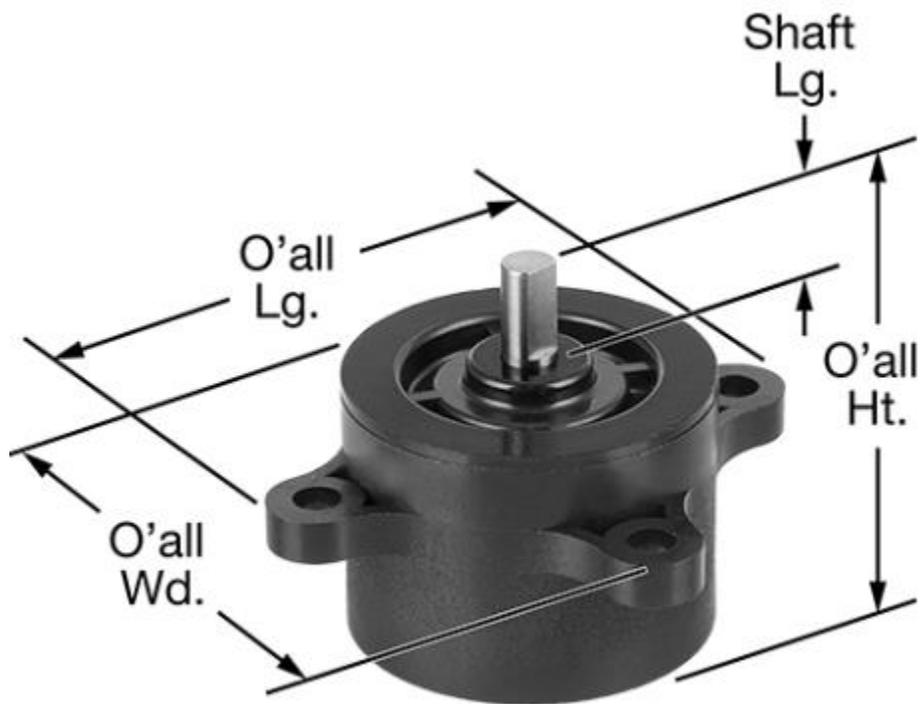
**Figure 1: Winch**



**Figure 2: Wire Rope for Winch (Draw Cable)**



**Figure 3: Steel Pipe (Bow Handle Interface)**



**Figure 4: Rotational Damper**



**Figure 5: Archery Scale**

## APPENDIX B: PRELIMINARY PROJECT SCHEDULE

<b>Task</b>	<b>Due Date</b>
Three design concepts created	Feb. 4
Design concept selected	Feb. 4
Parts selected and ordered	Feb. 7
Device fully assembled	Feb. 28
Initial testing complete	Mar. 7
Design presentation review	Apr. 1
Device fully functional	Apr. 12
Poster due	Apr. 14
Final presentation	Apr. 22
Final report due	Apr. 28

## APPENDIX C: BILL OF MATERIALS

<b>Draw Board with Automatic Let-Down System Bill of Materials</b>		
<b>Part Description</b>	<b>Price</b>	<b>Qty</b>
Hand Winch	34.73	1
Wire Rope with Hook (10 ft.)	38.69	1
Steel Pipe (1 ft.)	9.26	1
Archery Scale	39.99	1
Rotary Damper 1	62.51	1
Rotary Damper 2	62.51	1
Rotary Damper 3	62.51	1
Rotary Damper 4	62.51	1
<b>Total for All Parts</b>		
All Parts	372.71	8

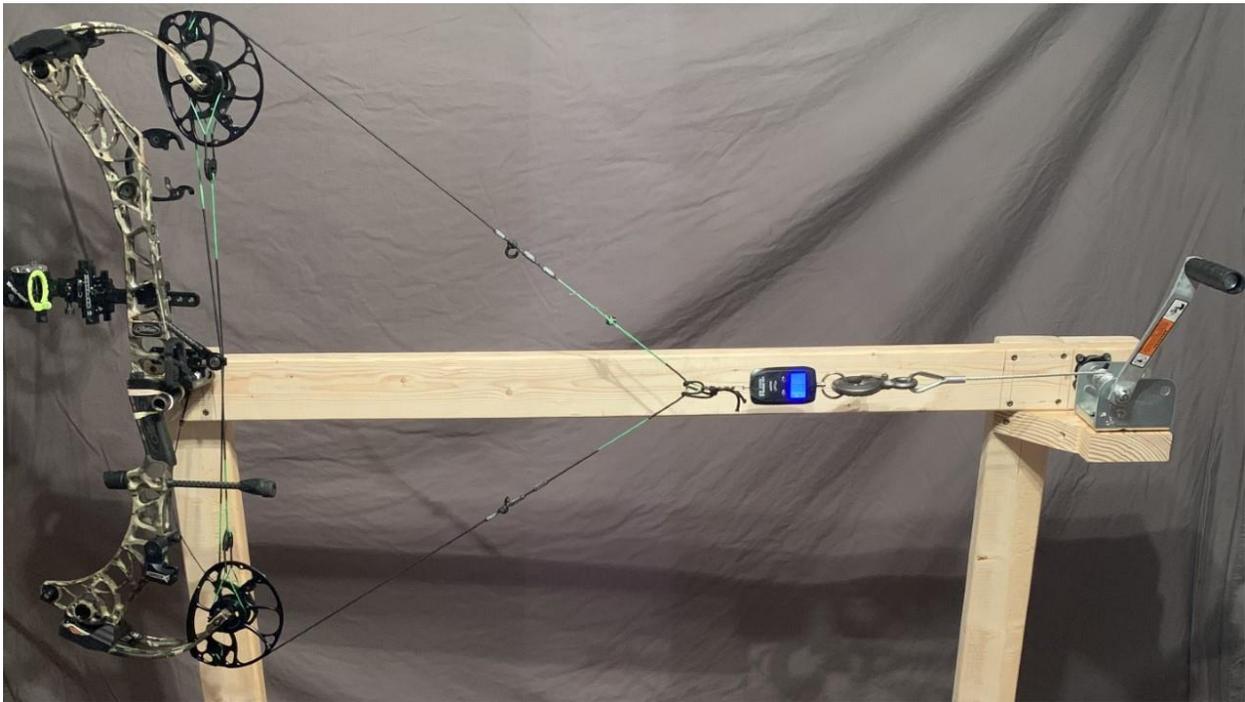
## APPENDIX D: ADDITIONAL IMPLEMENTATION IMAGES



**Figure 6: Device Base**



**Figure 7: Winch Mechanism Attachment to Base**



**Figure 8: Complete Device Final Iteration**

