JME 4110: Battery Operated Extendable Limb Shears

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Joint Engineering Program
University of Missouri–St. Louis ▪ Washington University in St. Louis

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This project entails the design, analysis, and construction process of battery operated extendable limb shears. The design consists of shears mounted on top of extendable poles and is powered by a DeWalt hand-held drill mounted on a manufactured steel box. By using the mechanics of pulleys and tension force, the shears can cut branches up to 1.5 inches in diameter and as tall as 16 feet above the ground.

JME 4110
Mechanical Engineering
Design Project

Battery Operated Extendable Limb Shears

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1 Introduction

1.1 Value proposition / project suggestion

Cutting and trimming tree branches can be costly and it is also not an easy feat to do. With traditional shears, one would have to secure a ladder and scale it to cut off the desired branches. Then you would have to make sure the ladder is tall enough and that the branch can even be reached at all. One could also buy battery operated extendable shears that are currently on the market.With this option, you can have the risk of the shears failing on you as the ones currently on the market are flimsy and can only cut up to 1.2 inches in diameter. Our design of battery operated extendable limb shears is reliable, easy-to-operate, and can extend up to 16 feet. There will be no need for a ladder and you can feel comfortable operating the device.

1.2 List of team members

James Lehn

Ngoc Nguyen

Cory Sellers

Larissa Wells

2 Background Information Study

2.1 Design Brief

This project will be designing and prototyping extendable, battery operated limb shears. The shears should be extendable up to 15 ft. while remaining light and comfortable enough to use at its full extension. The shears should come in one piece or be simple and easy to put together. They should have an ergonomic handle and trigger that is comfortable and easy to use, even at full extension. The shears should be powered by a common power tool battery and be able to cut branches up to 1.5 in. in diameter.

2.2 Background summary

Our background information search for similar designs led to the two products shown below. Both of these designs match the basic goal of our project: extendable battery powered limb shears. However neither of these products come close to reaching our goal of a 15 ft. extension, nor are they capable of cutting branches of 1.5 in. diameter. Reviews on these designs also complained about the shears being difficult to control due to heavy weight at the top of the poles as well as the danger of the pole collapsing.

Figure 1 below shows the Cordless Electric Pruning Shears - Professional Tree Branch Pruner Lithium Battery Powered, with 7.5 Foot High Reach Extension Pole, 1.2 Inch Cutting Diameter, LED Display Screen found at: shorturl.at/hltU9

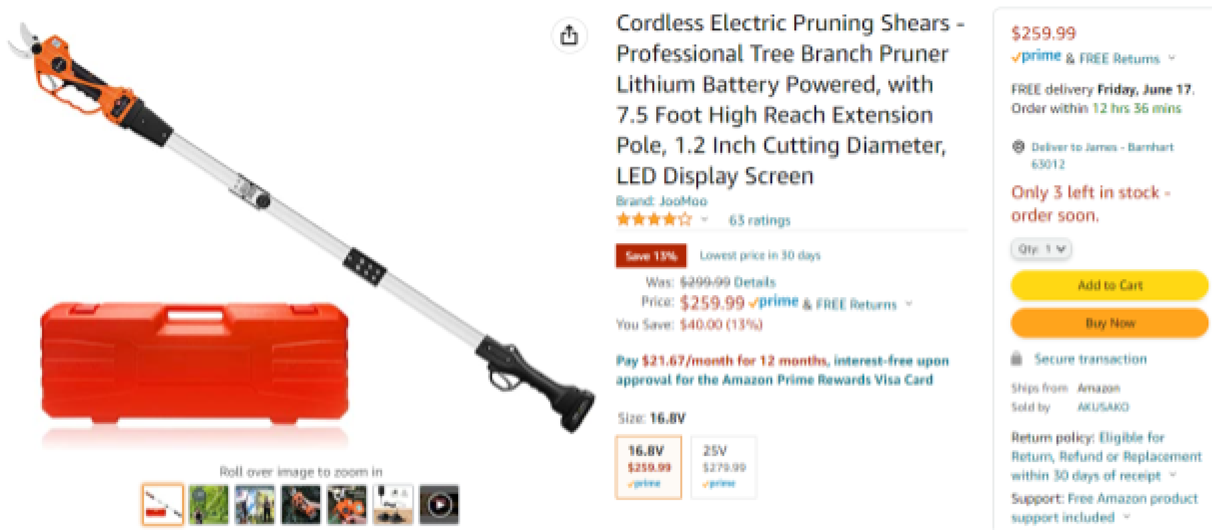

Figure 1: Existing Extendable Shears Example 1

Figure 2 below shows the Scotts 7.2V Electric Cordless Telescoping Pole Pruner - 2 Ah Battery and Charger Included found at: shorturl.at/jlrwz

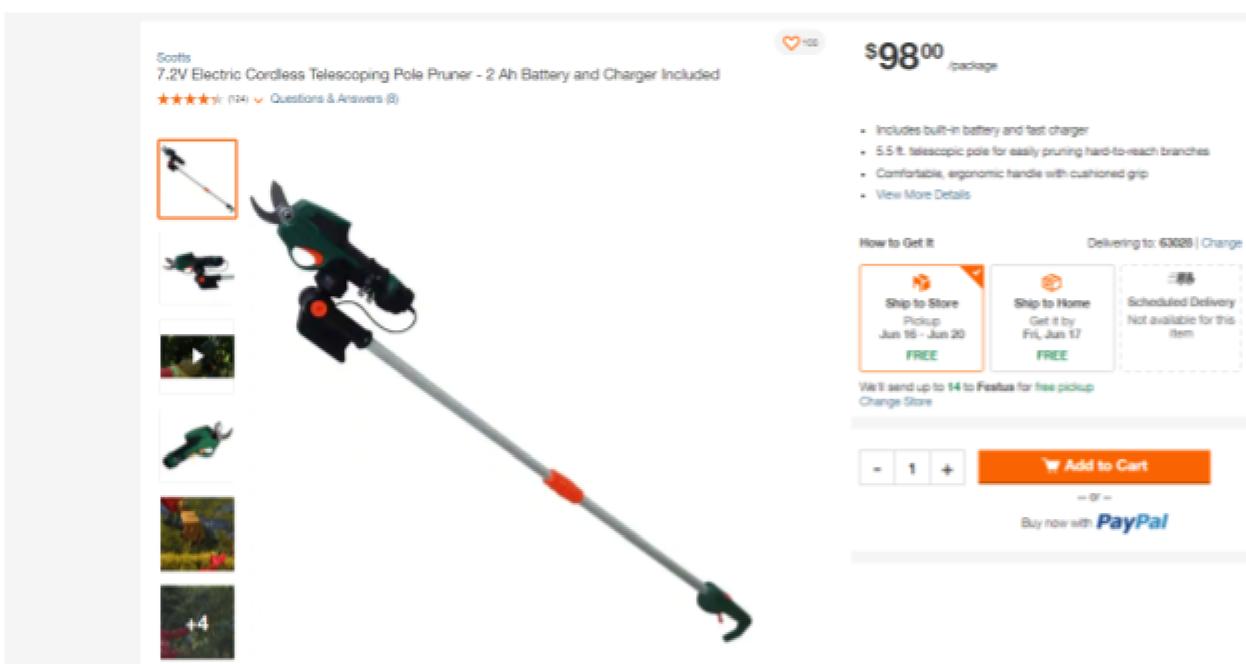

Figure 2: Existing Extendable Shears Example 2

3 Concept Design and Specification

3.1 User Needs and Metrics

3.1.1 User Needs Interview

Table 1: User Needs Interview

Question	Customer Statement	Interpreted Need	Need Number	Need Importance (1=min., 5=max.)
What size branch should the shears be able to cut?	They should be able to match or exceed the max cutting diameter of other shears on the market.	The shears should be able to cut branches of up to 1.5 in. diameter.	1	3
How long should the shears be able to extend?	They would have to be very long to compete against other extendable shears currently on the market.	The shears should be as long as is reasonable with a max length of 15 ft.	2	5
How long should the unextended length of the shears be?	They shouldn't be much bigger than regular garden tools for storage.	The collapsed shears would ideally be no longer than 4 ft.	3	3

How should the shears be powered?	They should be able to use a common battery to other power tools.	The shears should be powered by a common Dewalt 20V battery.	4	4
How much should the shears weigh?	They will need to be light enough to hold and maneuver with relative ease.	The shears should weigh less than 20lb.	5	5
What should it take to operate the shears?	It should only take one person to operate.	The shears should be one-person operable.	6	5
Should any part of the shears be removable?	The shear blades should be removable for replacement when dull.	Shear blades should be detachable.	7	4

3.1.2 List of identified metrics

Table 2: List of Identified Metrics

Metric Number	Associated Needs	Metric	Units	Min Value	Max Value
1	1	Branch Diameter	in.	1.0	1.5
2	2	Extended Length	ft.	12	15
3	3	Collapsed Length	ft.	4	7
4	4	Common Battery	Binary	0	1
5	5	Weight	lb.	10	20
6	6	One-person use	binary	0	1
7	7	Removable shears	binary	0	1

3.1.3 Table/list of quantified needs equations

Table 3: Quantified Needs Equations

		Metric													
		Branch Diameter	Extended Length	Collapsed Length	Common Battery	Weight	People Required	Removable Shears	Number of Cuts	Chance of Collapse	Number of Extensions	# of Pieces when collapsed	Need Happiness	Importance Weight (all entries should add up to 1)	Total Happiness Value
Need#	Need	1	2	3	4	5	6	7	8	9		9			
1	cut branches of up to 1.5 in. diameter.	1											0	0.06	0
2	15 ft. long extended.		1										0	0.10	0
3	4 ft. long, fully collapsed.			1									0	0.06	0
4	powered by a common Dewalt 20V battery.				1								0	0.08	0
5	weigh less than 20lb.					1							0	0.10	0
6	one-person operable.						1						0	0.10	0
7	detachable blades.							1					0	0.08	0
8	Sever branch with 1 cut								1				0	0.10	0
9	Extend without collapse									1			0	0.10	0
	Stable and controllable in use										1		0	0.10	0
10	Collapse and store as a single unit											1	0	0.08	0
Units		in.	ft.	ft.	binary	lb.	integer	binary	integer	Percentage	Integer	Integer	Total Happiness		0
Best Value		1.5	15	4	1	10	1	1	1	0	1	1			
Worst Value		1	12	7	0	20	2	0	5	100	5	5			
Actual Value															
Normalized Metric Happiness															

3.2 CONCEPT DRAWINGS

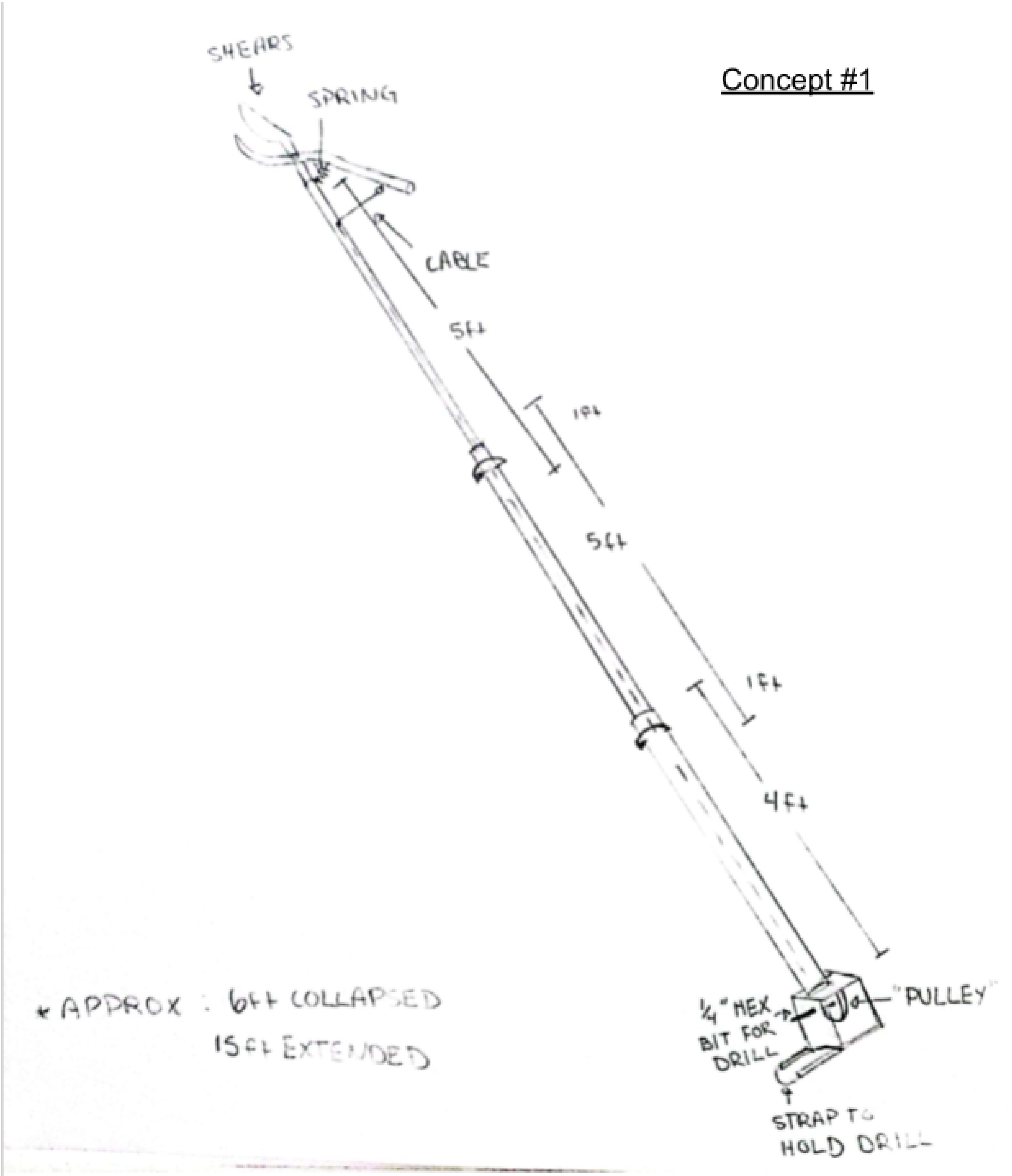

Figure 3: Drawing of Concept #1

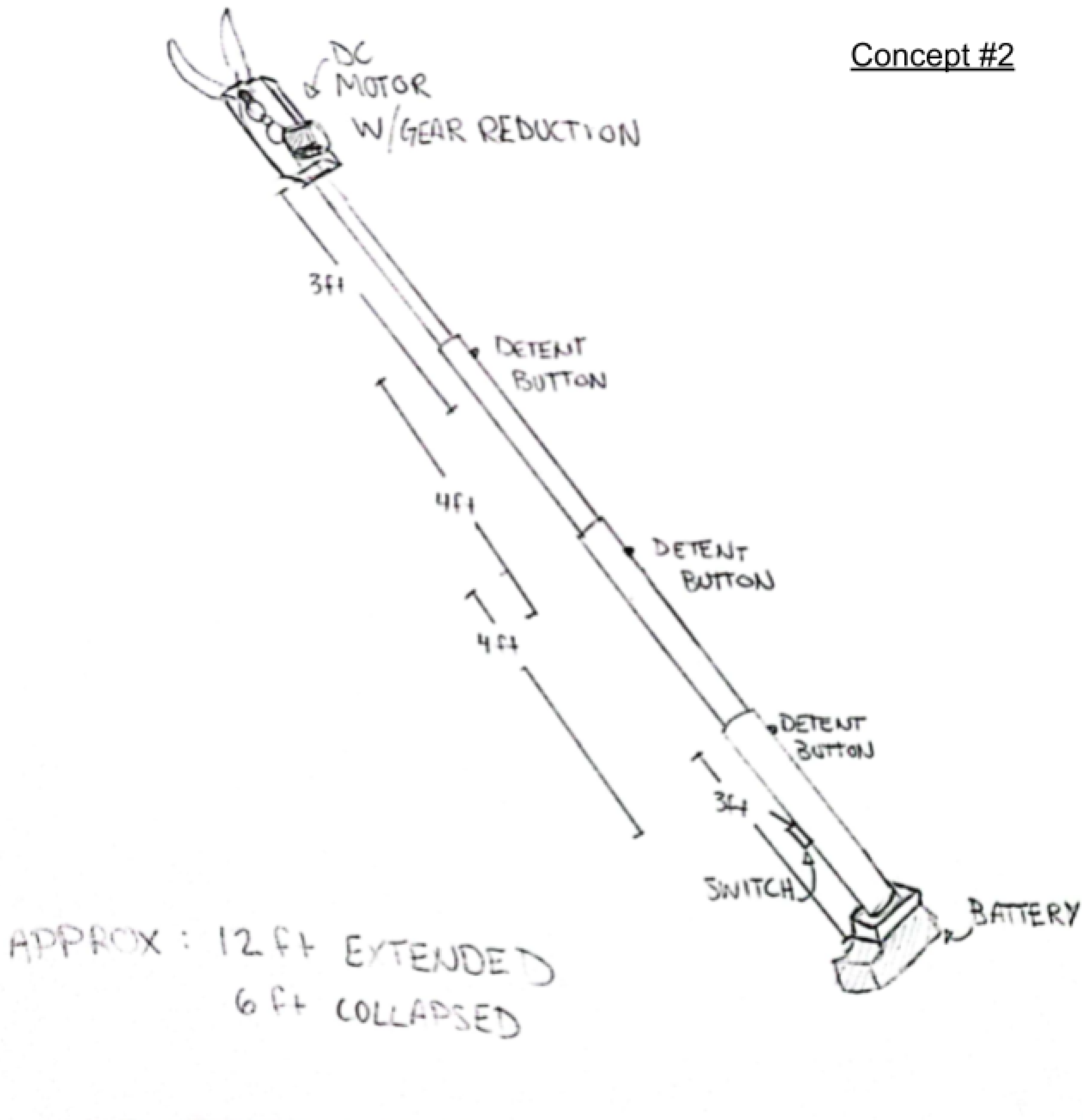

Figure 4: Drawing of Concept #2

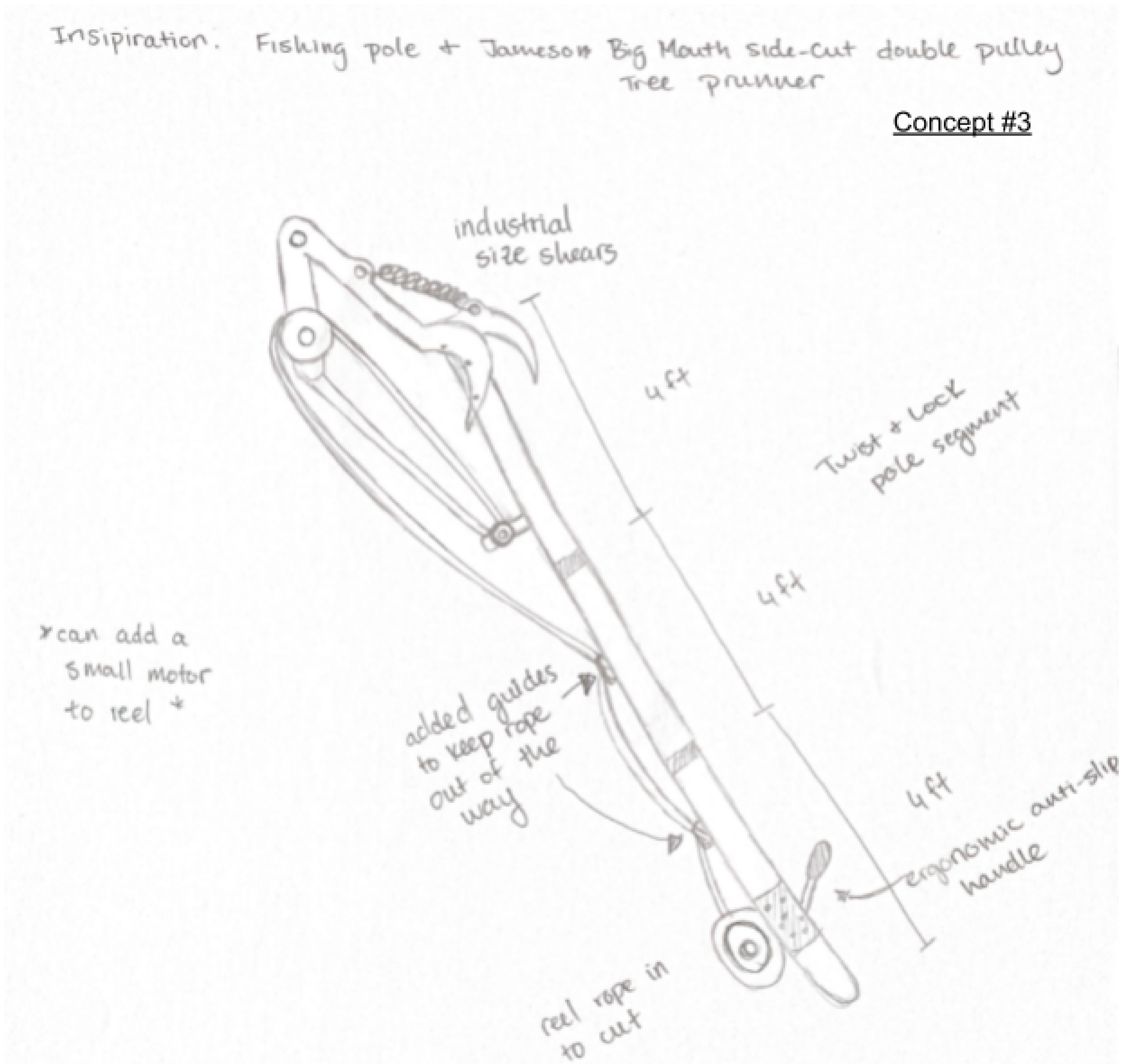

Figure 5: Drawing of Concept #3

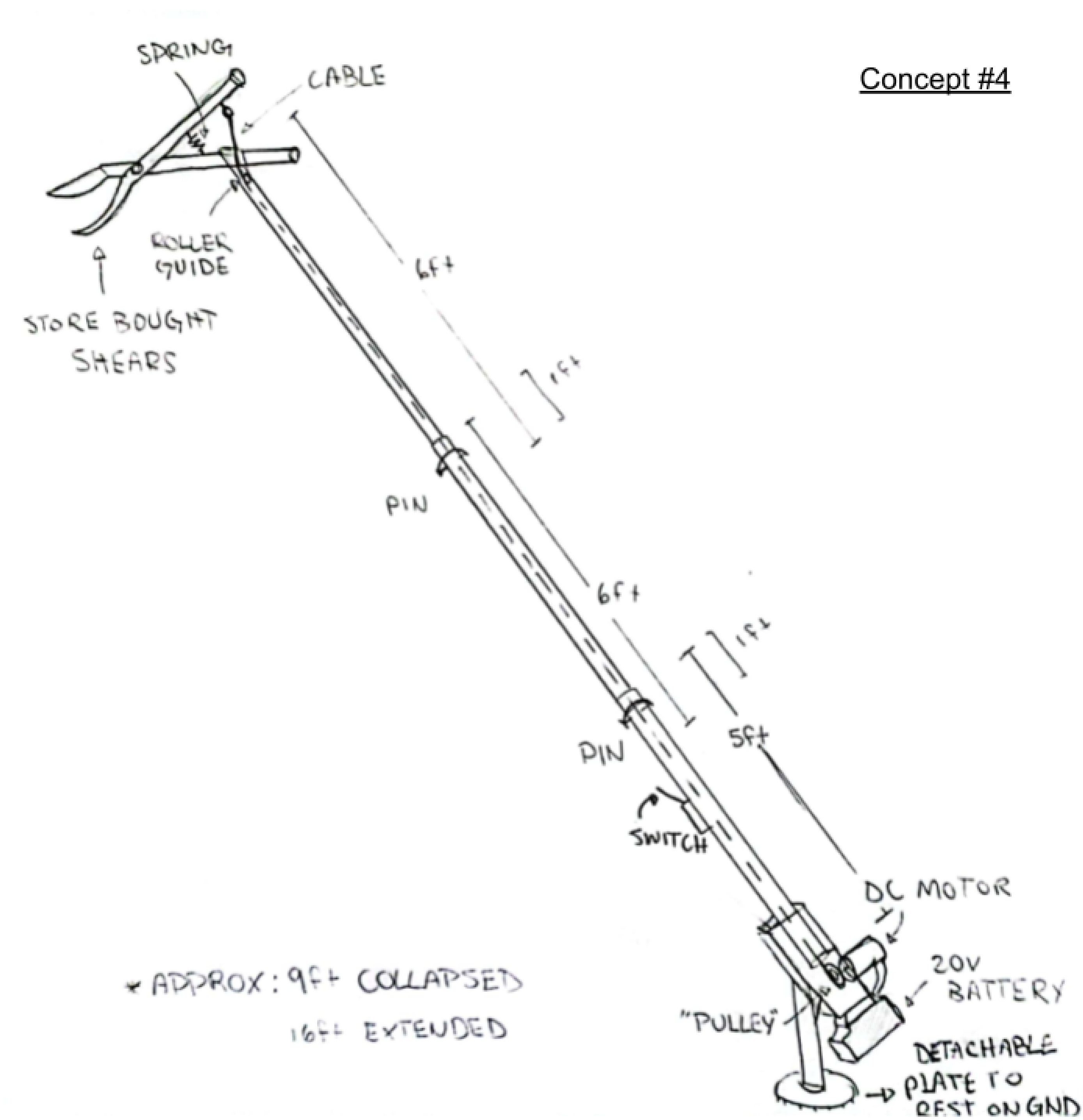

Figure 6: Drawing of Concept #4

3.3 A concept selection process.

3.3.1 Concept scoring

Table 4: Happiness Scoring for Concept #1

Concept #1		Metric													
		Branch Diameter	Extended Length	Collapsed Length	Common Battery	Weight	People Required	Removable Shears	Number of Cuts	Chance of Collapse	Number of Extensions	# of Pieces When Collapsed	Need Happiness	Importance Weight (all entries should add up to 1)	Total Happiness Value
Need#	Need	1	2	3	4	5	6	7	8	9		9			
1	cut branches of up to 1.5 in. diameter.	1											1	0.06	0.0625
2	15 ft. long extended.		1										1	0.10	0.104166
3	4 ft. long, fully collapsed.			1									0.333	0.06	0.020812
4	powered by a common Dewalt 20V battery.				1								1	0.08	0.083333
5	weigh less than 20lb.					1							0.5	0.10	0.052083
6	one-person operable.						1						1	0.10	0.104166
7	detachable blades.							1					1	0.08	0.083333
8	Sever branch with 1 cut								1				1	0.10	0.104166
9	Extend without collapse									1			0.9	0.10	0.09375
10	Stable and controllable in use										1		0.5	0.10	0.052083
11	Collapse and store as a single unit											1	1	0.08	0.083333
Units		in.	ft.	ft.	binary	lb.	integer	binary	integer	Percentage		Integer	Total Happiness		0.8437
Best Value		1.5	15	4	1	10	1	1	1	0	1	1			
Worst Value		1	12	7	0	20	2	0	5	100	5	5			
Actual Value		1.5	15	6	1	15	1	1	1	10	3	1			
Normalized Metric Happiness		1	1	0.333	1	0.5	1	1	1	0.9	0.5	1			

Table 5: Happiness Scoring for Concept #2

Concept #2		Metric													
		Branch Diameter	Extended Length	Collapsed Length	Common Battery	Weight	People Required	Removable Shears	Number of Cuts	Chance of Collapse	Number of Extensions	# of Pieces When Collapsed	Need Happiness	Importance Weight (all entries should add up to 1)	Total Happiness Value
Need#	Need	1	2	3	4	5	6	7	8	9		9			
1	cut branches of up to 1.5 in. diameter.	1											0.5	0.06	0.03125
2	15 ft. long extended.		1										0	0.10	0
3	4 ft. long, fully collapsed.			1									0.333	0.06	0.020812
4	powered by a common Dewalt 20V battery.				1								1	0.08	0.083333
5	weigh less than 20lb.					1							0	0.10	0
6	one-person operable.						1						1	0.10	0.104166
7	detachable blades.							1					0	0.08	0
8	Sever branch with 1 cut								1				1	0.10	0.104166
9	Extend without collapse									1			0.75	0.10	0.078125
10	Stable and controllable in use										1		0.25	0.10	0.026041
11	Collapse and store as a single unit											1	1	0.08	0.083333
Units		in.	ft.	ft.	binary	lb.	integer	binary	integer	Percentage		Integer	Total Happiness		0.5312
Best Value		1.5	15	4	1	10	1	1	1	0	1	1			
Worst Value		1	12	7	0	20	2	0	5	100	5	5			
Actual Value		1.25	12	6	1	20	1	0	1	25	4	1			
Normalized Metric Happiness		0.5	0	0.333	1	0	1	0	1	0.75	0.25	1			

Table 6: Happiness Scoring for Concept #3

Concept #3		Metric													
		Branch Diameter	Extended Length	Collapsed Length	Common Battery	Weight	People Required	Removable Shears	Number of Cuts	Chance of Collapse	Number of Extensions	# of Pieces When Collapsed	Need Happiness	Importance Weight (all entries should add up to 1)	Total Happiness Value
Need#	Need	1	2	3	4	5	6	7	8	9		9			
1	cut branches of up to 1.5 in. diameter.	1											1	0.06	0.0625
2	15 ft. long extended.		1										0	0.10	0
3	4 ft. long, fully collapsed.			1									1	0.06	0.0625
4	powered by a common Dewalt 20V battery.				1								0	0.08	0
5	weigh less than 20lb.					1							0	0.10	0
6	one-person operable.						1						1	0.10	0.104166
7	detachable blades.							1					0	0.08	0
8	Sever branch with 1 cut								1				1	0.10	0.104166
9	Extend without collapse									1			0.85	0.10	0.088541
10	Stable and controllable in use										1		0.5	0.10	0.052083
11	Collapse and store as a single unit											1	1	0.08	0.083333
Units		in.	ft.	ft.	binary	lb.	integer	binary	integer	Percentage		Integer	Total Happiness		0.5573
Best Value		1.5	15	4	1	10	1	1	1	0	1	1			
Worst Value		1	12	7	0	20	2	0	5	100	5	5			
Actual Value		1.5	12	4	0	20	1	0	1	15	3	1			
Normalized Metric Happiness		1	0	1	0	0	1	0	1	0.85	0.5	1			

Table 7: Happiness Scoring for Concept #4

Concept #4		Metric													
		Branch Diameter	Extended Length	Collapsed Length	Common Battery	Weight	People Required	Removable Shears	Number of Cuts	Chance of Collapse	Number of Extensions	# of Pieces When Collapsed	Need Happiness	Importance Weight (all entries should add up to 1)	Total Happiness Value
Need#	Need	1	2	3	4	5	6	7	8	9		9			
1	cut branches of up to 1.5 in. diameter.	1											1	0.06	0.0625
2	15 ft. long extended.		1										1	0.10	0.104166
3	4 ft. long, fully collapsed.			1									0	0.06	0
4	powered by a common Dewalt 20V battery.				1								1	0.08	0.083333
5	weigh less than 20lb.					1							0	0.10	0
6	one-person operable.						1						1	0.10	0.104166
7	detachable blades.							1					1	0.08	0.083333
8	Sever branch with 1 cut								1				1	0.10	0.104166
9	Extend without collapse									1			0.75	0.10	0.078125
10	Stable and controllable in use										1		0.25	0.10	0.026041
11	Collapse and store as a single unit											1	1	0.08	0.083333
Units		in.	ft.	ft.	binary	lb.	integer	binary	integer	Percentage		Integer	Total Happiness		0.7292
Best Value		1.5	15	4	1	10	1	1	1	0	1	1			
Worst Value		1	12	7	0	20	2	0	5	100	5	5			
Actual Value		1.5	15	7	1	20	1	1	1	25	4	1			
Normalized Metric Happiness		1	1	0	1	0	1	1	1	0.75	0.25	1			

3.3.2 Preliminary analysis of each concept's physical feasibility

Concept #1: This design would require a lightweight, high strength material for the extendable pole to keep the product within the weight limits while also meeting the strength requirements to not break in regular use. It would also require a very strong cable for controlling the shears. The pulley would need to turn with little friction resistance so the cable can be easily unwound during the extension of the pole. This design has no need for a battery because it would be compatible with virtually any electric drill. The design would require a strong strap or other connection with the drill in order to prevent separation or damage to any part of the product or drill.

Concept #2: This design would require a lightweight, high strength material for the extendable pole to keep the product within the weight limits while also meeting the strength requirements to not break in regular use. In order to connect the motor to the battery, this design would require an internal wire system that would be able to accommodate the extension and collapse of the pole without getting damaged or tangled within. The motor of this design would have to be very light to keep the shears from being too top heavy to control at full extension.

Concept #3: This design would require a lightweight, high strength material for the extendable pole to keep the product within the weight limits while also meeting the strength requirements to not break in regular use. The material used for the blade branch controlled by the pulley system would also need to be very light to keep the product from being too top heavy to control. All of the pulleys incorporated in this design would need to be very low friction to keep the rope easy to repeatedly reel.

Concept #4: This design would require a lightweight, high strength material for the extendable pole to keep the product within the weight limits while also meeting the strength requirements to not break in regular use. It would also require a very strong cable for controlling the shears. The pole connected to the ground plate would need to be a strong material to hold up the weight of the shears without fracture. The hinge connecting this pole to the shears would need to be low friction so that the shears can be tilted at different angles with ease while the ground plate remains flat on the ground.

3.3.3 Final summary statement

Our chosen winner for our design is concept #1. This concept scored the highest in the scoring of our quantified needs equations and was the only concept that had rank on every metric with no 0 happiness values. We also predicted that this concept would have the lowest chance of the extension pole collapsing while in use, which is the need we identified as the overall performance measure. Another feature that made this concept more appealing than the others is the idea of being powered by a drill. Instead of having to worry about which battery is most common in power tools, this concept gives the shears the ability to be powered by any basic power drill which would be a common tool in most households. Concept # 2 was rejected mainly due to the complications that would come from including the DC motor which would have to connect to the battery through internal wires. The motor would make a more complex design and would also make the shears more difficult to control due to the added weight on top. The issue with control for this concept would be furthered by the number of extended sections that could make the pole unstable. The shear blades in this concept would also not be removable as desired.

` Concept #3 also lacks the feature of removable blades and would not use the desired battery. The lack of these features as well as the complexity and weight of this concept led to its low happiness score and rejection. Concept #4 would utilize removable blades, but they were not as well unified with the design as concept #1. Concept #4 tried to get rid of some of the issues found in concept #2 by placing both the DC motor and battery at the bottom. To accommodate the weight of the product, this product was designed with a stand that would rest on the ground. While this feature would make the product lighter to handle, it would also give the user less free control of where the blades are placed and would decrease the reach significantly from the handheld designs. If extra length were added to make up for the loss of reach, the added sections would only make the pole more unstable so this concept was rejected.

3.4 Proposed performance measures for the design

Our biggest priority while designing and building our prototype is to make sure that it will be safe to use. For this reason, we chose the need to be fully extendable without collapse as our overall performance measure.

4 Embodiment and fabrication plan

4.1 Embodiment/Assembly drawing

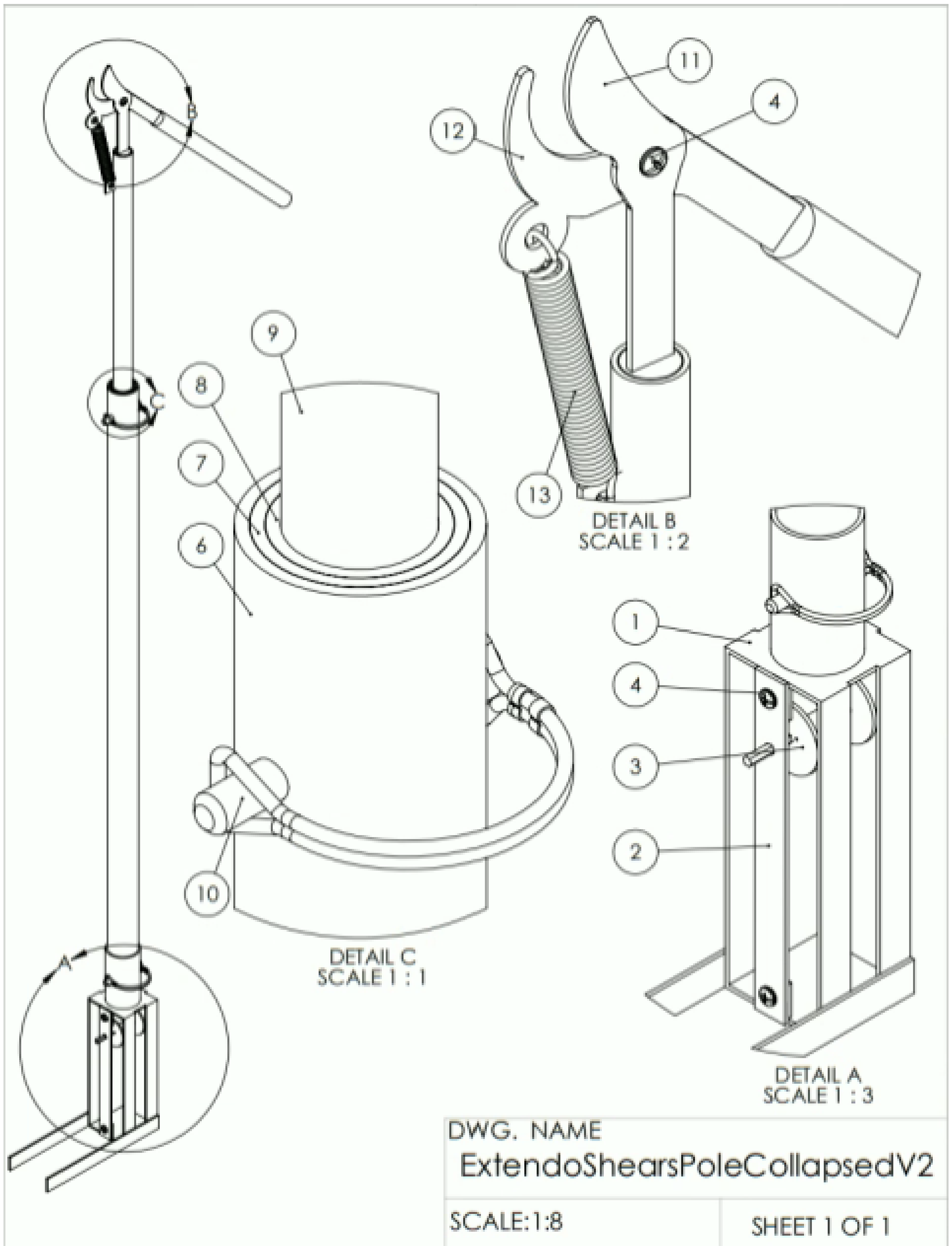

Figure 7: Embodiment/Assembly Drawing

4.2 Parts List

Table 8: Parts List & Description

#	PART NAME	DESCRIPTION	QTY.
1	BOTTOM BOX	Box at the bottom that the drill is attached to	1
2	BOTTOM BOX PLATE	Plate so you can attach and remove the spool	1
3	SPOOL	Where the cable spools	1
4	98181A125	Pan Head Combination Screw	3
5	95462A029	Steel Hex Nut	3
6	2 in. POLE	2 inch Fiberglass Pole	1
7	1.75 in. POLE	1.75 inch Fiberglass Pole	1
8	1.5 in. POLE	1.5 inch Fiberglass Pole	1
9	1.25 in. POLE	1.25 inch Fiberglass Pole	1
10	98416A140	Wire-Lock Clevis Pin	4
11	LOPPER BLADE	Edge of the loppers that do the cutting	1
12	LOPPER HOOK	Hook shaped part that backs the blade	1
13	RETURN SPRING	Spring that pulls on the blade after the cut	1
14	RETAINING PIN	Pin that holds in the spool on the backside	1

4.3 Draft detail drawings for each manufactured part

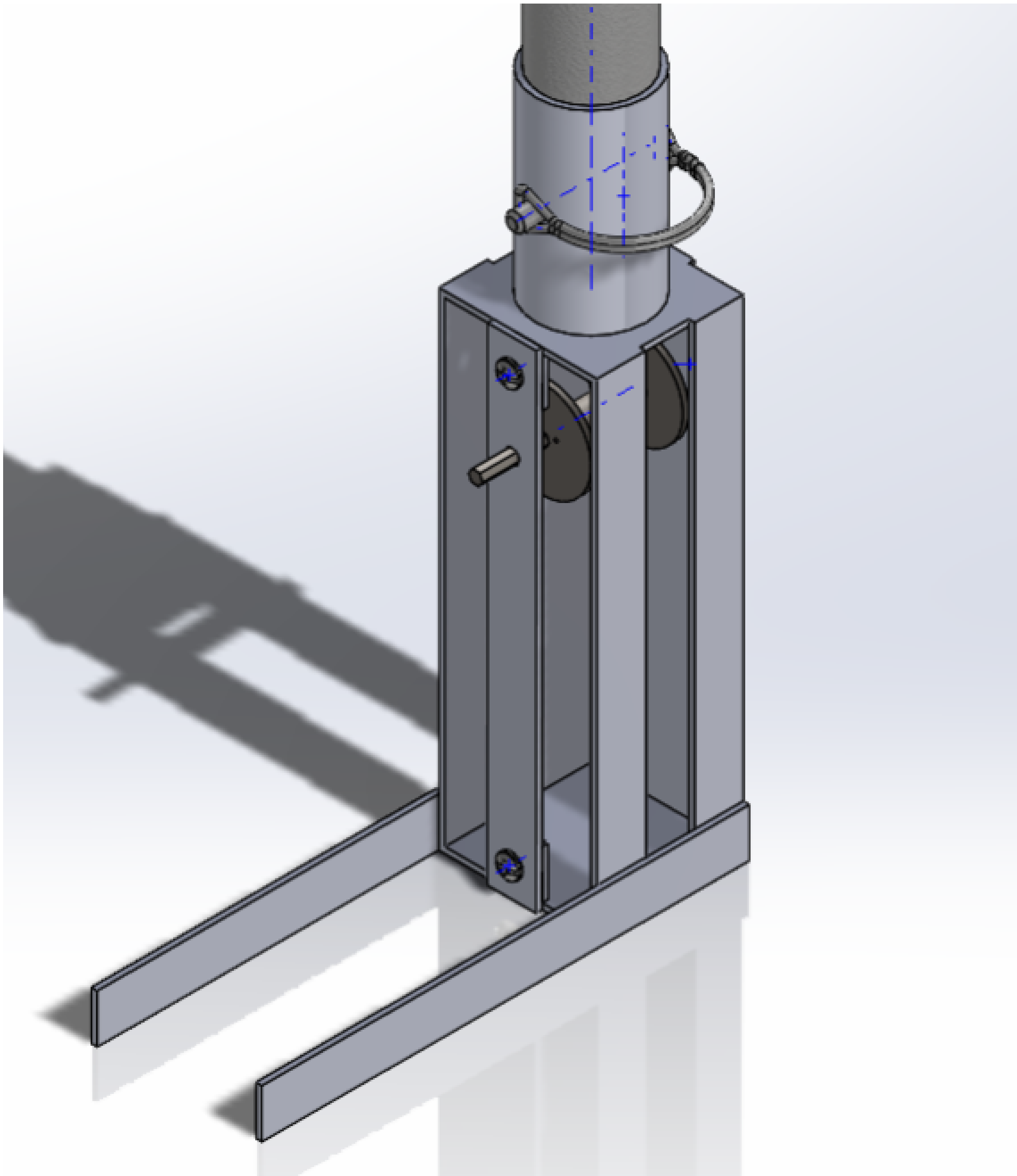

Figure 8: Close up CAD drawing of drill mount

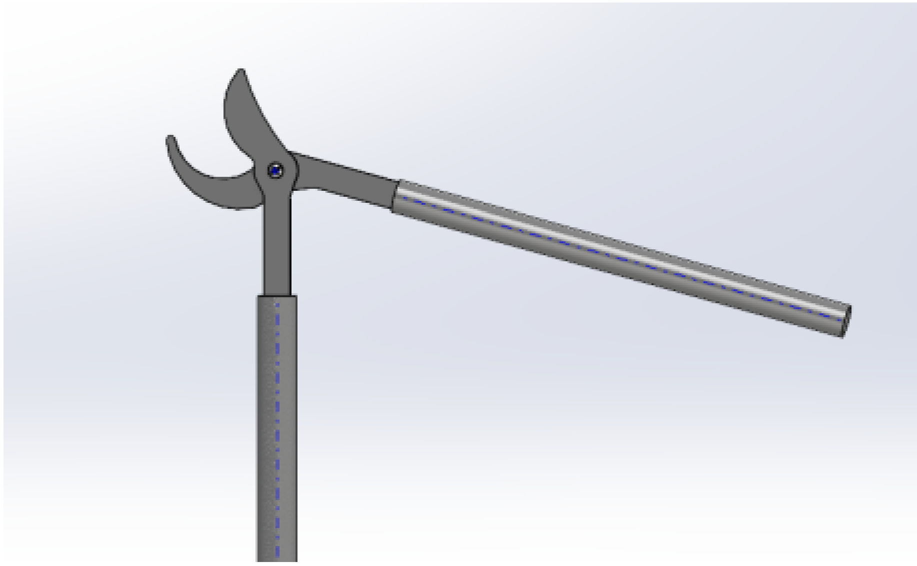

Figure 9: Close up CAD drawing of mounted shears

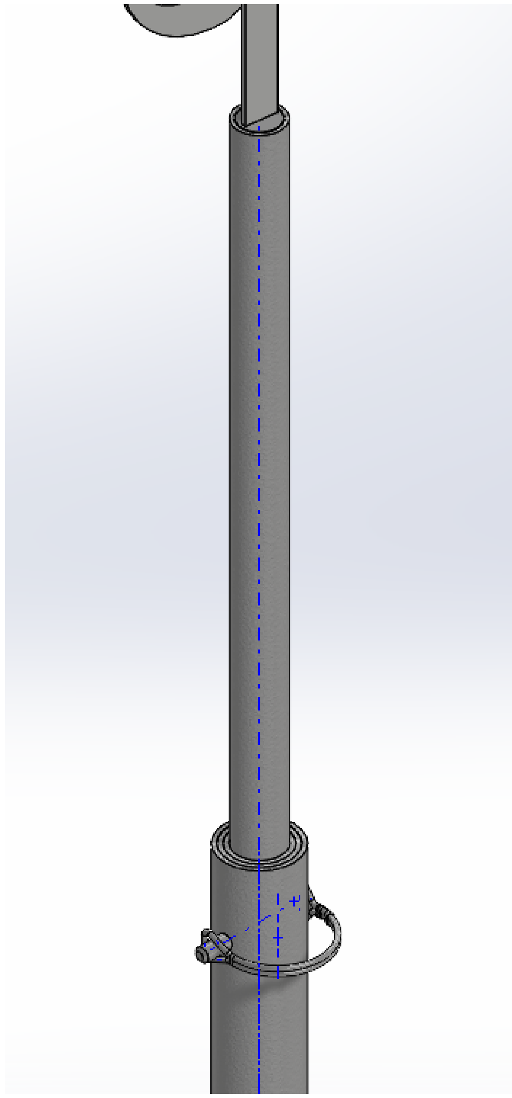

Figure 10: Close up CAD drawing of PTO pin through poles

4.4 Description of the design rationale

The part we will be fabricating is the strap for the drill and the bottom box. From the initial drawings of the bottom box that houses the drill bit, we were able to initialize the measurement to build a fabrication on Solidworks. Building and assembling the initial design with CAD, helps us ensure all the parts will fit and work together correctly. It also makes it easier to note out the errors in the initial design and can be easily fixed in Solidworks software. In our final assembly of the bottom box, we went with a nylon strap to hold the drill, along with 1.5" wide hole and 2" wide hole for the cable and extension rod to go through the bottom box, and a winch drum on the inside with 2" long and ½" steel pipe welded to a ¼" hex. We drafted the part in Solidwork so that we can use the simulation software and compare the materials against one another. Right now, our problem is with deciding between aluminum vs fiberglass. Aluminum has a higher compressive stress and most likely will not be affected with a strong torque from the drill. The fiberglass on the other hand can be affected by the torque, so we added a bolt stopper to the winch drum design. This can reduce the amount of torque from the drill onto the fiberglass rod.

5 Engineering analysis

5.1 Engineering analysis proposal

5.1.1 Signed engineering analysis contract

MEMS 411 / JME 4110
MECHANICAL ENGINEERING DESIGN PROJECT

ASSIGNMENT 5: Engineering analysis task agreement

ANALYSIS TASKS AGREEMENT

PROJECT: Extendo Shears NAMES: Ngoc Nguyen, James Lehn, Cory Sellers, Larissa Wells INSTRUCTOR: M. Jakiela, C. Giesmann

The following engineering analysis tasks will be performed:

Analysis before prototype:

1. Find the force to be applied for the shears to cut through the branch.
   - Calculated by hand using shear strength of the branch and force equations
2. Determine the number of pulleys needed to provide that force, given the torque of our drill.
   - Calculated by hand using the necessary force found in part 1 and the estimated torque of the drill we plan to use.
3. Ensure that the cable and pins will not break under the tension force.
   - Calculated by hand under max loading conditions.
4. Ensure the pole will not break from buckling or bending under tension of the cable.
   - Calculated by hand using max loading conditions using assumed material strengths
5. Compare design load & stress to allowable load & stress of steel cable wire, PTO clips, & pulley.
   - Used the calculated results and verified maximum load & stress of steel cable wires, PTO clips, and pulley that are currently on-the-market.

Analysis after prototype:

1. Test that the shears are able to cut through branches repeatedly without failure of any part.
   - Repeated tests on the final prototype.

The work will be divided among the group members in the following way:

- Hand Calculations: Larissa Wells and Ngoc Nguyen
- Prototype Testing: James Lehn and Cory Sellers

8-1-22

Instructor signature: ; *Print instructor name:* GIESMANN / JAKIELA

(Group members should initial near their name above.)

5.2 ENGINEERING ANALYSIS RESULTS

5.2.1 Motivation

In order to make sure our prototype would work as expected without any part failing or breaking, we identified several calculations that we would do before beginning the build of the prototype. Primarily, we wanted to be able to power our shears with a drill, so we needed to know the force required to cut through a 1.5 in. diameter branch and whether any adjustments would need to be made to the design so that the drill could provide the power needed to apply that force. There are also several parts we needed to make strength calculations to make sure the prototype would not break under the force of the tension in the cable. We needed to make sure the cable would not snap under its own tension and also that it would not cause any buckling or breaks in the extended pole or PTO pins.

5.2.2 Summary statement of analysis done

To determine the power needed to cut a branch, the necessary force at failure needed to be found. This was calculated using the ultimate shear strength of green oak and the shear strength equation τ=F/A. The force on the handles needed for the blades to produce this force was found using basic static equations, **Σ**F=0. Using basic static equations, the tension in the cable providing this force could be found. The torque from the drill needed to exert the calculated force was then found using T=rF. The result of this calculation was used to determine if an extra pulley would be required in the design. The bending force exerted on the pins by the tension in the cable was calculated for each pin using the bending force equation σ=My/I. The estimated max force on the pins and cable were compared to the allowable max stress stated by the product descriptions to determine if there is any chance of failure while the prototype is in use.

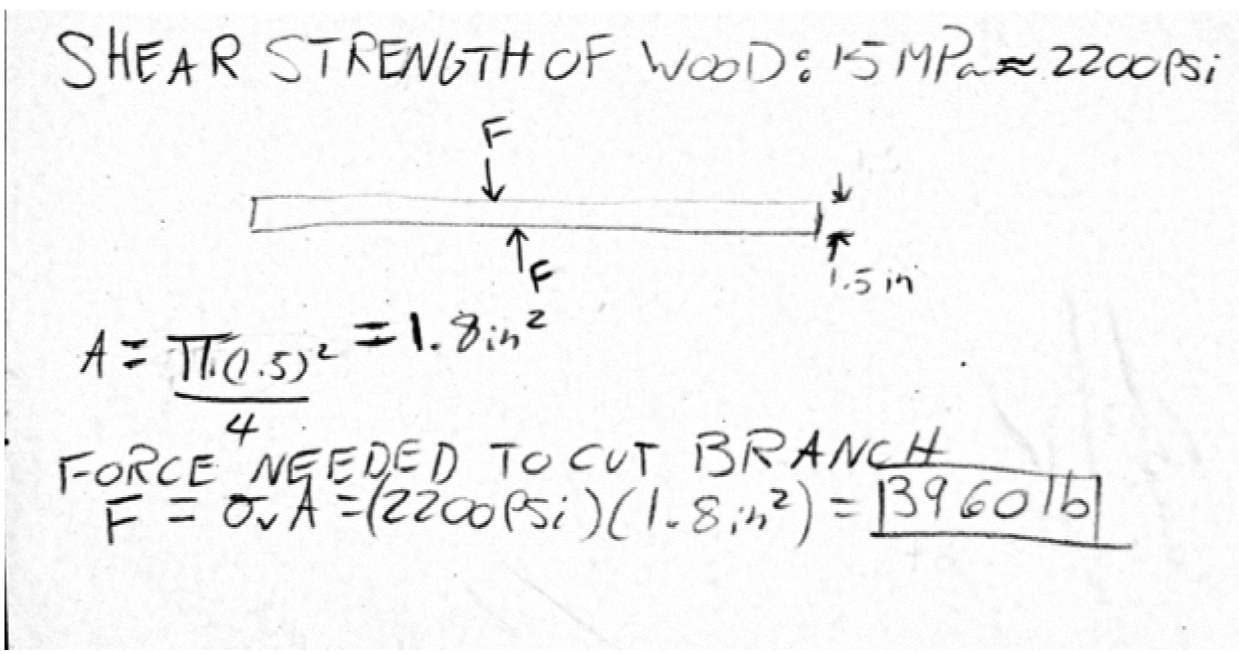

Figure 11: Shear strength of branch calculation

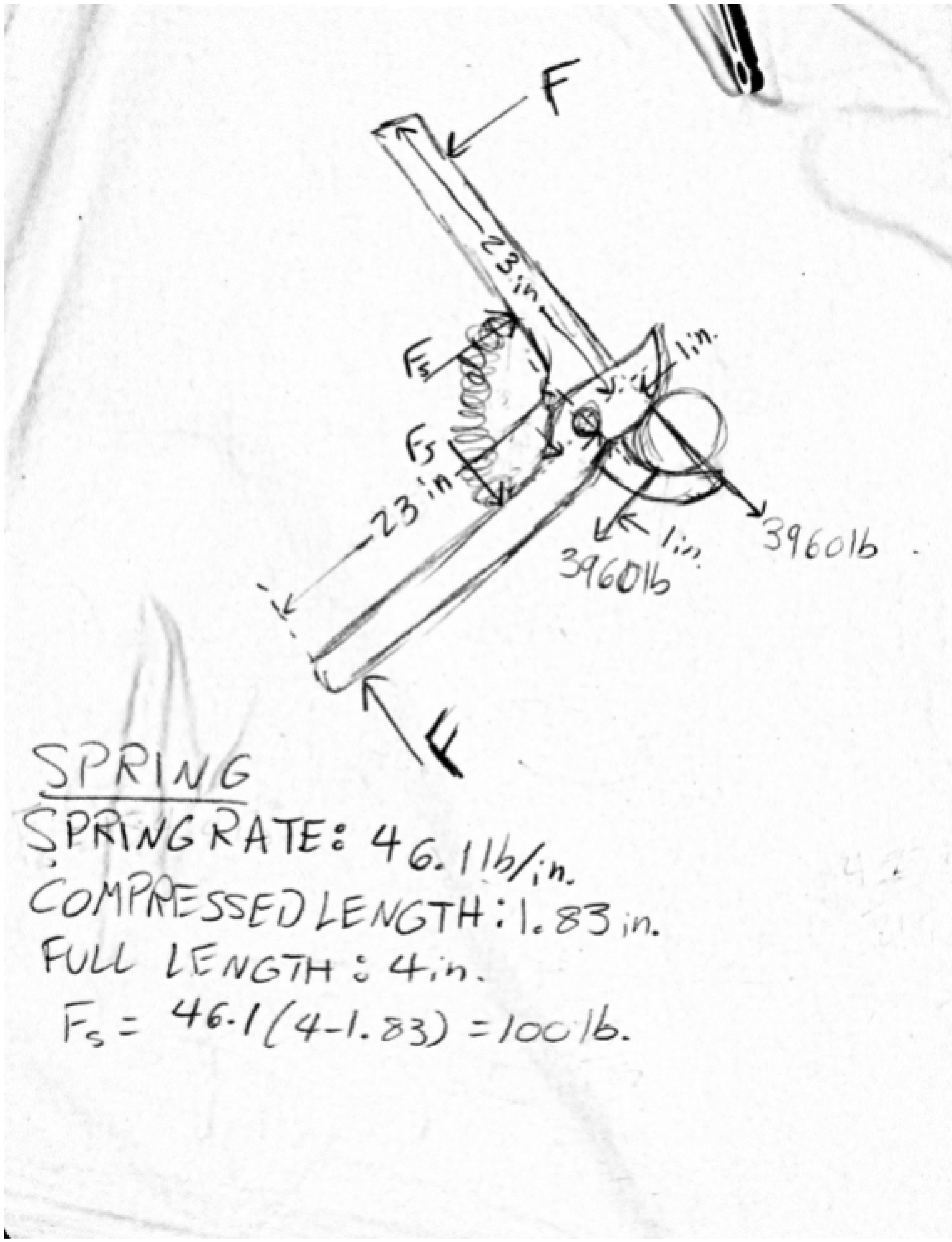

Figure 12: Force diagram of shears

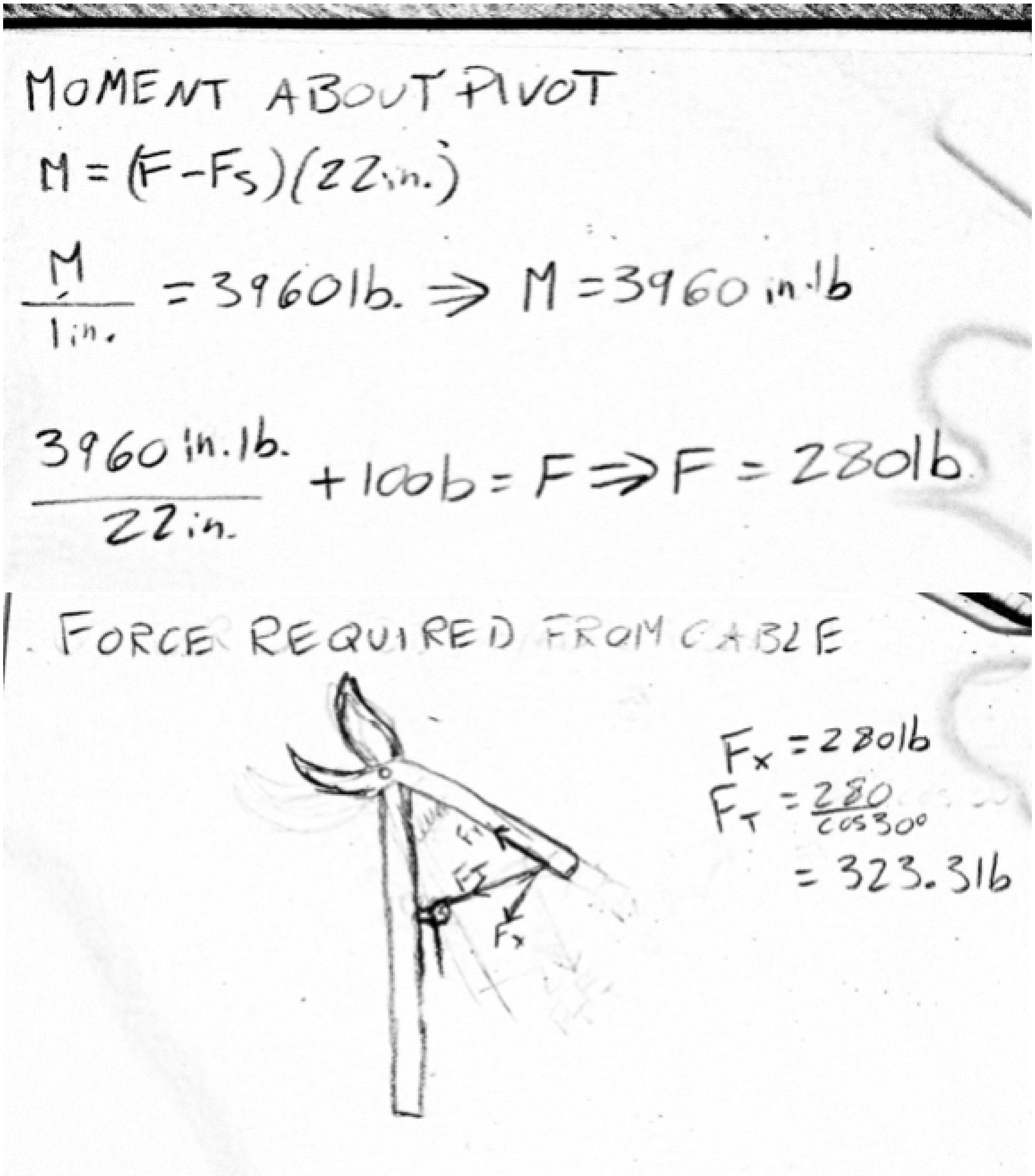

Figure 13: Force from cable calculation

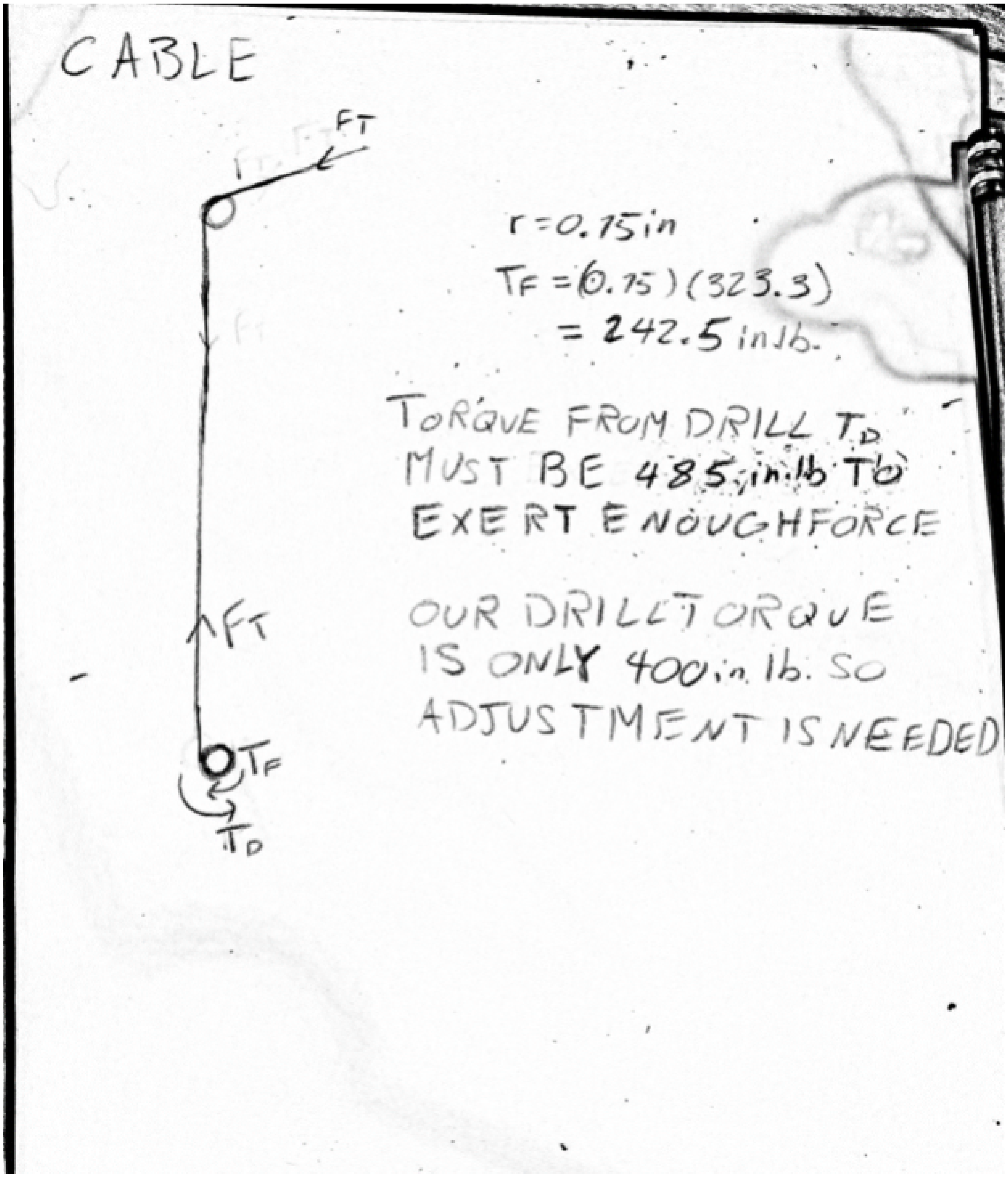

Figure 14: Torque calculation and assessment

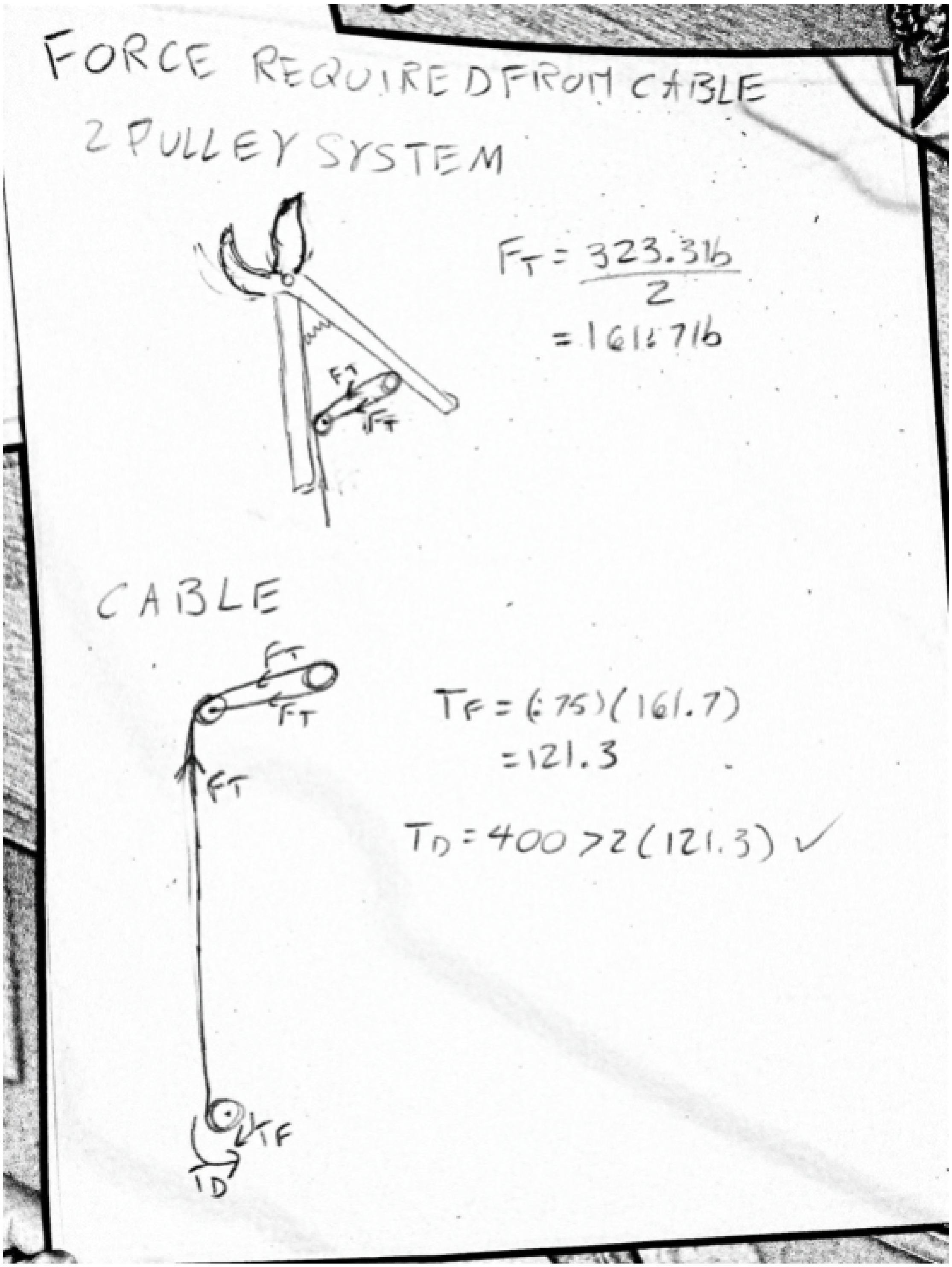

Figure 15: Force and Torque calculations with added pulley

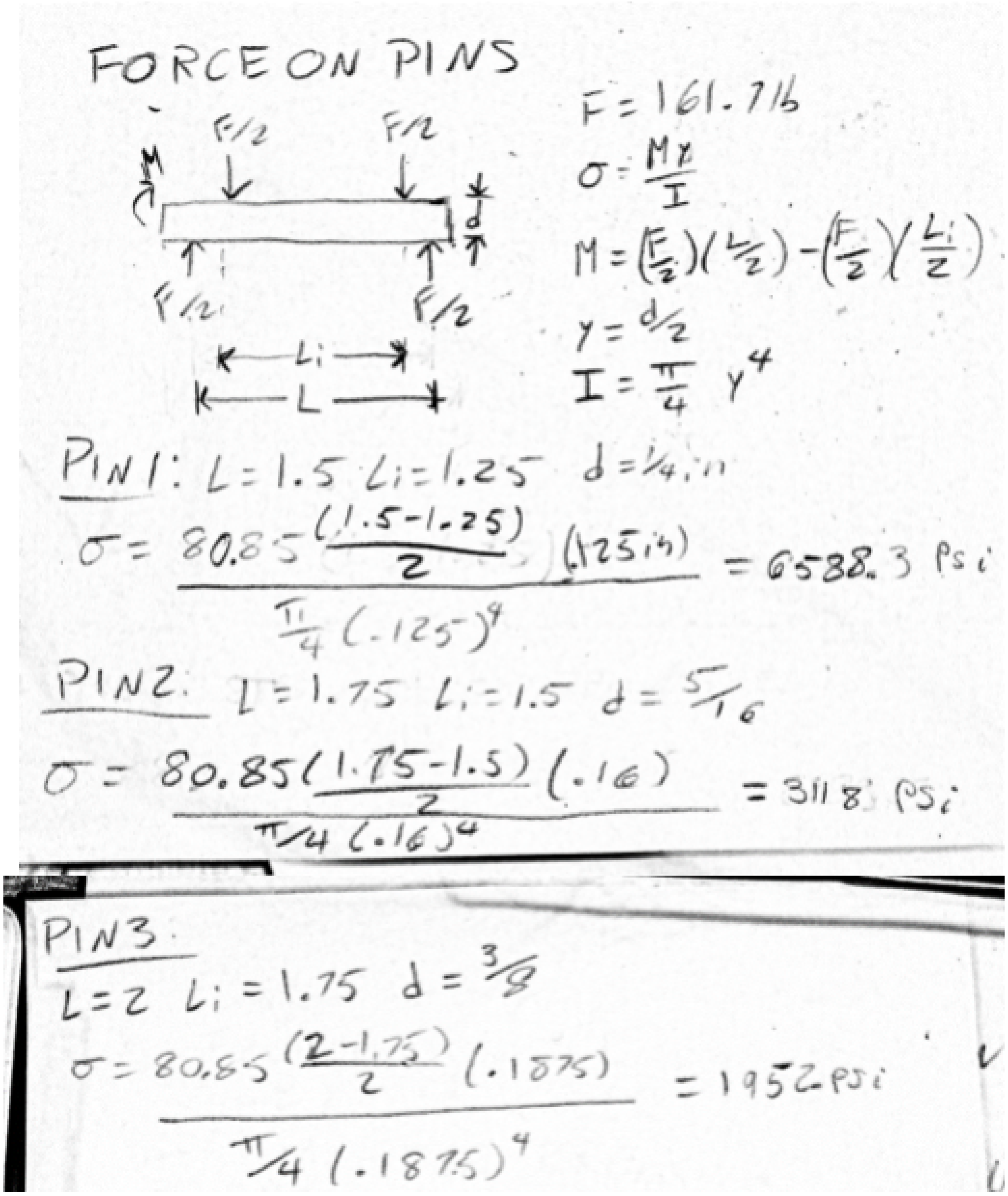

Figure 16: Force on pins calculations

5.2.3 Methodology

For the analysis done prior to building the prototype, all calculations were done by hand. Larissa and Ngoc both carried out the calculations separately as a way to check the work and increase accuracy.

5.2.4 Results

Using 2200 psi as the shear strength of a green oak branch, we found that the force required to cut through a 1.5 in. diameter branch would be 3960 lb. The force on the handles needed to translate that force on the branch was found to be 280 lb. This force was found to require a tension of 323.3 lb in the steel cable. The torque at the pulley from the drill would need to be 485 in. lb. in order to counteract the tension in the cable and pull the shears closed. If a second pulley was factored into the design, the cable tension was decreased to 161.7 lb. which would require a torque of only 242.6 in. lbs.

The max stress exerted on the pins by the tension of the cable was found to be 1688.3 psi. for the ¼ in. pin, 3118 psi. for the 5/16 in. pin, and 1952 psi for the ⅜ in. pin. All of these are well under the 19091.88 psi max shear strength of carbon steel, so there is no concern for the pins breaking.

The flexural strength of fiberglass is 16,000-32,000 lbs. depending on the composition. The fiberglass pole was determined “safe by inspection” because the 161.7 lb. tension in the cable would never be enough to break it through bending. The steel cable was also deemed “safe by inspection” because the cable has a safe working load of 340 lbs. and a breaking strength of 1700 lbs. This is well above the 161.7 lb. tension expected in the cable.

5.2.5 Significance

Since our test subject, a green oak branch, required 3960 lb force to cut through a 1.5in diameter along with 100 lbs force of the spring and a required force of 280 lb to pull the shears handle closed, we learned that we would need to add a double-pulley system onto the design to overcome the tension and pull the shears closed, and cut the branch. Otherwise we would have to upgrade our drill force, which can cause the fiber-glass pole to break due to the higher tension. The double-pulley would reduce the torque of the drill acting on the cable, keeping the fiber-glass pole from breaking.

6 Risk Assessment

6.1 Risk Identification

To identify the risks associated with this project, the group reviewed the scope of the project. This began with identifying what needed to be accomplished to stay on schedule and within budget. Looking at the documented schedule, we were able to identify many risks that could have an impact on both the schedule itself and what impact that would have on other aspects of the project. Within the schedule, we also focused on items that may be harder to source and items that needed extensive fabrication. Moving on to the performance of the prototype, we were able to identify more risks that could have an impact on whether or not our prototype would meet the scope and identified parameters.

The risks identified for our project are; shipping delay of the the telescoping handles, too much torque needed to shear tree limb, the drill clutch will not work for the "stopping" after the branch is cut, unexpected force or calculation error, fall behind schedule during the construction process, not being able to access the necessary Codes & Standards, failure to create two video for design presentation, high cost of materials, lack of communication between team members, materials to break during the transportation/shipping process, safety hazard during building process, team member(s) leaving for vacation, failure to have all paperwork needed for the design documentation and publication, first prototype build is inadequate, and bad weather conditions (extreme storm).

6.2 Risk Analysis

The risks associated with the project directly affect the performance, cost, and schedule. The performance of the shears has many specifications and safety requirements that must be met. If these are not met by the performance of the shears, there are associated risks. These risks could be that it does not cut up to 1.5 in branch, or the shears could collapse and injure an individual. There is an associated budget for this project with built in contingency. These shears are a first of their kind and could result in having to make many revisions to the prototype, and these costs money. This could result in going over budget, presenting a big risk. Also associated with a first of its kind project is the time period for the project. This project required a tight timeline and at any moment, could be thrown off schedule by delays or design problems.

The causes and and potential effects on our project are: shipping delay of the the telescoping handles would result in delay in the building process (schedule), too much torque needed to shear tree limb could result in a major failure in the performance of the shears, the drill clutch will not work for the "stopping" after the branch is cut could result in the shears self-destructing causing harm, unexpected force or calculation error would result in a schedule delay and failure of performance, not being able to access the necessary Codes & Standards could result in failure to meet the performance specification, failure to create two video for design presentation would result in a schedule delay if need to redo, high cost of materials could result in going over-budget (cost), lack of communication between team members could cause delays in scheduling, materials to break during the transportation/shipping process would result in schedule delays and possibly cost delays, safety hazard during building process could affect the schedule of the project, team member(s) leaving for vacation could affect the schedule of the project, failure to have all paperwork needed for the design documentation and publication could affect the schedule of the project and the overall performance of the entire project, first prototype build is inadequate would result in schedule delays and possible unaccounted costs, and bad weather conditions (extreme storm) could cause delays in the testing process (schedule).

6.3 Risk Prioritization

The goal to prioritize the risk associated with this project was to keep the group as far ahead and prepared as possible. Starting with our schedule, we were able to keep on track and meet our milestones prepared at the beginning of the project. We also avoided risks as we progressed through the project. For example, the first risk was shipping delays with the telescoping fiberglass handles. To avoid this, we purchased these within 5 minutes of receiving the permission to begin purchasing items. Another notable example was building the prototype as soon as possible to allow time for testing. This ensured us time within the schedule to make changes if need be. Keeping all documents well labeled and completed on time allowed an easy transition to the final document prior to the due date as well.

Risk Management Register

0	Open Red Risks
3	Open Yellow Risks
4	Open Green Risks
0	Risks w/ no Response Strategy
0	Closed risks

Project Name: Extendo Shears
Project Manager: Ngoc Nguyen
Start Date: 6/13/2022

Location:
Add'l Info:
Updated On:
Overall Project Risk Indicator: 11

Risk Level

Probability					
5	5	10	15	20	25
4	4	8	12	16	20
3	3	6	9	12	15
2	2	4	6	8	10
1	1	2	3	4	5
	1	2	3	4	5
	Impact				

Legend:
Impact
1 - Negligible
2 - Marginal
3 - Significant
4 - Critical
5 - Catastrophic

Pro
1 - R
2 - U
3 - P
4 - L
5 - Ca

Item	Project/ Phase	Risk Status	Risk	Potential Impact (Cause and Effect)	Risk Response Strategy	Triggers (Indicators that the risk will occur)	Estimated Schedule Impact (Days)	Maximum Exposure	Estimated Exposure (Contingency) $63	Risk Category	Risk Sub Category	Action Owner	Start Exposure	End Exposure	Baseline Risk Sc: Impact: Tech Perf	Schedule	Cost	Safety	Probability
0																			
1		Open	Shipping delay of the the telescoping handles	Delay in the building process due to shipping time of the telescoping handles. This is the only item that cannot be purchased at a local store	The handle will be the first item purchased as soon as we get the OK to begin our purchasing. We will expedite the shipping if need be	We are notified of shipping delays or a backorder update.	7	$20	$5	Schedule	Material Constraints	James, Cory	07/25/22	08/08/22		3	3		2
2		Open	Too much torque needed to shear tree limb	The tree limb may require more torque that the drill can produce. This would result in the shears not cutting all the way	Be prepared to add pulleys of different sizes to multiply the torque of the drill	The shears will not cut all the way through the branch	1	$20	$5	Performance	Means to Track and Measure Project Performance	James, Cory	08/01/22	08/08/22	5		3		3
3		Open	The drill clutch will not work for the "stopping" after the branch is cut	Could break other components such as the handle, cable, drill, or pulies.	Lots of testing will need to be performed to ensure the device cannot destruct itself. Potential shear pin addition	Lots of tension will cause buckling or bending within the components of the device	2	$5	$3	Performance	Means to Track and Measure Project Performance	Team	08/01/22	08/08/22	1			2	3
4		Open	Unexpected force or calculation error	Could cause the device to fail cutting or break	Recalcutions will be necessary asap and a potential design change may need to be required	Will be determined during testing; could be any failure of a part(s)	2	$50	$10	Schedule	Schedule Requirements Addressed	Larissa, Ngoc	08/01/22	08/08/22	4		5		1
5		Open	Fall behind schedule during the construction process	If the construction phase takes longer than expected, the deadlines may not be met	Construction will begin as soon as possible and parts will be made as soon as the materials are available to stay on track.	Delays in materials and fabrication of parts will increase the chance of the construction process not meeting the deadlines.	2	$0	$0	Schedule	Schedule Requirements Addressed	Team	07/25/22	08/08/22		4			2
6		Open	Not being able to access the necessary Codes & Standards	Delay in publication of the design documentation as well as meeting the requirement of the class	Meet with Lauren as soon as possible	Codes & Standard file cannot be open and/or it does not relate to the project	2	$0	$0	Project Development	Contract Structure Allows for Shared Risks	James	07/25/22	08/01/22		3			4
7		Open	Failure to create two video for design presentation	Cannot film video or video does not showcase the prototype adequately can results in poor design presentation	Have a team member responsible for film and another responsible for reviewing the footage	Video is blurry and/or video does not meet the requirements that is listed on the presentation guide	1	$0	$0	Technology	Training of Personnel in Ops & Mtce of Technology	Team	08/01/22	08/08/22	2				2
8		Open	High cost of materials	Building materials is too costly for professors to approve of the purchase	Review the list of materials and analyze which product can be source cheaper	Cost analysis of materials is higher than the resource alloted for the class	2	$20	$10	Financial/Regulatory	Cost, Budget, Forecast in Alignment	Team	07/25/22	08/08/22			3		3
9		Open	Lack of communication between team members	Can cause a delay throughout the project lifecycle and will cause the group to recieve a failing grade	Set up longer project calls and discuss each step of the project in detail	A team members start to slack off and stop taking on tasks for the project	3	$0	$0	Operational Impact	Operational Flexibility	Team	07/25/22	08/15/22		2			1
10		Open	Materials to break during the transportation/shipping process	Material arrive as broken will delay the building stage as we will need to reorder the broken part	Need to reorder and expedite the broken part as soon as possible	Buying the part from an unknown source	7	$50	$20	Performance	Means to Track and Measure Project Performance	James, Cory	07/25/22	08/01/22		3	5		3
11		Open	Safety hazard during building process	Not taking the necessary safety precautions can cause injuries to team members	Seek medical help for injuries and review tool safety guides	Team member carelessly using tools without proper gear and lack of awareness about their surrounding	3	$0	$0	Construction	Contractor Safety Program	Team	07/25/22	08/08/22				2	1
12		Open	Team member(s) leaving for vacation	Member(s) did not notify team of vacations can cause delay in assignments and building process	Reorganize the group and reassign tasks	Member(s) lacking	2	$0	$0	Operational Impact	Operational Flexibility	Team	07/25/22	08/08/22		2			1
13		Open	Failure to have all paperwork needed for the design documentation and publication	Not having all the work save and accessible can delay the presentation and write-up of the project	Making sure that all paperwork are scanned and uploaded onto the team Google Drive	Lack of files made for the canvas assignments	5	$0	$0	Schedule	Schedule Requirements Addressed	Team	08/08/22	08/15/22		2			1
14		Open	First protoype build is inadequate	The finish protoype did not meet the user needs	Depending on time & schedule, the team can revisit the design phase and see what can be troubleshoot	The prototype not working as plan during the testing phase.	5	$20	$10	Construction	QA/QC Program	Team	07/25/22	08/08/22	5		3		2
15		Open	Bad weather condition (extreme storm)	Bad weather condition can result in team members not making it to the build site, extending the building phase	Reschdule the meeting date as soon as possible	Bad weather forecast day-of-meeting	3	$0	$0	Schedule	Weather, Site Conditions, Essential Services	Team	07/26/22	08/08/22		3			2

Figure 17: Risk assessment

7 Codes and Standards

7.1 Identification

1. **ASTM-A492 − 95** *Standard Specification for Stainless Steel Rope Wire*

   This standard covers the commonly used types of round stainless steel wire intended for stranding into wire rope, including the chemical compositions, condition, mechanical requirements, finish, packaging, and delivery of the product.

2. **AS/NZS 62841.1:2015** *Electric motor-operated hand-held tools, transportable tools and lawn and garden machinery – Safety*

   This standard provides safety requirements designed to give the user protection against hazards that might occur during normal operation and abnormal operation of a hand-held tool or machine.

3. **ASME B5.56M-1994** *Specification and Performance Standard, Power Shears*

   This standard applies to power shears used to cut metal by shearing, utilizing a fixed lower knife(s) and a non-rotary, moving upper knife(s).

7.2 Justification

1. The stainless steel wire standard applies directly to our project, as it is an important piece to the product design. The main force, from the drill, will be transferred to the shears using a steel wire. This is a very critical part to our project design and will have lots of load bearing on it. It is important that the selected wire meets and exceeds this standard for safety. If this wire were to break, it could cause damage and harm to the user as well as the product itself.

2. The electric motor-operated hand tool code is relevant because our device will be powered by a battery operated hand drill. This code is the Australian code because the same code for the U.S. is out of budget. This code ensures the driving force, the drill, in our project has been deemed safe to use. Also cited in this code are lots of other standards, many referring to electrical and fire related standards. The electrical citations are important as the drill is electric and has the potential to cause the user harm if not properly engineered.

3. The power shears standard refers to large metal shears used by steel and machining shops. We will be using the theory behind the cutting of the power shears as it is very similar to the hand operated lopper shears used for cutting wood. The intended design will have a shear cutting head that is similar to cutting heads used on the power shears.

7.3 Design Constraints

7.3.1 Safety

From the standard, AS/NZS 62841.1:2015 and ASME B5.56M-1994, there are specifications and performance standards around the safety of power tools and shears. For our design, the cutting head of the shears must be safe for the intended cutting size as well as provide safe, reliable cutting. If we were to create our own shears, then it would require more standards and lots of testing to prove reliability. This would take time and effort. Therefore, we decided it would be better to source a pair of shears that already meet industry standards. This will help us save time and effort to focus on other parts of the design. By outsourcing the shears, we can ensure the safety of the design and know that it will meet the specifications and performance standards to be on the market.

7.3.2 Quality

The standard ASTM-A492 − 95 will give us a size constraint on the wire we will use in our design. In order to meet standards, the steel wire must be of high quality and in new condition. By knowing the size constraints, we can make the appropriate assumptions for our engineering analysis as well as understand the sizing of other design parts as well (i.e. size of pulleys and winch drum). Using the steel wire that is high in quality will ensure us that the part will not break while cutting the branch and will last through several uses.

7.3.3 Manufacturing

The current design utilizes a popular drill that is currently being sold on the market will have a constraint coming from the hand held tool standard. To meet the standard AS/NZS 62841.1:2015, we cannot fashion a drill or use an old, out-dated drill as it would defeat the purpose of the standard ASME B5.56M-1994.

7.4 Significance

1. The steel wire will be purchased from a hardware store that carries several different diameters with corresponding strengths of wire. This ensures that the steel wire purchased will meet the required strength. This also takes any worry of not meeting this standard, as they must meet this standard to be sold to the public.
2. The drill to be used is a Dewalt DCD791B. This is a very reputable drill that most households own and it is coming from a well-known manufacturer that meets and exceeds many standards and codes required for safety and performance.
3. The shears/loppers are to be purchased from a reputable hardware store and manufacturer. As shears can be deadly if not made correctly, buying it from a hardware store will ensure and uphold the standards and codes set out by ISO.

8 Working prototype

8.1 prototype Photos

The figure below shows the shears with the poles collapsed. In this form, the shears are about 7 ft. long.

Figure 18: Collapsed prototype

The figure below shows the shears when fully extended. In this form, the shears are approximately 16 ft. long.

Figure 19: Extended prototype

8.2 Working Prototype Video

A short video clip showcasing the overall performance of our final prototype:

https://youtube.com/shorts/QEDK_n86NLM

In the video, the prototype is fully extended to 16 ft, cutting down 3 branches of a live-oak tree that are roughly around 0.5 - 1.5 inches in diameter.

8.3 Prototype components

The figure below shows the top of the prototype where the shears were mounted onto the extendable poles. To attach the store bought shears, one arm was inserted into the top pole and bolted in place. One pulley is bolted to the pole to guide the cable to the arm of the shears where another pulley is bolted to decrease the force needed to close the shears.

Figure 20: Shears mounted on pole

This figure below is a closer view of the spring mounted on the shears. The spring was placed on the outside of the shears by bolting one end to the arm of the shears and welding a ring on the blade of the shears to attach the other side to. This spring keeps the shears open so they can be properly positioned around a branch for cutting.

Figure 21: Close up of shear blades and compression spring

The figure below shows the drill in the drill mount as well as the cable spool. The box and drill mount was welded and a strap was added to keep the drill in place. The drill grips the hex bolt welded to the cable spool in order to wind the cable and close the shears.

Figure 22: Close up of drill in drill mount

The figure below is a closeup of one of the PTO pins used to hold the prototype in its extended position. A hole was drilled through the two poles at each overlapping layer to put the pin in place.

Figure 23: Close up of PTO pin going through pole

9 Design documentation

9.1 Final Drawings and Documentation

9.1.1 Engineering Drawings

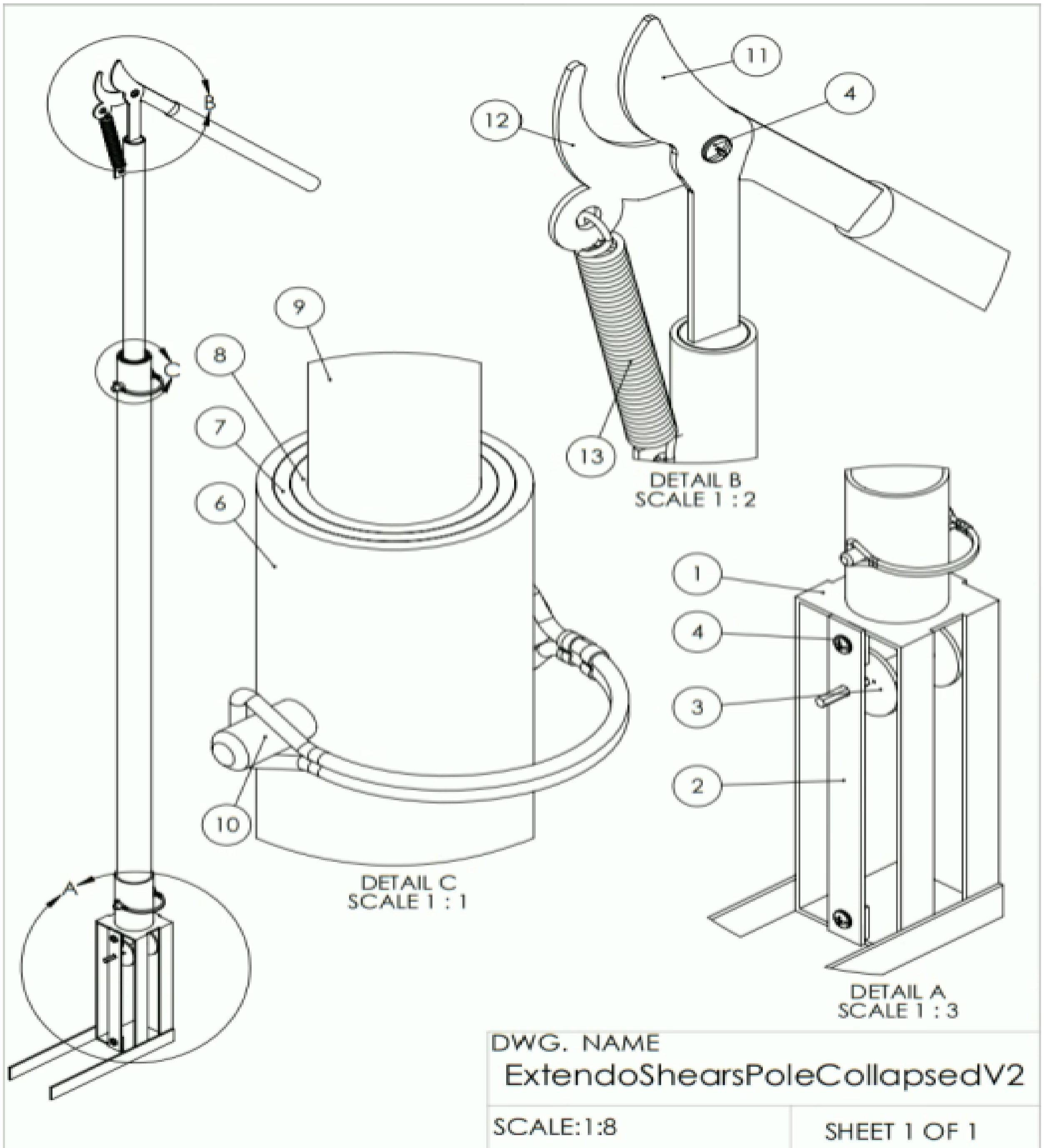

Figure 24: Final engineering drawing

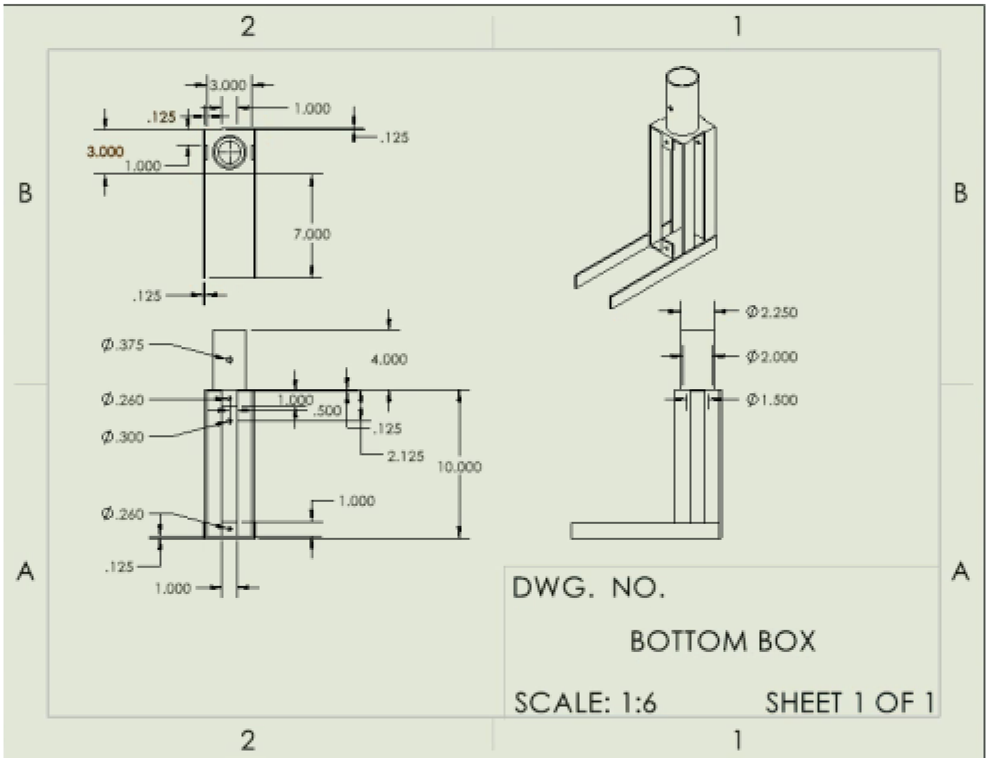

Figure 25: Engineering drawing of bottom box

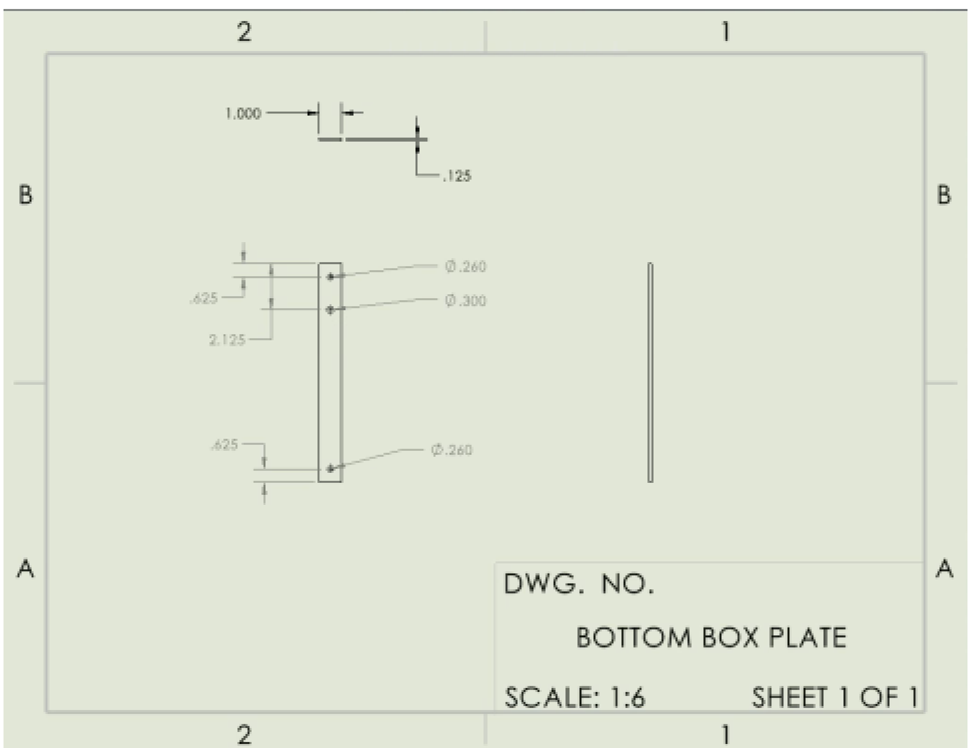

Figure 26: Engineering drawing of bottom box plate

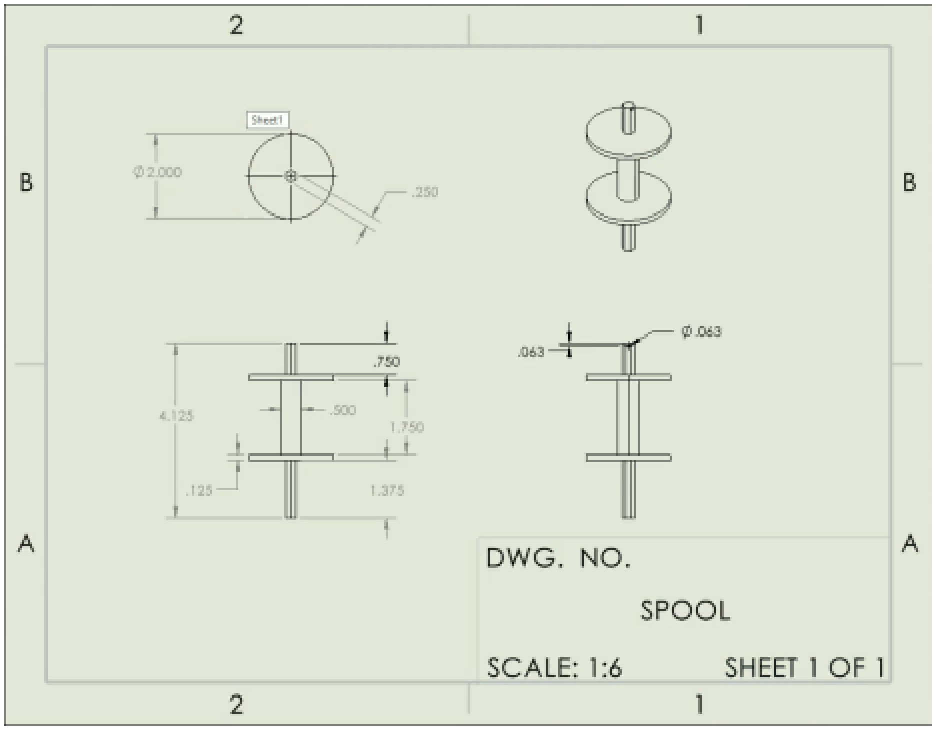

Figure 27: Engineering drawing of spool

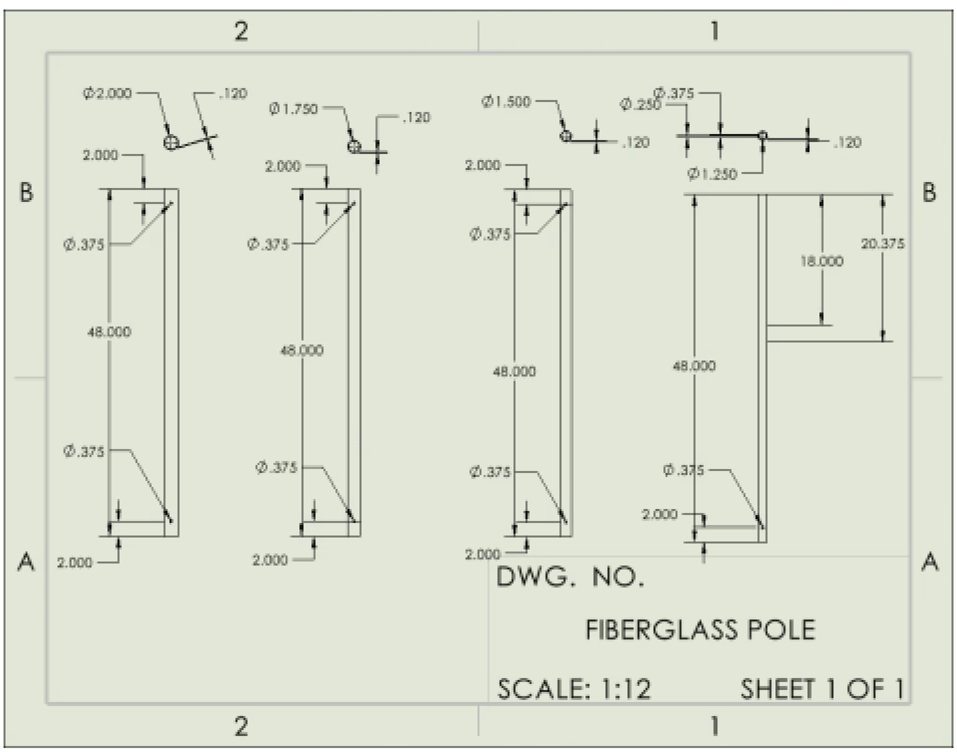

Figure 28: Engineering drawing of fiberglass pole

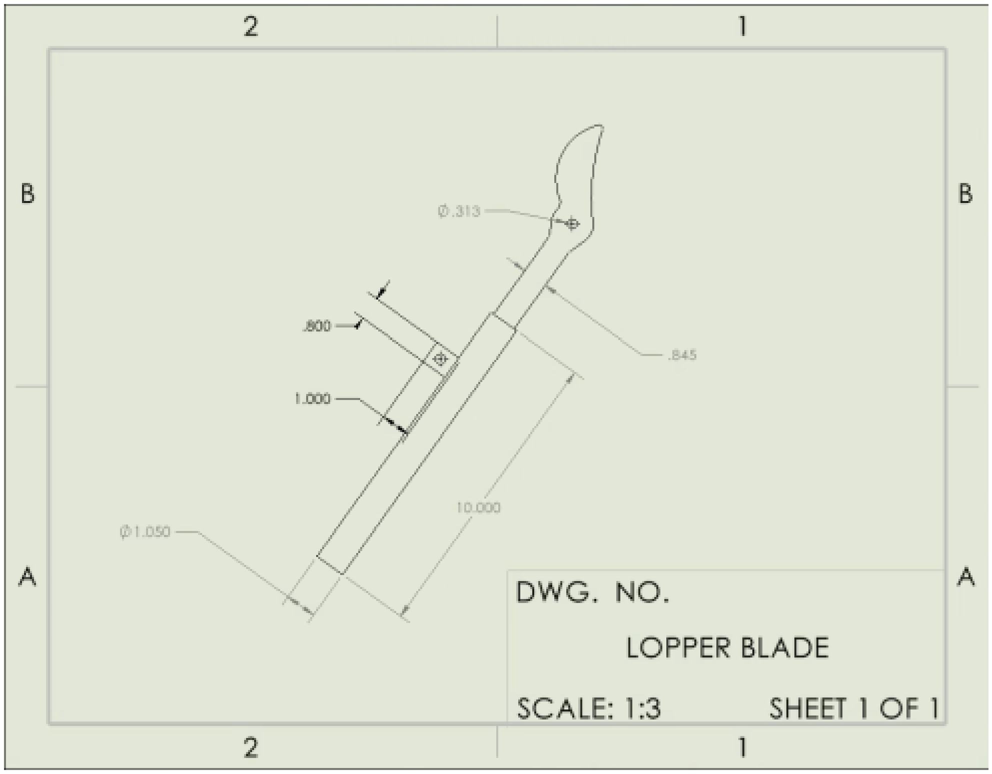

Figure 29: Engineering drawing of lopper blade

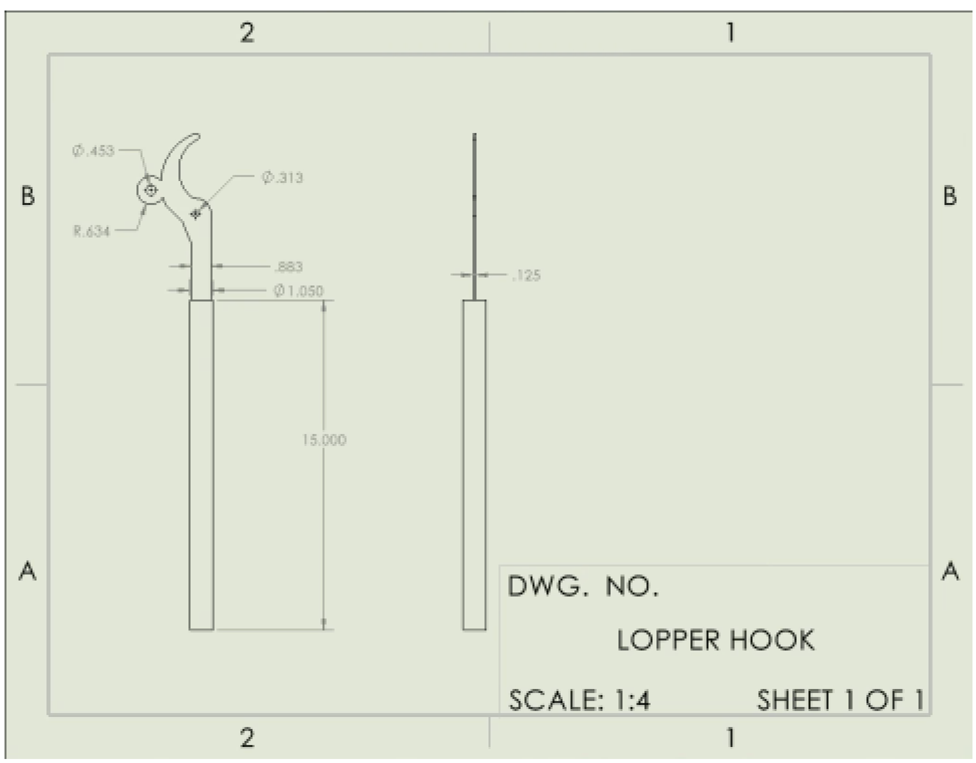

Figure 30: Engineering drawing of lopper hook

9.1.2 Sourcing instructions

1: Bottom Box - The Bottom Box was fabricated from 1in. × 1/8in. steel bars, which can be found in a lot of scrap yards or can be bought in 10 foot sections for $12.40. It was scrounged and repurposed by welding them together to make a box out of them. Then to be able to attach the pole to the metal box, a section of steel tubing, which can also be found in most scrap yards or you can go to most metal places and they will give you a small piece for really cheap. The tubing was welded to the top with a hole through it. The Bottom Box has long extensions on the bottom so you can slot in the drill and it remains stationary in the box. A drill attaches to the pulley that goes into the bottom box and sits between the metal extensions at the bottom of the box, shown in the picture below. Since it works with almost any hand drill, the drill can be sourced from already owned tools, bought used for around $30 depending on the seller or bought new for around $150 depending on the brand.

Figure 31: Close up of bottom box and steel tubing

2: Bottom Box Plate - The plate is just another piece of the same steel to make a removable piece so the spool can be taken on and off.

3: Spool - The Spool is an allen wrench, which is really cheap and can be bought at any hardware store for less than $5. It was bent straight from an “L” shape. Then a pair of washers welded to them as guides. Then a hole is drilled in the back of the straightened wrench so a cotter pin can be put through it to keep it from falling out the front. Then a hole is drilled in one of the washers to retain the cable at the bottom when it is fully extended.

Figure 32: Closer views of spool

6-9: Fiberglass Pole - This pole is made up of 4 sections. They have been modified after we ordered them from DX Engineering. The poles are the most expensive part of the project, coming in at $56 before shipping. They have had holes drilled in them so they can be locked together at full extension.

Figure 33: Close view of extendable poles

11: Lopper Blade - The Lopper Blade is a store bought pair of Fiskars Loppers bought from a local hardware store and modified to fit into our top pole. Then an attachment point is made to the handle for a return spring to be added to it.

Figure 34: Close view of lopper blade

12: Lopper Hook - The Lopper Hook is the other half to the Fiskars loppers from above. This piece has a washer welded to it as a way to attach the return spring to it.

Figure 35: Close view of lopper hood and welded washer

9.2 Final Presentation

Link to the video presentation: https://youtu.be/BXT5_kceolc

10 Appendix A - Parts List

Table A.1: Initial Cost Estimate

Cost Estimate							
Extendable Battery Powered Shears							
Department: Project Management							
Division: Estimates						Date:	7/6/2022
No.	Item Description	Unit	Unit Cost	Qty.	Material	Labor	Total
Handle (approx. 5 lbs)							
1	DX Engineering Telescoping Fiberglass Tubing Sets DXE-TF15	per set	$69.94	1			$69.94
2	PTO Pin Assortment	per box	$9.99	1			$9.99
Drill Mount							
3	1/8" X 1" Hot Rolled Steel Flat (drill Brackets)	per 8ft	$12.04	1			$12.04
4	1/2 OD x .049 wall x .402 ID 1020 DOM A513 Round Steel Tube (cable drum)	per 2ft	$11.02	1			$11.02
5	Eklind 1/4 inch SAE Long Arm Hex L (shaft)	per wrench	$1.99	1			$1.99
6	1/2-in x 3-in Zinc-Plated Coarse Thread Hex Bolt	per bolt	$1.05	2			$2.10
7	1/2-in x 13 Zinc-plated Steel Nylon Insert Nut	per nut	$0.26	2			$0.52
8	1 In. X 12 Ft. Lashing	per 2	$3.99	1			$3.99

	Straps 2 Pk (drill strap)	straps					
9	1.5" Pulley	per pulley	$6.98	2			$13.96
Shears							
10	21.5-in Steel Bypass Lopper	per loppers	$22.98	1			$22.98
11	Compression Spring 4" Long, 0.97" OD, 0.72" ID	per 6 springs	$17.07	1			$17.07
12	1/8-in Weldless Galvanized Steel Cable	per ft	$0.55	20			$11.00
13	3/8-in to 16 x 5.74-in Galvanized/Uncoated Steel Shoulder Eye Bolt with Hex Nut	per bolt and nut	$4.58	2			$9.16
14							$0.00
15	Total Direct costs	N/A	N/A	N/A	N/A	N/A	
16							
17	Indirect Overhead Costs	N/A	N/A	N/A	N/A	N/A	
18							$185.76
19							
20							
21	Total before contingency	$185.76					
22	Contingency (15%)	$213.62					
23	Engineers estimate	N/A				**Total:**	**$213.62**

11 Appendix B - Bill of Materials

Table B.1: Final Cost Estimate

Cost Estimate-FINAL							
Extendable Battery Powered Shears							
Department: Project Management							
Division: Estimates						Date: 8/12/2022	
No.	Item Description	Unit	Unit	Qty.	Material	Labor	Total

			Cost				
Handle (approx. 5 lbs)							
1	DX Engineering Telescoping Fiberglass Tubing Sets DXE-TF15	per set	$69.94	1			$69.94
2	PTO Pin Assortment	per box	$12.99	1			$12.99
Drill Mount							
3	1/8" X 1" Hot Rolled Steel Flat (drill Brackets)	per 8ft		1			$0.00
4	1/2 OD x .049 wall x .402 ID 1020 DOM A513 Round Steel Tube (cable drum)	per 2ft		1			$0.00
5	Eklind 1/4 inch SAE Long Arm Hex L (shaft)	per wrench		1			$0.00
6	1/4-in x 2-in Zinc-Plated Coarse Thread Hex Bolt	per 2 bolts		2			$0.00
7	1/4-in x 13 Zinc-plated Steel Nut	per nut		2			$0.00
8	1 In. X 12 Ft. Lashing Straps (drill strap)	per strap	$6.99	1			$6.99
9	1.5" Pulley	per pulley	$6.98	2			$13.96
Shears							
10	21.5-in Steel Bypass Lopper	per loppers	$22.98	1			$22.98
11	Compression Spring 4" Long, 0.97" OD, 0.72" ID	per 6 springs	$17.07	1			$17.07
12	3/32-in Weldless Galvanized Steel Cable	per ft	$0.35	20			$7.00
13	1/4-in x 2-in Zinc-Plated Coarse Thread Hex Bolt	per 2 pack	$1.52	2			$3.04
14	Misc washers	all washers	$6.38	1			$6.38
15	Cable Clamp	per 2 clamps	$7.98	1			$7.98
16							
17	Total Direct costs	N/A	N/A	N/A	N/A	N/A	
18							
19	Indirect Overhead Costs	N/A	N/A	N/A	N/A	N/A	
20							$168.33
21							
22							
23	Total before contingency	$168.33					
24	Contingency (0%)	$168.33					
25	Engineers estimate	N/A				**Total:**	**$168.33**

12 Appendix C – Complete List of Engineering Drawings

https://drive.google.com/drive/folders/1wMv9KMuW_ppk1Taj8s0swMpUKNDtIoJZ?usp=sharing

https://drive.google.com/drive/folders/1nZG3Wi-J4Y9EGbWBVRrMQ6XBXapklFUh

13 Annotated Bibliography

[1] American Society for Testing and Materials. (2019). Standard Specification For Stainless Steel Rope Wire (ASTM Standard No. A492-95). https://webstore.ansi.org/Standards/ASTM/astma492952019

This standard is related to the quality and safety of the steel cable used in the prototype.

[2] Standards Australia. (2015). Electric motor-operated hand-held tools, transportable tools and lawn and garden machinery - Safety General requirements (AS/NZS Standard No. 62841.1). https://infostore.saiglobal.com/en-us/standards/as-nzs-62841-1-2015-111034_saig_as_as_232284/

This standard is related to the safety and performance of our purchased shears.

[3] American Society of Mechanical Engineers. (2019). Specification and Performance Standard Power Shears (ASME Standard No. B5.56M). https://www.asme.org/codes-standards/find-codes-standards/b5-56m-specification-performance-standard-power-shears/1994/drm-enabled-pdf

This standard is related to the safety of the drill used in the prototype and provided guidelines for what kind of drill we would have to use and changes that could not be made to it.