« SpinSaw - 360° »

by

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Bachelor of Industrial Design

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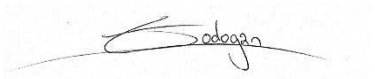
Student Signature : 

Student Name : « Jaaziel Codogan »

Abstract

« According to an article published on the Canadian Occupational Safety website, forestry is regarded as one of the most dangerous industries in Canada. In 2018 the industry suffered eleven fatalities and over one thousand three hundred injury claims. Another article published by the International Journal of Environmental Research and Public Health stated that extreme weather conditions subject workers to extreme cold and heat conditions which in turn leads to reduced work capacity, heat stress and dehydration. Treacherous terrain and site factors such as slopes and soil types pose serious dangers to workers and lead to machinery accidents. Falling trees and branches and tree hang-ups pose serious risks to workers. The combination of shocks, whole-body-vibration and noises can be generated by both outside and inside sources and are known to have a great impact on worker's comfort. The impact of these vibrations can transfer to the feet through the floor of the vehicle and can lead to vascular diseases in the lower limbs. This thesis proposes an in-depth study of daily processes and challenges facing forestry workers using data collection methods such as observational studies, interviews, and surveys. A one-to-one scale ergonomic model would be developed to understand ergonomics and human scale as well as to evaluate the feasibility of the design. A solution will be developed to improve the safety of forestry workers by enhancing their protection in hazardous working conditions and provide workers with a more relaxed working environment. »

Acknowledgements

« I would like to thank God for providing me with the strength and grace to push through this course. Without him, it would be impossible. I would also like to thank my parents, Dexter and Sherron Codogan, for believing in me and encouraging me every step of the way. Their support, unconditional love, and endless sacrifices have allowed me to be in the position I am today. I am forever grateful.

Special thanks to my advisor Jesse James who was kind enough to take time off from his busy day to meet and answer my questions. Without him, I would not have been able to produce such an in-depth study.

Lastly, I would like to thank Catherine Chong and Sandro Zaccolo for assisting me throughout the thesis process and providing a fruitful learning experience. »

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CHAPTER 1- Introduction

1.1 « Problem Definition»

Figure 1- Retrieved from Commons:upload. Wikimedia Commons. (n.d.). Retrieved December 13, 2021, from https://commons.wikimedia.org/wiki/Commons:Upload.

« Forestry workers spend most of their time outside, maintaining and conserving parks and forest land. In the 20th century, it focused mainly on managing land, monitoring plants for insects and diseases, and collecting forest data. According to the government of Canada, Canada is known as a global leader in the production of multiple forest products such as softwood lumber, wood pulp, and wood pellets. Approximately 80% of the forest‘s employment is concentrated in Quebec (31%), British Columbia (27%) and Ontario (21%).

The Logging and Forestry industry is considered to have the most dangerous occupations in Canada. It is estimated that falls account for 25% of all work-related injuries or illnesses on the job. Falling from ground level accounted for 13% of those injuries. Key industry risks include falling trees and branches, falling from heights, falling because of slippery/uneven terrain, tool-related injuries, noise and vibrational hazards and electrical hazards. How might we improve the safety of Forestry workers in Canada?

Research will be conducted to gather general information about the topic. At the same time, user interviews and user observations will be used to gain a more in-depth understanding of the common problems workers face. The goal of this thesis report is to create a unique solution that would improve the physical safety of forestry workers on the job, and in turn reduce the number of work-related industries in the industry.

1.2 « Rationale and Significance »

« To get a complete understanding of forestry workers, specifically Arborists, their daily activities, working conditions and use of equipment will be analyzed to gain more conclusive information. The nature of the research questions will be directed towards fully understanding the environmental, working, and physical conditions Arborists typically experience on the job. Understanding these conditions and how the Arborist interacts with their tools during these conditions will provide relevant information that will influence the final design solution.

The questions in the table below will be used to gain insight and informative data to inform the final design. The final design will be based on the Thesis criteria of enhancing the

human lifestyle through incorporating full-bodied human interaction and full-bodied ergonomics and human factors.

Questions	Area of Study	Research Method
What is the sequence of steps you do when completing a job?	Current norms and practices	One on one Interview
What is the most common cause of injury on the job based on your experience?	Common health and safety issues	Video Review/ 1 on 1 Interview
Describe anything that would make your job easier and less stressful?	Working Conditions	One on one Interview
What sort of tools do you use on the job?	Commonly used equipment	Observational Interview

Table 1- Investigative Approach Taken

1.3 « Background/ History/ Social Context »

« Canada's Forest Industry is a significant contributor to Canada's economic growth. Canadian forests account for 43% of the nation's landmass and represent approximately 10% of the world's total forest cover. This industry also provides over 300,000 jobs nationwide and supports over 300 communities. Unfortunately, the industry has gained a reputation for being unsafe due to the high volume of worker injuries incurred on the job. According to data published on Workplace Safety North's website, in 2020, 1,578 injuries were reported. Contact with objects or equipment accounted for 38% of the total injuries. Bodily reaction and exertion related injuries accounted for 37%, falls represented 17%, while 8% represented other injuries. Forestry workers are also exposed to occupational hazards such as noise-induced hearing loss, poisoning, and respiratory infections.

Increased Safety measures, such as Health and Safety representative basic training, JHSC certification and JHSC Certification refresher courses, have been implemented but have not had any profound effect on reducing injuries or fatalities. Key hazards have persisted. These hazards stem from unsafe operation of equipment, inadequate maintenance of machine guarding, and failure to follow lockout procedures. The potential for harm also exists from poor lifting procedures, working in uncomfortable positions, work or equipment operation requiring repetitive motion, inadequate attention to workplace hazards while walking, and failure to follow procedures while handling hazardous substances have also persisted.

CHAPTER 2- Research

2.1 « User Research»

Figure 2- retrieved from- Google. (n.d.). Google. Retrieved December 13, 2021, from https://www.google.ca/webhp?espv=2.

« The goal of this chapter is to evaluate a specific, focused research topic utilizing scholarly and consumer research methods and tools and provide a detailed analysis of the user profile. It will also show relevant information derived from user interviews, surveys, and questionnaires will also be shown. This analysis of user research will be used to benchmark and technically analyze existing consumer products and market trends. »

2.1.1 « User Profile »

Figure 3 - Caucasian, Male for use in developing user profile. Retrieved from Genna Buck October 21, 2014. (2015, November 5). *Cool jobs Q&A: Arborist*. Macleans.ca. Retrieved December 13, 2021, from https://www.macleans.ca/work/jobs/cool-jobs-qa-arborist/.

Name	Bob White
Age	38
Occupation	Arborist
Education	**AQF Level 3 (Certificate III) in arboriculture**
Family	Married with 2 boys aged 5 & 7
Location	Toronto, Ontario
Frequency	5 days per week
Duration	40hrs/ week
Other Activities	Enjoys cycling and spending time with his family

Table 2- User Profile

User Behavior

« Bob White is a father of two. He lives in Toronto, Ontario, with his family and enjoys spending time with his two sons. Bob has been an Arborist for over ten years and has experience working for small and large companies. However, five years ago, Bob began his own private arborist company. He subcontracts climbing from companies in the Ontario area.

His jobs usually consist of tree trimming and removal. Bob works with a small team and usually keeps them updated on the jobs being performed at the worksites. A typical day for Bob involves identifying possible worksite hazards, conducting jobsite walkarounds ensuring that everyone has the correct PPE before working, and planning and executing the necessary daily tasks. »

User Profile Summary

User	**Description**
Primary	Conservation Scientists, Foresters, Forest and Conservation Technicians, Forest and Conservation Workers
Secondary	Equipment Manufacturers ● Tiger ● Brand T Truckers
Tertiary Users	Distributors ● Wajax ● Redhead Equipment Ltd

Table 3- User Profile Summary

Demographics

A literature search was conducted on Google and on Humber Library's Search Engine to collect important data relevant to the target demographic:

- “Forestry Industry average age”
- “Forestry Industry gender demographics”
- “Forestry worker average retirement age”
- “Forest Industry worker average income”
- “Average forestry worker education “

Findings: The findings from the data gathered have been summarized according to each category being observed.

Age- When conducting this search, several significant facts arose. The average working age of a male forestry worker is 39.7 years, and for a female worker, it is 36.2 years. This situation is a cause for concern because these average working ages are very high compared to other industries. As such, this industry suffers from an ageing workforce.

Average Retirement Age- The average retirement age of forestry workers is approximately 68 years. This situation shows that there is a small duration between working and retirement as compared to other industries.

Gender- Men represent about 84% of the forest industry workforce, while women represent 16%. This state of affairs shows a significant disproportion between male and female workers in the industry.

Average Income- The average forestry salary in Canada is $48,750, representing an hourly rate of $25. Entry-level salaries start at $35,100 per year; however experienced workers earn $79,975.

However, these rates differ in different provinces:

- British Columbia - $64,077
- Ontario - $52,455
- Nova Scotia - $42,059
- Alberta - $39,159
- Quebec - $35,100

Education- Research shows that the most commonly studied areas by forestry workers in the industry are Natural Resources & Conservation, Agriculture, and Biology.

Demographics Summary

Demographics		User Behaviour		Personality		Cognitive Aspects	
Age	36-37	Intense Labour	8hrs per day. 5days per week	Locus of Control		Technical Skill	
Avg Retirement Age	68					Pre-requisite knowledge	
Gender	Predominantly Male			Self-Efficacy			
Education	Majors	Location	Residential- Urban/ Rural				
Income	Avg salary -$48 750	Level of Skill & Knowledge	Medium	Uncertainty Avoidance			

Table 4- Demographics Summary

2.1.2 « Current User Practice »

The data presented in the table below was used to examine the general user's practices to evaluate their daily tasks, procedures and attitudes they experience on the work-site.

The table below is an observation by video, showcasing the typical tasks of an arborist

Drop Zone Safety: Pruning & Felling (Nov 15, 2016)
https://www.youtube.com/watch?v=_-1ITdY4Sj8&t=182s

				
Prep/ Setup- Job briefing. -Emergency Action Plan -Hazard Identification -Special Precautions -Planning Requirements -Equipment Inspections	**Step 1- Pruning Limbs** -Ensure there is a clear path to your dropzone. - Identify caution area which is 6ft outside the dropzone.	**Step 2- Anticipate potential problems** -Workers must be on the lookout constantly for potential hazards while trees are being pruned	**Step 3- Prune Limbs in Small pieces** -This is done using the command and responses protocol. -This enables better limb control or the limb bouncing out of the drop zone area	**Step 4- Use a rope for Control** -Use multiple ropes if necessary to control tree limbs -3 types of roping methods include: two ropes, tip-tie and butt-hitch

Figure 3- Current User Practice

2.1.3 « User Observation »

Activity Mapping

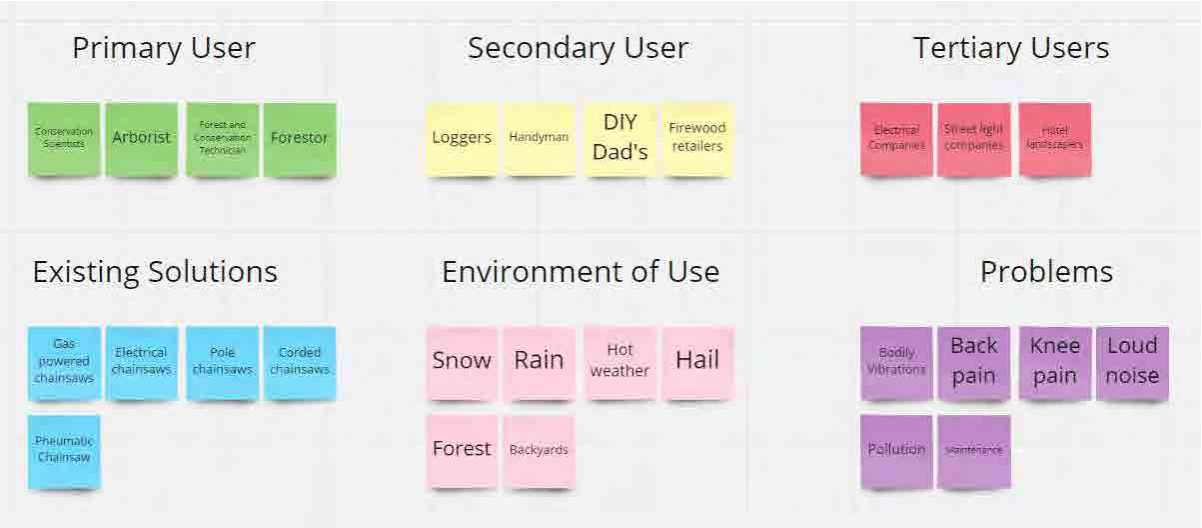

Figure 4- Activity Mapping

Figure 5- Activity Mapping

2.1.4 « User Observation »

Human Factors of Existing Products

To improve the arborist's safety and efficiency, existing human factors of the chainsaw such as component layout, size, space and volume restrictions needed to be evaluated. Chainsaws have two major touchpoints; the two handles used to control the chainsaw. Details such as the distance between both handles, distance between the handles and the user, handle height and size and grip material selection, all need to be considered and benchmarked. The majority of chainsaws follow a similar handle shape. This is because the shape of the handle is crucial to the chainsaw's performance. The weight of the chainsaw also affects its ergonomics because users need to manoeuvre the chainsaw to achieve their desired cut. Heavier chainsaw models negatively affect the user's ability to handle them nimbly. Light chainsaws are far easier to control and allow the user to perform for more extended periods before becoming exhausted. Another consideration affecting the human factors of chainsaws is their weight distribution. Chainsaws with unevenly distributed weights are difficult to handle because of their "off-balanced" nature. Research into existing models show that gasoline-powered and electrical powered chainsaws center their weight.

2.1.5 « User Observation »

Safety and Health of Existing User Products

« Existing chainsaw models barely address the issue of safety. Other than using a shield to block flying debris from hitting the user, there are no additional safety features incorporated into the design to minimize the health and safety risks users are exposed to. Chainsaws come with many pain points, including loud noises that can lead to hearing loss and violent bodily vibrations, which can cause musculoskeletal damage. User observation also revealed that Arborists have to bend often to reach low lying trunks and branches. This repetitive process of bending low for long periods can lead to serious back injury and muscular discomfort. This Spin Saw - 360 design aims to mitigate the existing pain points of the user and increase their overall safety on the job.

2.2 « Product Research »

« The following section of this Thesis report will cover the benchmarking of existing solutions used in the forestry industry based on market trends, expert interviews/ surveys, blogs and discussion boards in order to help identify the key benefits and features while highlighting possible areas for improvement. »

2.2.1 « Benchmarking »

Benefits and Features of Existing Products

Product 1- Risley Delimber LM3600

https://www.fs.fed.us/t-d/programs/forest_mgmt/saleprep/smallwood/Delimbers.pdf

Figure 6

-https://www.google.com/imgres?imgurl=https%3A%2F%2Fi.ytimg.com%2Fvi%2FwVZ34lntCIs%2Fmaxresdefault.jpg&imgrefurl=https%3A%2F%2Fwww.youtube.com%2Fwatch%3Fv%3DwVZ34lntCIs&tbnid=Xa1UphMBVRROHM&vet=12ahUKEwjWwuKUu7LzAhUxgHIEHZCxDE4QMyglegQIARAh..i&docid=2WeQUVwFQS5VHM&w=1280&h=720&q=risley%20lm%203600%20delimber&hl=en&ved=2ahUKEwjWwuKUu7LzAhUxgHIEHZCxDE4QMyglegQIARAh

Description – The Lim-it line LM3600 is the largest roll-stroke tree length wood processor in the woods today. Designed and built to consistently produce the LM3600 delimbs, Measures and processes both hardwood and softwood with speed and accuracy. Available for a wide range of forestry approved carriers, the LM3600 provides a unique mounting and layover control system, optimized for each carrier's operational and transport requirements.

Specifications-

Overall Weight: 25800lbs
Delimbing tube Capacity: 35"
Transportation: Hydraulic Telescopic layover control with mounting bracket
Risley Circular Saw Blade: 18"
Hultdins Supercut Saw with automatic oil Tensioning System
Equal Displacement Hydraulic Cylinder: 19.75 feet @7.7 feet per second
Hydraulic Piston Roll Motor 18.58 feet per second
Standard Configuration: Choice of Spiked or Cheveron cells
Optional Upgrade: FibreSaver Rubber Chained Rolls
Rilsey COMS II (Computer Optimized measuring system)
Rilsey COMS II 3D (Computer Optimized Measuring System for Volume Measuring)
Pressure: 3600-4500 psi
Oil Flow: 100-140 gallons per minute
Optimum Carrier Site: 30 ton

Benefits and Features

- 36" processing table
- One piece 12x12x1/2" Boom
- New Transport Control System
- Robust Delimbing Head
- Adjustable Boom Rollers
- Hultdins Supercut Buttsaw
- FibreSaver Rolls
- COMS II Measuring System with DIAMETER And Top Size Indicator

Product 2- Husqvarna SG13 Stump Grinder

https://www.husqvarna.com/ca-en/products/stump-grinders/sg13-stump-grinder/970445401/

Figure 7 - **https://d323w7klwy72q3.cloudfront.net/i/a/2017/20170816ve/BY9804.JPG**

Description – Portable size, big performance. The SG13 stump grinder makes quick work of small to medium-sized stumps. The heavy-duty construction, ball bearing supported cutting wheel, and powerful Honda engine combines as a seamless package. The handle is easily adjustable as you dig deeper into the ground, and incorporated lift handles make it easy to load and unload.

Specifications-

- Cylinder displacement
  23.7 cu.inch
- Cylinder displacement
  389 cm³
- Motor/engine manufacturer
  Honda

Benefits and Features

Folding Handle

An innovative, adjustable handle enables the operator to adjust the angle of the handle to maintain a comfortable and safe stance.

Robust design

Built strong for demanding professional applications

Long life bearings

Sealed, permanently lubricated and self-adjusting bearings provide reliability and long life.

Easy Transport

Two lift handles on each side allow two people to lift the unit into a truck or SUV.

Product 3- John Deere 803MH Harvester

https://www.deere.com/en/tracked-harvesters/803mh/

Figure 8- **https://d323w7klwy72q3.cloudfront.net/i/a/2017/20170816ve/BY9804.JPG**https://www.deere.com/assets/images/common/products/tracked-harvesters/803mh/Harvester_Tracked_803MH_large_49012839271cb53be637569590e472c603674aab.jpg

Description – Our tracked harvesters meet tough conditions with thoughtful solutions. They are designed with proven components to withstand rugged environments, such as steep slope logging and swamp logging. Explore standard and long-reach boom options, multiple harvesting head choices, expansive visibility and long and wide undercarriages for greater stability. Built on over 180 years of ground-breaking innovation and backed by over a half-century of experience in the woods, John Deere Tracked Harvesters were made to tackle your most demanding tasks.

Specifications-

DRIVELINE

Engine Manufacturer	John Deere
Engine Model	6090H
Displacement, ltr (Inches³)	9 (549)
Rated Speed, rpm	2000
Engine Output, kW (hp)	213 (286)
Engine Torque, Nm (lbf / ft)	1270 (937)
Carrier Rollers - Each Side	2
Track Rollers - Each Side	9
Track Shoe Width, mm (inches)	610 (24)
Height Over Cab, mm (ft/in)	3430 (11 ft 3 in)
Width, mm (ft/in)	3280 (10 ft 9 in)
Overall Track Length, mm (ft/in)	4610 (15 ft 1 in)
Track Length On Ground, mm (ft/in)	3570 (11 ft 9 in)
Tailswing Radius, mm (ft/in)	1940 (6 ft 4 in)
Ground Clearance, mm (ft/in)	715 (2 ft 4 in)
Superstructure Width, mm (ft/in)	3150 (10 ft 4 in)

Slewing Angle, Degrees	360

Benefits and Features

- Reach beyond New extended stick option (for 800MH models only) enables a longer reach to minimize the number of cut trails and maximize machine efficiency.
- Multiple boom-set/ attachment combinations A variety of boom sets and felling and harvesting attachments can be combined to optimise productivity across a wide range of conditions.
- Surefooted stability Long, wide undercarriage provides solid balance to maximise stability, no matter the terrain.
- The dual swing system increases power and performance in demanding felling or harvesting conditions, boosting overall productivity.
- Ample tractive effort Strong tractive effort generously increases capability for negotiating difficult or steep terrain, deep snow, and swamps.
- Smart debris management Designed to keep your workspace free and clear, the productivity-boosting debris-management system is integrated into the hood and left-side guarding to prevent materials and debris from entering the cooling package. External screening sealed cooler compartment and standard variable-speed reversing fan provides cooling protection when and where needed.

Product 4- STIHL MS 261 Chainsaw
https://www.stihlusa.com/products/chain-saws/professional-saws/ms261/

Figure 9- https://www.stihlusa.com/WebContent/Images/Product/933/ms261.png?preset=Product.ProductDetails

Description – The MS 261 chainsaw delivers low emissions, high fuel efficiency and, of course, professional-grade performance. Its redesigned cylinder and ergonomic housing deliver a great power-to-weight ratio, weighing just 10.8 lbs. Designed for large volume cutting, the MS 261 also features our anti-vibration system for enhanced comfort. Other convenience features include pre-separation air filtration system and a redesigned spiked bumper. Add the MS 261 to your jobsite today.

Specifications-

DISPLACEMENT	3.06 cu. in.
ENGINE POWER	4.0 bhp
POWERHEAD WEIGHT	10.8 lbs.
FUEL CAPACITY	16.9 oz.
CHAIN OIL CAPACITY	9.13 oz.
OILOMATIC® CHAIN	.325 RM3
POWER SOURCE	Gas
GUIDE BAR LENGTH (Recommended)	16 in.

Benefits and Features

- Adjustable Automatic Oiler

  The Adjustable Automatic Oiler allows the user to adjust the lubricant of the guide bar and saw chain for different bar lengths and cutting conditions.

- Anti-Vibration System

  STIHL has developed a system for minimizing the vibration levels of handheld outdoor power equipment. The STIHL anti-vibration system helps reduce operator fatigue and provides a more comfortable working experience.

- **Caring for Nature**

  The STIHL Inc. “Caring for Nature” seal identifies its powered products that are more environmentally conscious, producing zero or low exhaust emissions. STIHL Inc. defines “low exhaust emissions” as being cleaner than EPA and/or CARB exhaust emission standards.

- STIHL ElastoStart™

  The ElastoStart™ starter handle is an exclusive feature of STIHL. It is a starting grip with a built-in shock absorber that helps reduce the effort when pulling on the starter cord. The ElastoStart™ starter grip noticeably reduces the sudden peak forces (compression) usually felt during cranking. The forces which occur at the grip after the first compression stroke are smoothed out.

- IntelliCarb™ Compensating Carburetor

  The IntelliCarb™ Compensating Carburetor is designed to automatically adjust the air/fuel ratio when the air filter becomes restricted or partially clogged and maintains the engine’s correct RPM. IntelliCarb™ uses air from the clean side of the air filter to control the diaphragm and flow of fuel. As the air filter becomes dirty and less air is available for the carburetor, the

IntelliCarb™ system adjusts the fuel flow to compensate for the decrease in air flow. This is in contrast to typical carburetors that utilize this air from the “dirty” side of the air box.

- Side-Access Chain Tensioner

  The side-access chain tensioner makes it much more convenient for the user to adjust the saw chain with a bar wrench as opposed to the typical location of the guide bar adjustment screw.

- **STIHL Quickstop®**

  STIHL chainsaws are equipped with a chain stopping system designed to reduce the risk of injury in certain kickback situations. It is called a STIHL Quickstop® chain brake. The STIHL Quickstop® chain brake is designed to stop the rotation of the chain if activated by the operator’s hand or by inertia if the saw kicks back with sufficient force. In some working positions, the STIHL Quickstop® chain brake can be activated by inertia, stopping the chain within fractions of a second.

- **Ematic™ Lubrication System**

  The Ematic™ guide bar, when used with STIHL OILOMATIC® saw chain, will provide proper lubrication and less oil consumption than conventional methods. The system works because two ramps, strategically placed in the guide bar rail, help contain the flow of oil and direct all lubrication to the sliding faces of the bar and chain links as well as the rivets and driver holes, which in turn can reduce bar oil consumption up to 50%.

- **Master Control Lever™**

  The Master Control Lever™ is an easy to use single lever, operating the choke, starting throttle lock and on-off switch. The operator must pull the throttle trigger before moving the Master Control Lever™ to the choke position.

- Decompression Valve

  The decompression valve, also referred to as 'deco' or 'deco valve', vents compression in the cylinder for easier starting. The decompression valve temporarily reduces the compression in the combustion chamber during cranking and helps reduce the effort needed to pull the starter rope. It is opened manually and closes automatically as soon as the engine fires.

- **Built in the USA**

  A majority of STIHL gasoline-powered units sold in the United States are built in the United States from domestic and foreign parts and components

2.2.2 « Benchmarking »

Functionality of Existing Products

Delimbers - Delimbers are available in many different forms. They are known as Gate Delimbers, Pull through Delimbers and Flail Delimbers. For the purpose of this evaluation, Pull, through Delimbers, will be used. A pull-through delimber is known as a processor with processor's heads mounted horizontally, without a feeding mechanism or measuring capabilities. A pull through delimber can be a standalone unit or mounted on a vehicle or trailer as the loader for stability and convenience. The loader picks up trees and places them in the pull-through delimber. The delimber usually has three blades that wrap themselves around the stem. When the loader pulls the branch through, the delimber removes the limbs from the tree. Most pull-through delimbers have a topping saw in them that will cut off the top of the tree.

Harvester- A harvester is a self-propelled machine with a cutting head attachment that can fall and process stems. Harvesters improve user convenience by removing the burden of heavy weightlifting and the safety hazards associated with trunk and stem processing. There are two main types that contain four to eight wheels on each side. Tracked harvesters are identical to their wheeled counterparts. However, tracked harvesters use tracks instead of wheels to move around.

Stump Grinder- This is a power tool, similar to a lawnmower, that is capable of removing tree stumps by means of a rotating cutting disc that chips away from the stump wood. The operator guides the device over the entire stump, and the blade reduces the wood to chips,

grinding the stump down to well below ground level. A stump grinder improves user convenience by making the stump removal process more efficient and reducing manual labour intensity.

Chainsaw- A chainsaw is defined as a gas, hydraulic, or electric-powered saw with a chain loop pulled around a bar at a high speed. This chain contains cutting teeth that are capable of slicing through wood. Chainsaws improve user convenience by cutting trees much faster than a worker with a saw or axe, reducing their work time and level of fatigue.

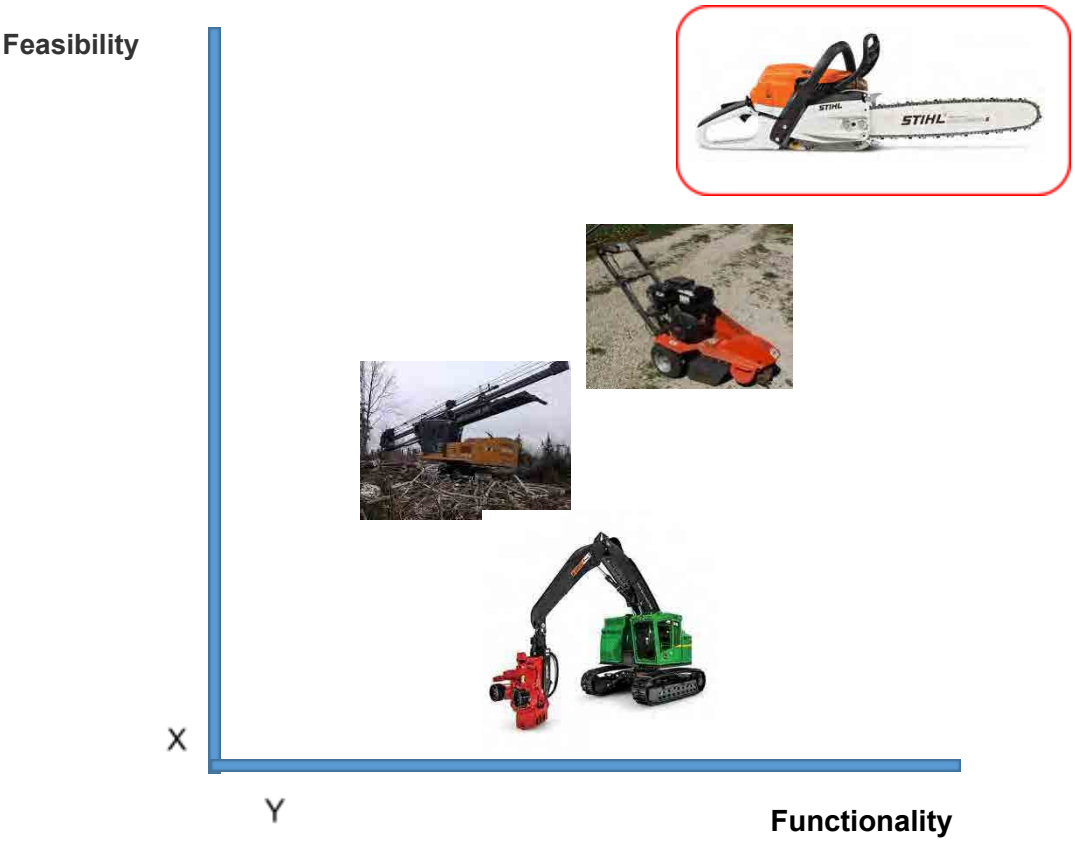

Table 5- X-Y plot

The X-Y Graph measures the feasibility and the functionality of the benchmarked products. The zone of opportunity is highlighted in red. This device offers the best combination of feasibility and functionality for the Thesis project.

2.2.3 « Benchmarking »

Aesthetics and Semantic Profile of Existing Products

Based on the product research conducted, the aesthetics relating to forestry equipment in the commercial industry follow along the lines of functionality. This is because the functionality is more important than design aesthetics in the field. The current aesthetic values are durability and ruggedness. However, this provides an opportunity to add aesthetic elements in the final design as they are overlooked or minimally considered. The majority of parts are exposed on each design, while the outer shells minimally encase the fragile or moving parts.

This Thesis hopes to incorporate more organic aesthetics into the design so that the user can appreciate their device on a physical and emotional level.

2.2.4 « Benchmarking »

Materials & Manufacturing of Existing Products

« Materials which appear in current benchmarked products are as follows »

Material	Benefits	Reference
Forged Steel	Improved Strength & Physical Properties Better Quality Cost Saving	*1.5 consequences of light travel time - astronomy*. OpenStax. (n.d.). Retrieved December 13, 2021, from https://openstax.org/books/astronomy/pages/1-5-consequences-of-light-travel-time
Steel Alloy	High Tensile Strength Lightweight Usable at high temperatures Heat dissipation properties Durable and tough	Ferro, H. (n.d.). What are the benefits of buying alloy steel bars? Retrieved December 15, 2021, from http://hindustanferro.com/what-are-the-benefits-of-buying-alloy-steel-bars.html
Stainless Steel	Corrosion Resistance. Fire and heat resistance Hygiene Impact resistance and strength Aesthetic appearance Sustainable Long term value	7 benefits of stainless steel: Why Stainless Steel is so good. SRS Group. (2021, April 7). Retrieved December 15, 2021, from https://www.srsgroup.co.nz/blog/7-benefits-of-stainless-steel/

Lexan Polycarbonate Sheeting	Higher level of impact resistance (250 times the impact resistance of glass) Less rigidity than acrylic and can be bought in flexible grades Can handle temperatures up to 240 degrees Fahrenheit Highly resistant to acids and other chemicals such as gasoline Can be drilled without worry of cracking Can be cold formed or bent without heating Low level of flammability	Lexan vs. Acrylic. Discover the Difference Between Lexan & Acrylic - A&C Plastics. (n.d.). Retrieved December 15, 2021, from https://www.acplasticsinc.com/informationcenter/r/lexan-vs-acrylic

Table 6- Materials & Manufacturing of Existing Products

The material choice and manufacturing methods associated with the materials specified in Table 6, are essential for forestry equipment performing in extreme weather and adverse terrain. Such as the Snowy weather in densely forested areas. Materials used in the products analyzed in the benchmarking phase include Lexan Polycarbonate Plastic, Stainless Steel, Forged Steel and other steel alloys. These materials are used because they are reliable under intense physical stress and durable for long periods. All materials also have high resistance to hot and cold temperatures. These materials also have high impact resistance and can withstand a significant amount of physical abuse.

2.2.5 « Benchmarking »

Sustainability of Existing Products

The materials used to manufacture the forestry equipment mentioned in Table 6 can all be recycled. However, the large carbon footprint associated with manufacturing steel has created political pressure to improve the sustainability of its manufacturing process. For example, steel tracks are often used in the delimber and the harvester because they provide excellent grip and load distribution, improving work productivity. Because steel is produced using energy-intensive manufacturing processes, the tracks have a high embodied carbon dioxide (CO_2) content.

The benchmarked forestry equipment each contains powerful engines. The mulcher and the harvester have large diesel engines, and the chainsaw and the stump grinder have small gasoline powered engines. These engines consume a lot of fuel and release significant amounts of CO_2 emissions into the environment.

2.3 « Summary of Chapter 2 »

Chapter 2 summarises what it means to be an arborist in the forestry industry. This research was accomplished through extensive literature searches, user observations and product benchmarking. To conclude this chapter's data will be retrieved from a one-on-one user interview.

1. Participants stated that their most used tools are chainsaws, positioners, snake tails, pickup trucks, utility trailers, loggers, saddles, helmets, radios, gloves, eye protection, straps, spurs.

2. Participants are often "on edge" on the job because of the high probability of hazards such as falling trees, falling branches and uneven terrain.

3. They also experience high anxiety working near heavy equipment due to flying debris.

4. Participants spoke about the fact that they need to be very alert during lousy weather because working conditions become far more dangerous and the chance of themself or other workers getting injured increases.

5. Participants stated that the most common work injuries they have seen are falls, getting struck by falling trees or branches, coming in contact with biological hazards, falling on rough terrain, slipping in bad weather and kickback from chainsaws.

CHAPTER 3 - Analysis

3.1 Analysis « Needs»

Figure 10 - retrieved from- Always hang birdhouses in tree-friendly ways. RSS. (n.d.). Retrieved December 15, 2021, from https://www.arboristnow.com/news/always-hang-birdhouses-in-tree-friendly-ways

This chapter will review the content displayed in Chapters 1 and 2 and evaluate it to best accommodate the needs of the user. Collecting all the user and product research data covers an extensive range of factors with which the user experiences and interacts.

3.1.1 « Needs/Benefits Not Met by Current Products »

- Arborists need to be comfortable while cutting because chainsaw vibrations can lead to trepidation disease damage. Exposing the body to vibration for extended periods can lead to permanent neuro-muscular and locomotory apparatus.
- Arborists need quieter equipment while working because prolonged exposure to loud noise negatively affects the user's hearing and can eventually lead to permanent hearing loss.
- Arborists need an appropriate tool to cut trees and tree branches in very tight spaces.
- Arborists need a device that reduces the number of times they need to bend or one that can assist with bending because repetitious bending over long periods can lead to severe lower back and knee injuries

3.1.2 « Latent Needs »

Based on promotional literature, it was determined that the top six benefits for Chainsaws are: comfort, efficiency, power, versatility, ease (simplicity of use) and compactness.

The relation between these benefits and corresponding Fundamental Human Needs are shown in the table below:

	Benefit	**Possible Corresponding Fundamental Human Needs**	**Relationship between benefits and FHN**
1	Comfort	Control over environment, Securing resources	Strong
2	Efficiency	Autonomy, Intrinsic Pleasure,Control over Environment	Strong
3	Power/Speed	Autonomy, Intrinsic Pleasure, Social Status	Strong
4	Versatility	Control over environment	Strong
5	Compactness	Aesthetically appeal, Storage Ability , Social Status	Moderate
6	Ease	Self-esteem (mastery) , Accomplishment	Strong

Table 7- Relation between these benefits and corresponding Fundamental Human Needs

Comfort- In this context refers to reducing the chainsaw's recoil (of the engine when starting) and the vibrations of the motor while in use. Both can decrease the user's sense of safety and security on the job.

Efficiency- In this context relates to the user's ability to recharge/refuel on the worksite. Minimized downtime on the job gives the user a sense of security because they have more time for other tasks

Power/Speed- This relates to the user's ability to deal with multiple types of wood varying in hardness. Which in turn, makes the user feel more skilled and accomplished.

Versatility refers to the user's ability to use their tool in multiple scenarios effectively. This would increase the user's sense of security on the job by giving the user greater control over their environment.

Compactness- In this context refers to the convenience of the user being able to store and carry their chainsaw.

Ease- This relates to self-actualisation, particularly higher self-esteem and a heightened sense of accomplishment.

Figure 11 below shows the needs that the final product will meet.

Figure 11- Google. (n.d.). Google slides - create and edit presentations online, for free. Google. Retrieved December 15, 2021, from https://docs.google.com/presentation/d/1OT1Is4hmIYhGXzDPc4mubTKN1a0Oqy5ULv6ge6HNdPk/edit#slide=id.g10228549b5a_0_214

3.1.3 « Categorization of Needs »

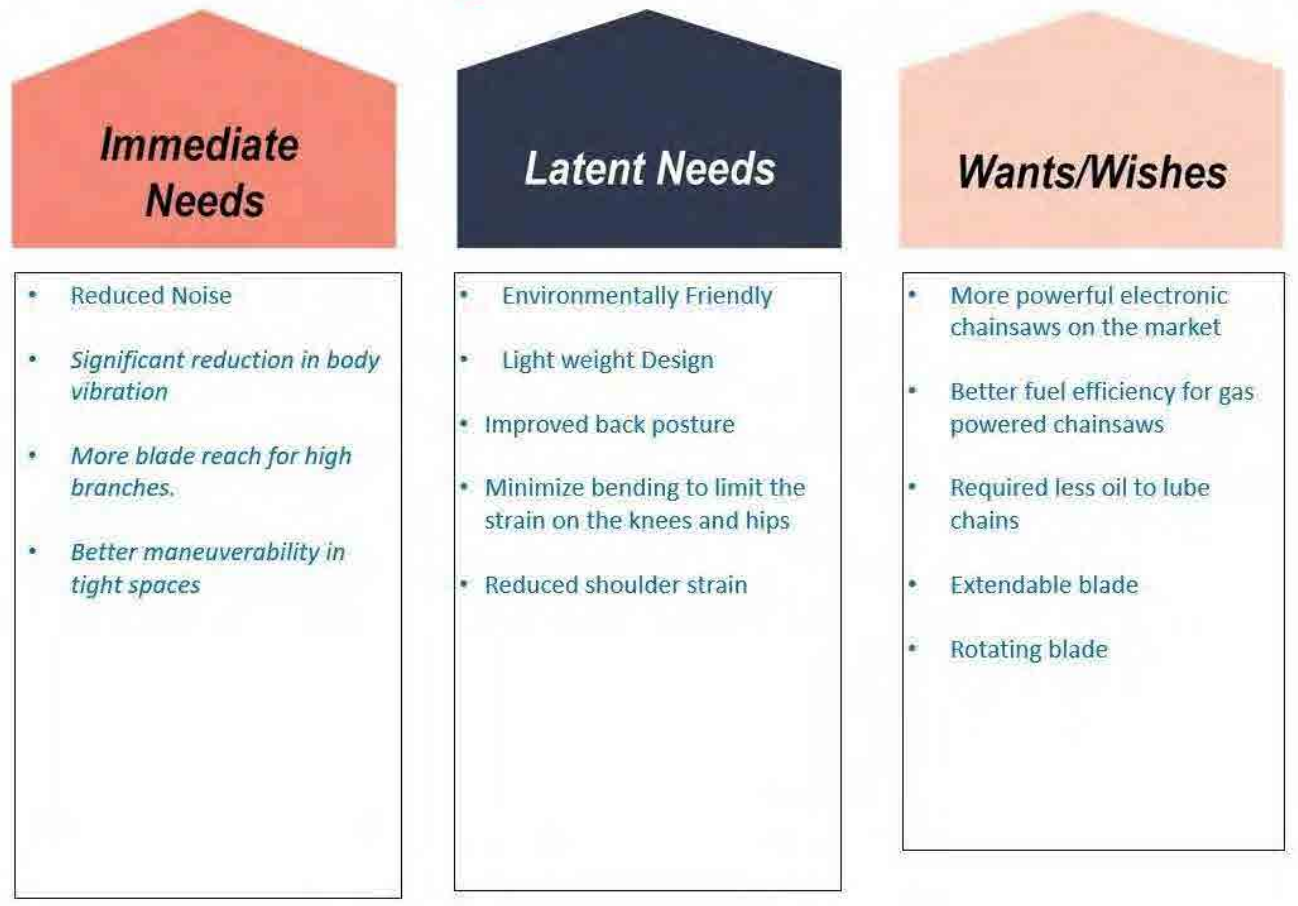

Figure 12- Google. (n.d.). Google slides - create and edit presentations online, for free. Google. Retrieved December 15, 2021, from https://docs.google.com/presentation/d/1OT1ls4hmlYhGXzDPc4mubTKN1a0Oqy5ULv6ge6HNdPk/edit#slide=id.g10228549b5a_0_187

3.2 Analysis « Usability »

The following data was investigated using an observational interview to evaluate the pains and gains that the user experiences while performing their typical daily activities. This was done in real-time so that the researcher can better understand and inquire about the different factors that negatively affect the arborist's safety. The data gathered from this observation would be used to hypothesize appropriate design solutions that will influence the final design. An observational study was conducted to examine the user actions while performing typical jobs on the worksite. This was recorded via a mobile smart device to conduct further in-depth analytics utilising mp4 playback. »

3.2.1 « User Journey Map »

A User Journey Map was created to capture the user's actions, thoughts, feelings, and user experiences while completing his tasks.

	Preperation	Task 1		Task 2	Task 3	Task 4	Completion
User Goals	Equipment Check	Protective Gear	Start Chainsaw	Cut notch into trees in a confined space	Cut tree trunk from rear in a tight space	Controlling/Directing falling tree	Cutting bigger logs into smaller pieces for transport
							
User Actions	Locates sharpening tool	Ensure that necessary protective	Hold handle firmly	Estimate safest direction for tree to fall	Be on lookout for safety hazards	Push tree in wanted direction	
	Sharpens chainsaw		Pull starter	Workers must be on the lookout constantly for potential hazards while trees are being pruned			
	chainsaw safety check		Rev engine to prevent it from	Identify caution area which is 6ft outside the dropzone.			
	Maintenance						
User Thoughts	Lets inspect the equipment guys	I must ensure I have on my safety gear dropzone	I hope this starts with one pull	I must keep my eye out for hung up branches	I hope this tree doesn't fall on me	I hope this rope is tied tight enough	Finally were done!
	Where did I put my sharpening tool?		Don't pull the starter too aggressively because the chainsaw can fly out of my hand	There are too many obstruction near this tree.	I hope this chainsaw does not get stuck.	I hope this rope is tied properly	Time to get paid
				This tree is rotten and may fall. Keep your distance.	I must be careful not to damage anyone's house		
User Feelings	a sense of responsibility	precautious	Hopeful	precautious	precautious	Anxious	Satisfied
					anxious		Happy

Figure 13- User Journey Map

3.2.2 « User Experience »

Storyboard / Photos							
User Experience							
+							
Neutral							
-							
Problems/Challenges	Takes a long time	Branches can suddenly fall and injure workers	Starter can fly out of hand	Hazards can occur without worker seeing it before hand	Workers can get hit by tree or branches	May lose control of tree	
	Tools can be easily lost (Which makes them hard to find)	Freak accidents often occur	May take many repititons to start which can strain the shoulder		Workers have a hard time of getting a good cut into the tree	Trees may fall on someone's property	
Ideas / Take-aways	Create a tool that can attach to utility belt	Improve the protective gear of workers	Utilize electric technology	Create a monitoring system that can warn workers in real time	increase the chainsaw's reach by adding a blade extension feature	Create a barrier of protection around the drop zone.	

Figure 14- User Experience Map

3.3 « Human Factors»

The goal of performing an ergonomic analysis is to assess the gain of the suggested solution of improving the safety of forestry workers in Canada. The results previously mentioned would help to provide a solid foundation for creating a refined, user-friendly human-centred design solution. This study will analyse the full-bodied human interaction and full-bodied ergonomic limitations of the user with the chainsaw. The Thesis criteria describe full-bodied design as a design solution that consists of a minimum of two significant touchpoints and no less than three in all.

Key objectives for testing

1. Observing how different primary users (5th percentile female and 95th percentile man) hold chainsaw in resting position.
2. Observing how battery pack fits 5th percentile woman and 95th percentile man.
3. Observing how the user holds the chainsaw in different handle positions.
4. Observe what circumstances require the user to use the swivel blade feature.

Literature Review

The Measurement of Man and Woman written by (Tilley & Dreyfuss, 2002), was referenced to establish male and female dimensions and human factors to ensure the final design accommodates all body types. This reference was utilized due to its precise and detailed assessment of the human body.

3.3.1 « Product Schematic Configuration Diagram »

The following images will lay out the core elements of the final design. This strategy will use abstract, graphic symbols rather than realistic parts/design because it is a more efficient method of representing the layout of elements of the product system.

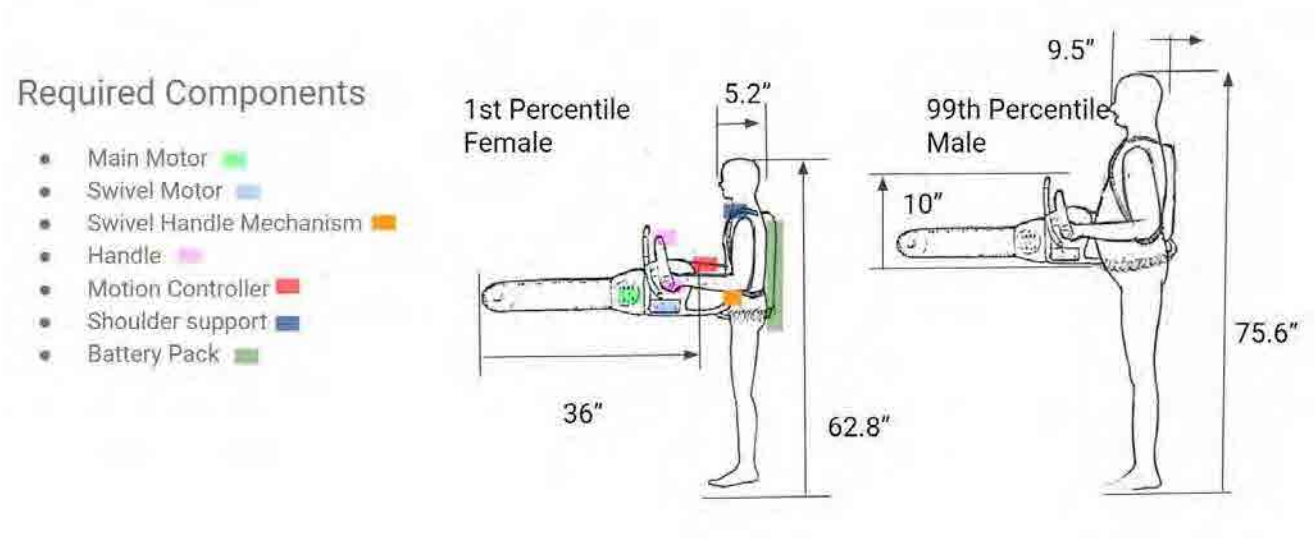

Figure 15- Product Schematic Diagram- Required Components

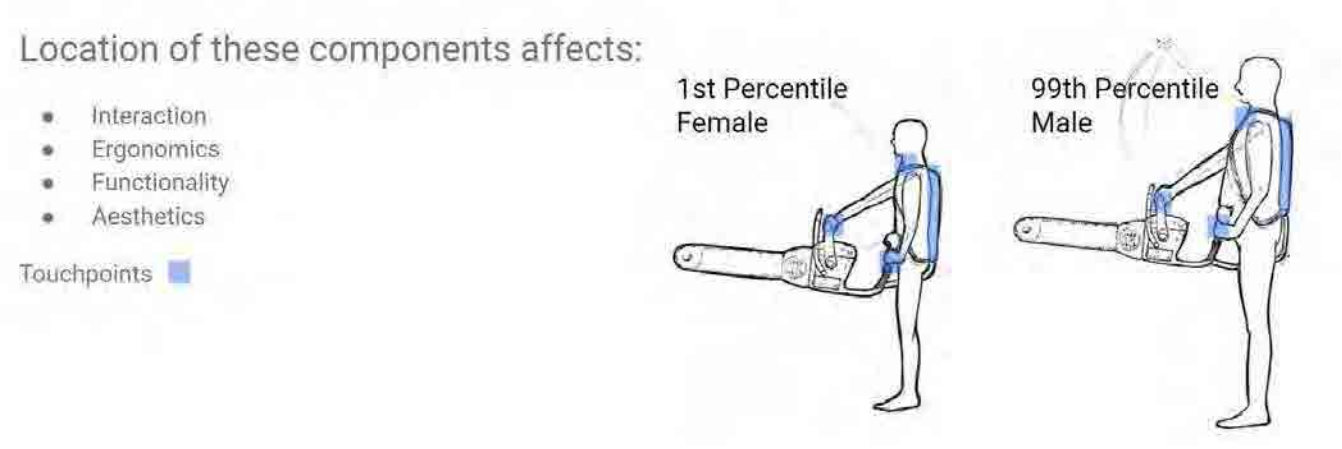

Figure 16- Product Schematic Diagram- Touchpoints

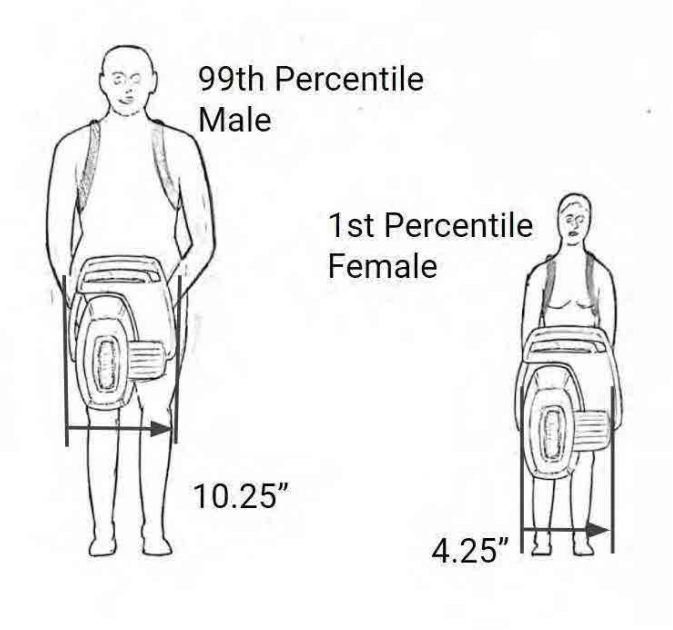

Figure 17- Product Schematic Diagram- Front View

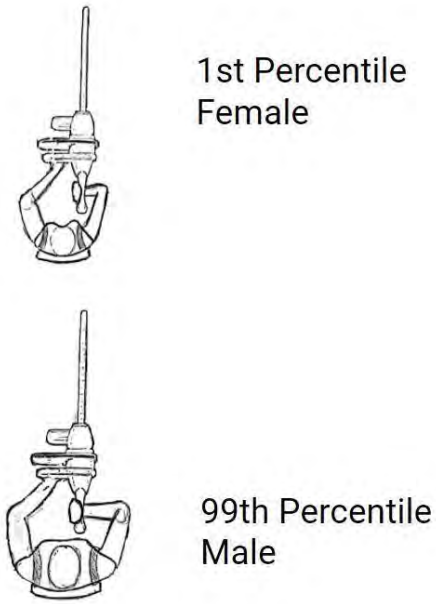

Figure 18- Product Schematic Diagram- Top View

3.3.2 « 1:1 Human Scale Study »

Methodology

The design of this 1:1 scale model referenced existing electric chainsaw dimensions to form an “ergonomic foundation,” which was then altered for the specific needs of this project. Dimensions such as the distance of the handle from the user, location of the chainsaw handle relevant to the user and the chainsaw’s overall length and width were used to create a “dimensional framework” for the ergonomic model. The model was created from pink extruded polystyrene. Users were invited to participate in the interactive ergonomic study.

Scale model features to be tested:

- The swivel blade
- Optional handle positioning (Using 95th percentile man and 5th percentile woman.)
- Ergonomics of battery. (Using 95th percentile man and 5th percentile woman.)

Results

The results are depicted below by photographs, ergonomic diagrams, ergonomic interactions, and key ergonomic aspects with help of a 1:1 scale model and anthropometric dimensioning data. The 1:1 scaled model was built using relevant data associated with the 99th percentile male and 1st percentile female. However, the physical evaluation was done using a 95th percentile male and a 5th percentile female.

5th Percentile Female

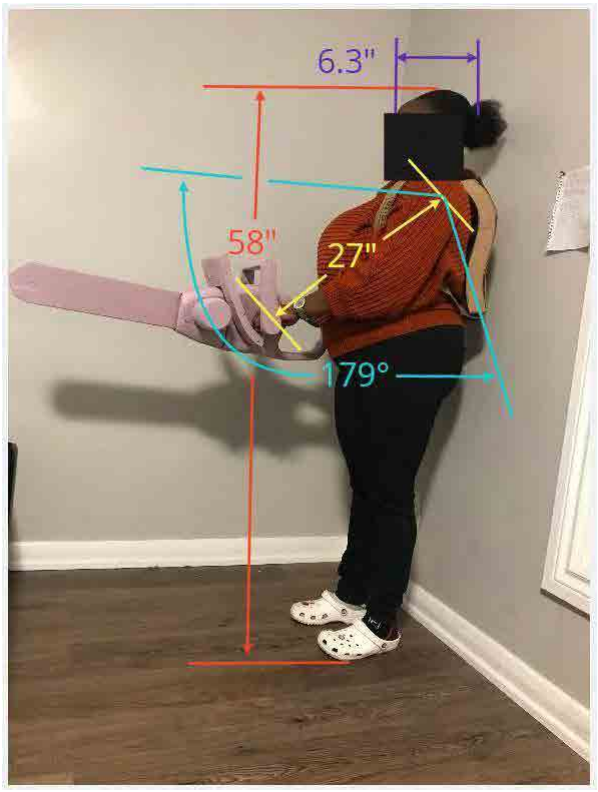

Figure 19 - 5th Percentile Female -Side View

Side View

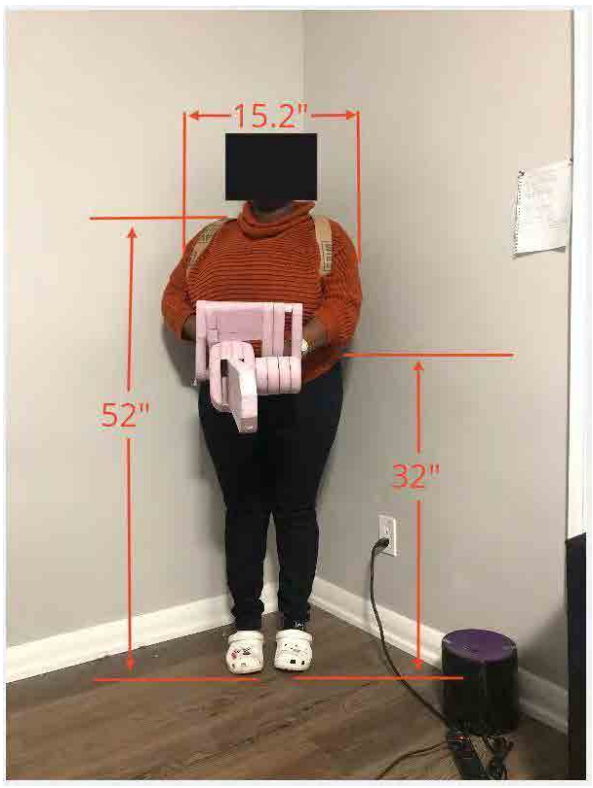

Figure 20 - 5th Percentile Female- Front View

Front View

Figure 21 - 5th Percentile Female- Side View

Rear View

95th Percentile Male

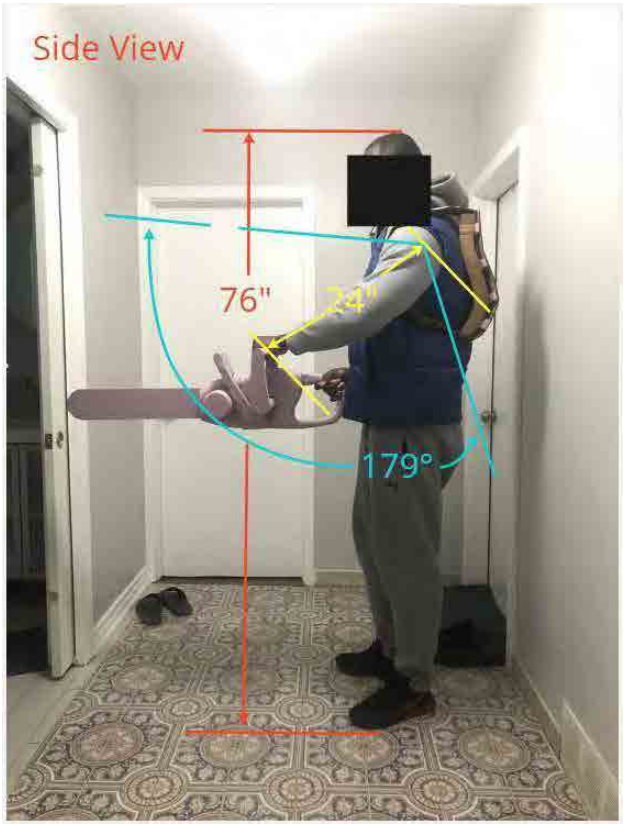

Figure 22- 95th Percentile Male- Side View

Side View

Figure 23 - 95th Percentile Male- Front View

Front View

Interaction - The following interaction depicts the user going through the process of cutting a tree.

Figure 24 - Interaction

Step 1: Cutting Tree

Figure 25 - Interaction

Step 2: Changing blade position

Figure 26 - Interaction

Step 3: Blade position changed

Figure 27 - Interaction

Step 4: Cut tree at better angle

Figure 28 - Interaction

Step 5: Cutting Tree (Continued)

Figure 29 - Interaction

Step 6: Change handle position

Figure 30 - Interaction

Step 7: Adjusting handle to reach low lying trunks and branches

Figure 31 - Interaction

Step 8: User cutting low trunk

The user observation study helped to point out the different human touchpoints and refine their ergonomics. However, there were a few limitations that were discovered after the process, such as:

- Having a working scale model would have provided much more ergonomic information on the chainsaw. This is because the main function of a chainsaw is to cut material. The observation of this cutting action would have provided useful ergonomic information. Not being able to analyze this cutting function early in the design process was a major limitation.
- Working with test subjects that have little to no forestry experience limits the valuable feedback that would have otherwise been gained if more experienced forestry worker test subjects were utilized.
- If a model is broken while testing it is very inconvenient and time-consuming especially when the broken part has intricate details. While testing the adjustable handle, it broke off the model. Repairing the model consumed a lot of time and took away from the observational process. In future testing, spare parts would be made in advance and swapped out if necessary, with broken parts

3.4 « Aesthetics and Semantic Profile »

Based on research and conversations with persons in the field, it can be determined that forestry workers often find themselves using chainsaws at uncomfortable angles when performing daily tasks. This is due to the varying location of tree branches, ideal notch positions, and the surrounding environment's shrub density. This was an essential factor in designing the swivelling blade feature for the chainsaw because it benefits the user by allowing them to remain in a comfortable position while cutting. This feature would significantly reduce the necessary muscle strain associated with maintaining unnatural, uncomfortable positions for long periods. Thereby effectively improving the safety of forestry workers. The testing proved that this feature has the potential to increase the versatility, manoeuvrability and comfort of the user when cutting notches.

An existing chainsaw model was used as a reference for the basic dimensioning of the design. This was important because it provided essential general ergonomic information concerning the average handle size, general form, and location of main chainsaw parts. Information was then altered to meet the specific ergonomic needs of the target user and this project. Overall, this process gave insight into the required distance between the main handle, the rear handlebar, and the total distance from the user’s body while the chainsaw is being held. Considerations into the distance between the shield and the lower handle had to be made to factor in the ranging hand sizes of 99th percentile males and 1st percentile females. However, testing revealed that they were placed too closely together. For the next testing phase, the shield’s location will be moved closer to the front of the chainsaw to provide more hand size compatibility and maneuverability.

The adjustable handle feature, located to the rear of the chainsaw, is critical because it solves the issue of repetitive bending to reach short trunks and low-lying branches, which can lead to a severe lower back injury. In the test, the handle proved to be somewhat successful. It was comfortable to hold for both users and improved their lower reach, reducing their need to bend constantly while cutting low trunks and branches. Unfortunately, the adjustable handle broke during testing, showing the need for better reinforcement or a stronger material selection, different to that used for the general frame.

3.5 « Sustainability- »

Safety, Health and the Environment

This section of the report examines the Forest industry's health, safety, and sustainability in Canada. It analyzes the current materials and manufacturing methods used to create the industry standard chainsaw. Alternative material and technological solutions were sourced to minimize the environmental footprint the chainsaw has on its environment. After benchmarking different types of chainsaws on the market, the evaluation indicated a need for an alternative power source to the traditional combustion engine. However, it would need to last much longer than the average battery-powered chainsaw. These findings encouraged a multitude of creative approaches to a better final design solution.

3.6 « Innovation Opportunity »

3.6.1 « Needs Analysis Diagram »

Based on promotional literature, it was determined that the top seven benefits for Chainsaws are: comfort, efficiency, power, versatility, ease (simplicity of use) and compactness.

Relating these benefits to corresponding Fundamental Human Needs is shown in the table below.

	Benefit	**Possible Corresponding Fundamental Human Needs**	**Relationship between benefits and FHN**
1	Comfort	Control over environment, Securing resources	Strong
2	Efficiency	Autonomy, Intrinsic Pleasure,Control over Environment	Strong
3	Power/Speed	Autonomy, Intrinsic Pleasure, Social Status	Strong
4	Versatility	Control over environment	Strong
5	Compactness	Aesthetically appeal, Storage Ability , Social Status	Moderate
6	Ease	Self-esteem (mastery) , Accomplishment	Strong

Table 8- Needs Analysis Diagram

Comfort- In this context refers to reducing the chainsaw's recoil (of the engine when starting) and the vibrations of the motor while in use. Both can decrease the user's sense of safety and security on the job.

Efficiency- In this context relates to the user's ability to recharge/refuel on the worksite. Minimized downtime on the job gives the user a sense of security because they have more time for other tasks

Power/Speed- This relates to the users ability to deal with multiple types of wood varying in hardness. Which in turn makes the user feel more skilled and accomplished.

Versatility- This refers to the users ability to use their tool in multiple scenarios effectively. This would increase the users sense of security on the job by giving the user greater control over their environment.

Compactness- In this context refers to the convenience of the user being able to store and carry their chainsaw.

Ease- This relates to the Self actualization particularly, higher self-esteem and a heightened sense of accomplishment.

Table 9- Needs Analysis Diagram

3.6.2 « Desirability, Feasibility and Viability »

Based on key insights of collected data relevant to the thesis problem definition, there are several opportunities for innovation. One opportunity for innovation is improving user versatility to tackle trunks, stubs, and branches below the knee. Another example of an opportunity for innovation is ensuring that the design's handles are adjustable to accommodate a wide range of human percentiles.

3.7 « Summary of Chapter 3 »

Defining the Design Brief

Overall, the ergonomic study of human touchpoints and human interactions with the design solution was successful. Observing how the user interacts with the physical model provided valuable insight initially missed while creating the first design solution. The evaluation has proven that users can manage the device more comfortably, efficiently, and effectively. The data gathered from this evaluation will be used to determine the design decisions by the researcher. The design solution direction is now more understandable and supported by anthropometric data.

Goal- The goal of this design Thesis is to improve the safety of forestry workers in Canada

Objectives

1. Mitigate the risk of developing musculoskeletal disorders from exposure to long periods of bodily vibration. - needs
2. Mitigate the repetitive strain of stooping low for long periods of time to cut low trunks and/or branches. - needs
3. Improve worker efficiency because of larger power output and increased battery capacity. - benefits
4. Improve user versatility to tackle trunks, stubs and branches below the knee, cut trees and branches in tight spaces and reach high branches in trees. - benefits
5. Ensure that the design handles are adjustable to accommodate a range of human percentiles. (99^{th} percentile man to 5^{th} percentile woman) - usability

6. Workers can work efficiently and effectively in confined spaces. - usability

7. Incorporate quick release systems into the design to simplify the donning and doffing procedure. - prep and finish up

8. Plan the placement of handles to improve user control and stability of the device. - mastery

9. Improve the aesthetic appeal of the device for users. - sustainability

10. Utilize sustainable materials in the final design solution. – sustainability

CHAPTER 4- Design Development

4.1 « Initial Idea Generation»

This chapter will focus on the design development of the proposed solutions explaining the design process, starting with idea generation and ending with the refined, validated concept. Figures will be utilized throughout this chapter to communicate this process visually.

4.1.1 « Aesthetics Approach & Semantic Profile »

Figure 32 - MoodBoard

4.1.2 « Mind Mapping »

Defining the Design Brief

A mind map was used early in the design process to help identify the potential users, the context of use, the problems users face and the current existing solutions.

Figure 33 - MindMap

4.1.3 « Ideation Sketches »

Defining the Design Brief

Early solutions were designed using a broader perspective to tackle the multitude of challenges forestry workers in Canada face daily. All concepts encompass the theme of improving the safety of Canadian forestry workers.

Ideation 1

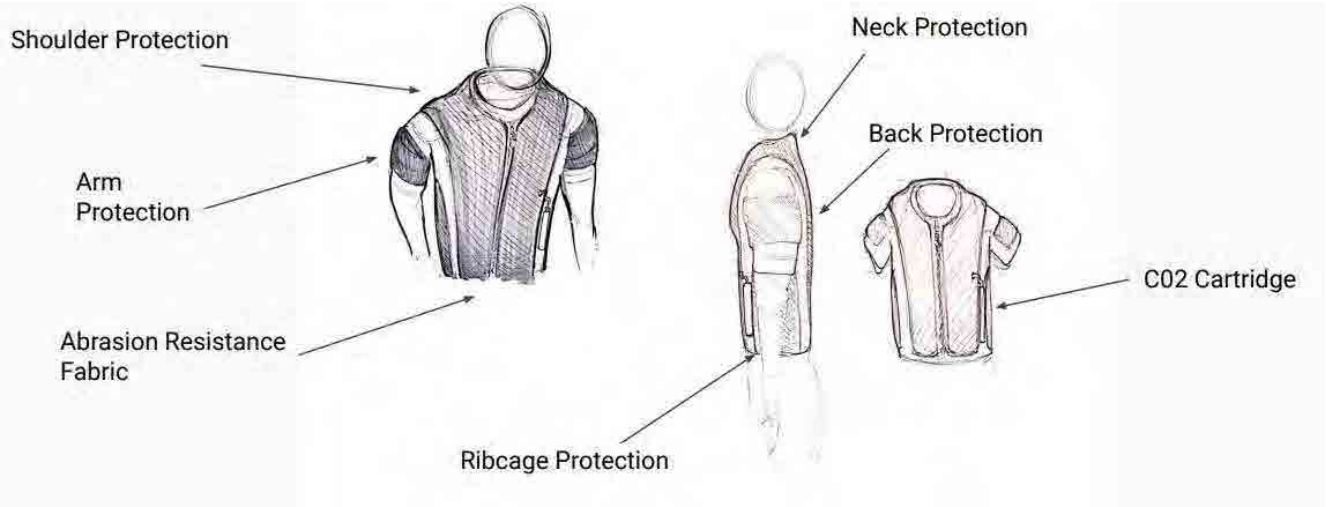

Figure 34 – Ideation 1

Ideation 2

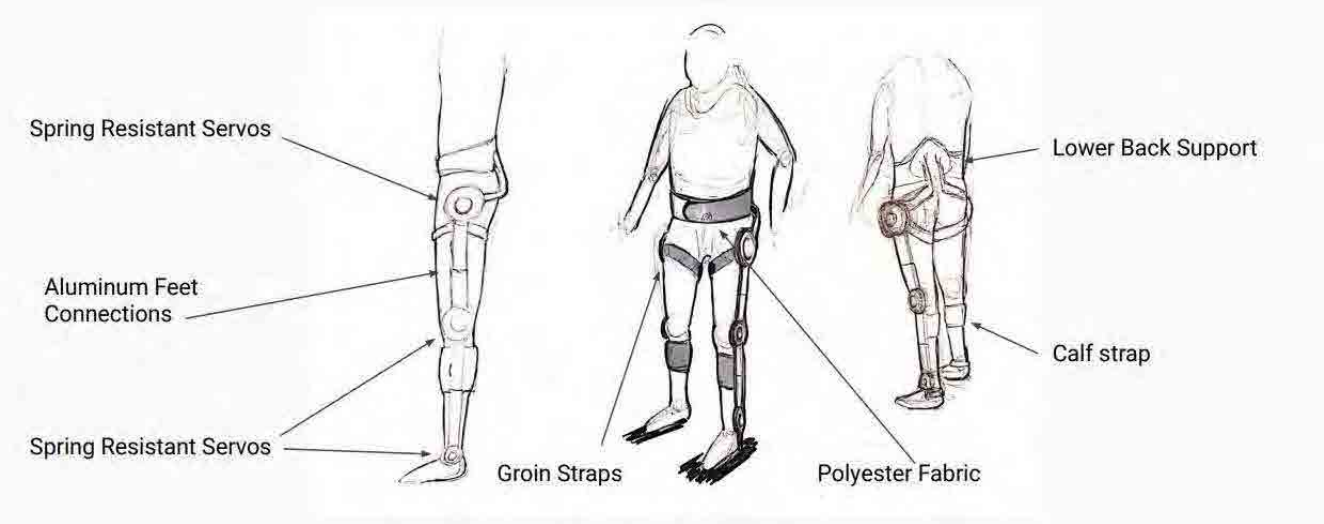

Figure 35 – Ideation 2

Ideation 3

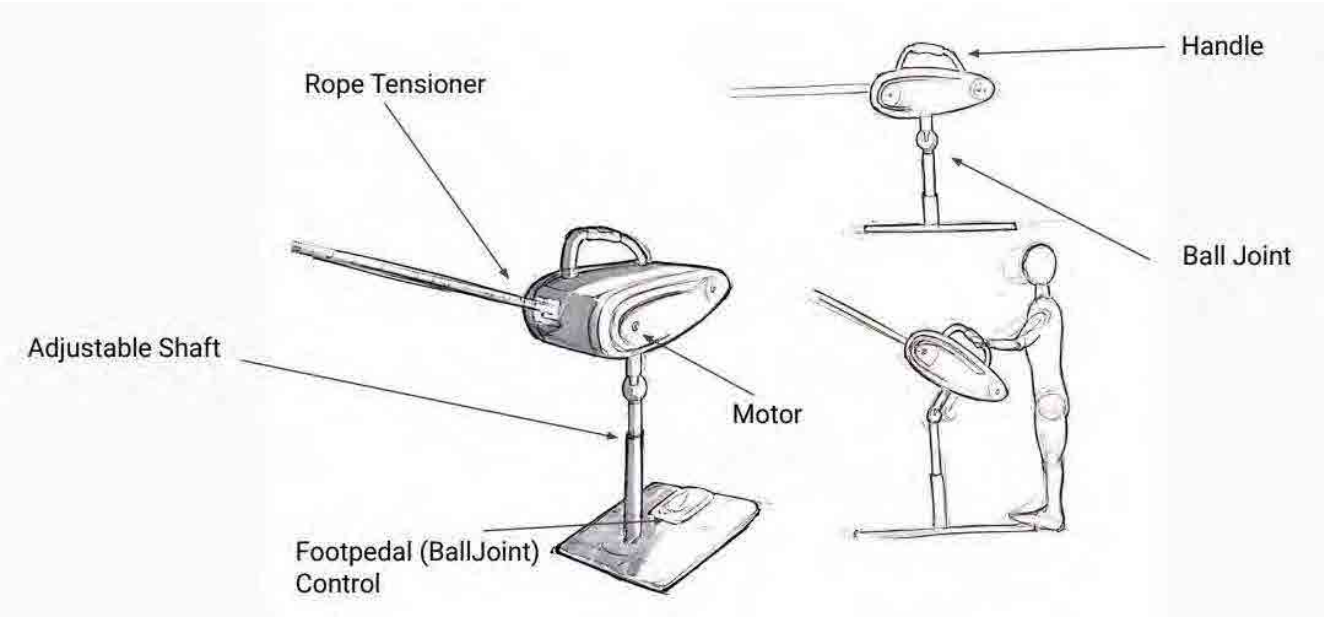

Figure 36 – Ideation 3

Ideation 4

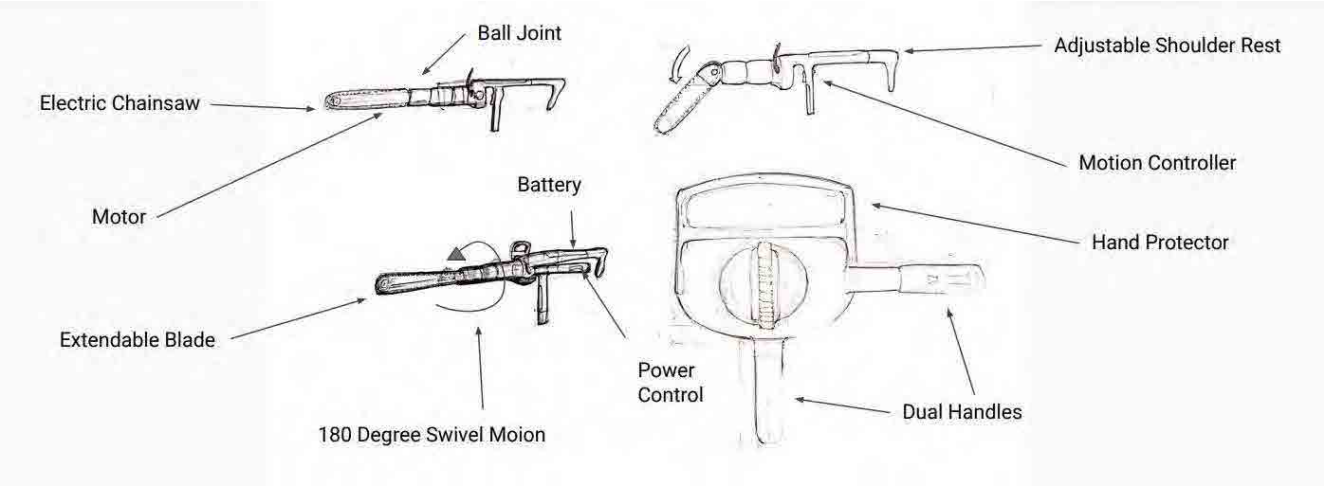

Figure 37 – Ideation 4

Ideation 5

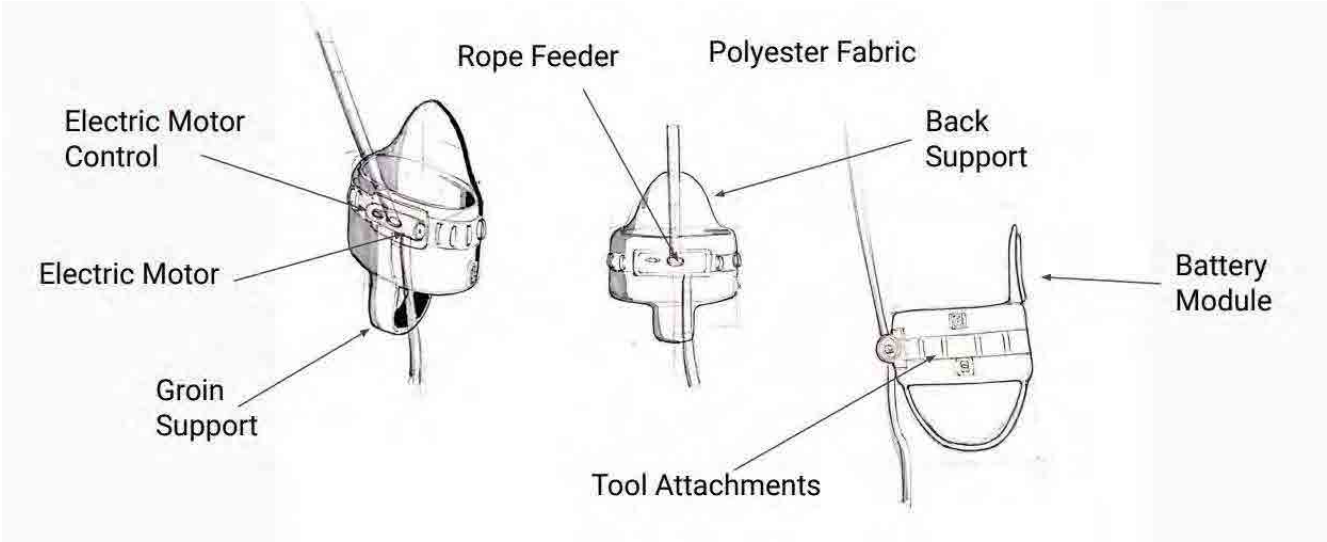

Figure 38 – Ideation 5

Ideation 6

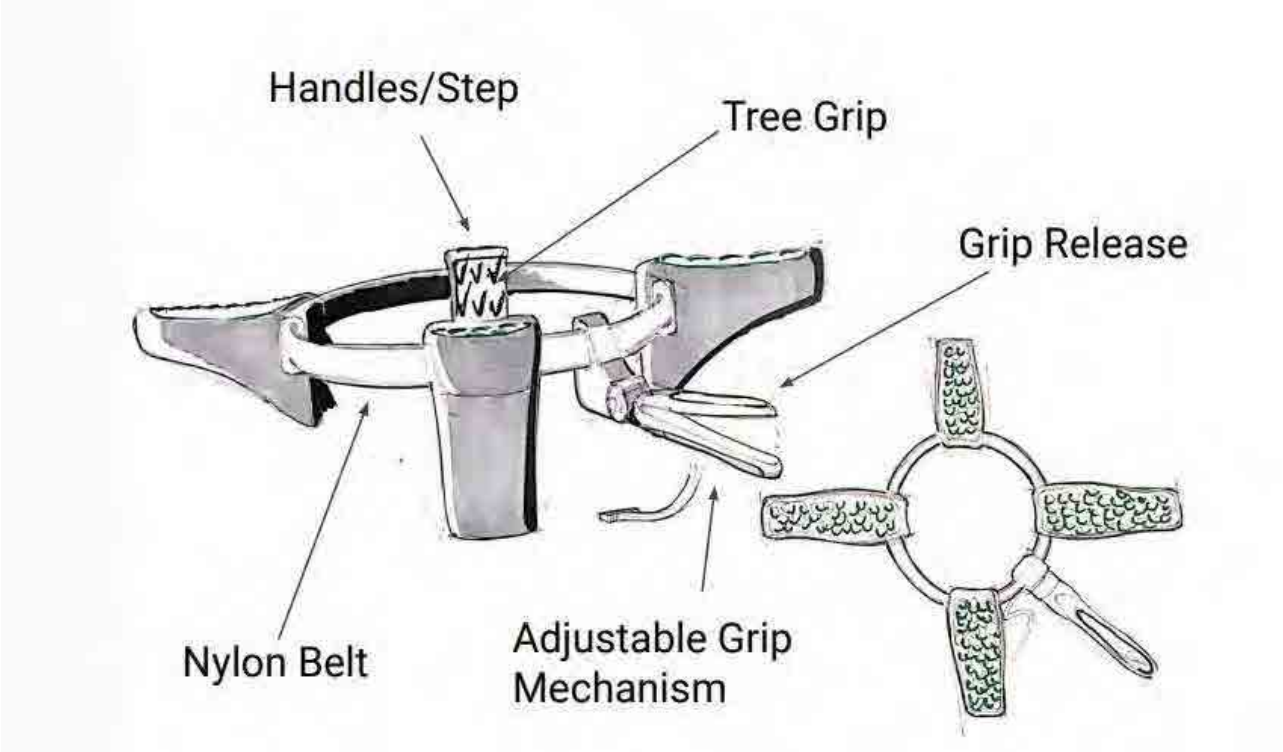

Figure 39 – Ideation 6

4.2 « Concepts Exploration »

From the initial six idea generations, three were selected and further developed.

4.2.1 « Concept One »

This design aims to increase the safety of arborists while climbing trees because fling from heights is one of the most prevalent causes of injury in the field. This design is essential because it will drastically improve the worker's safety by automating the climbing process and sparing the worker the danger of climbing traditionally with basic tree climbing gear. The manoeuvrability of the worker is increased because he is not tied down by numerous ropes or clinging to a branch for support. This design is to be used in outdoor environments and can operate in most weather conditions.

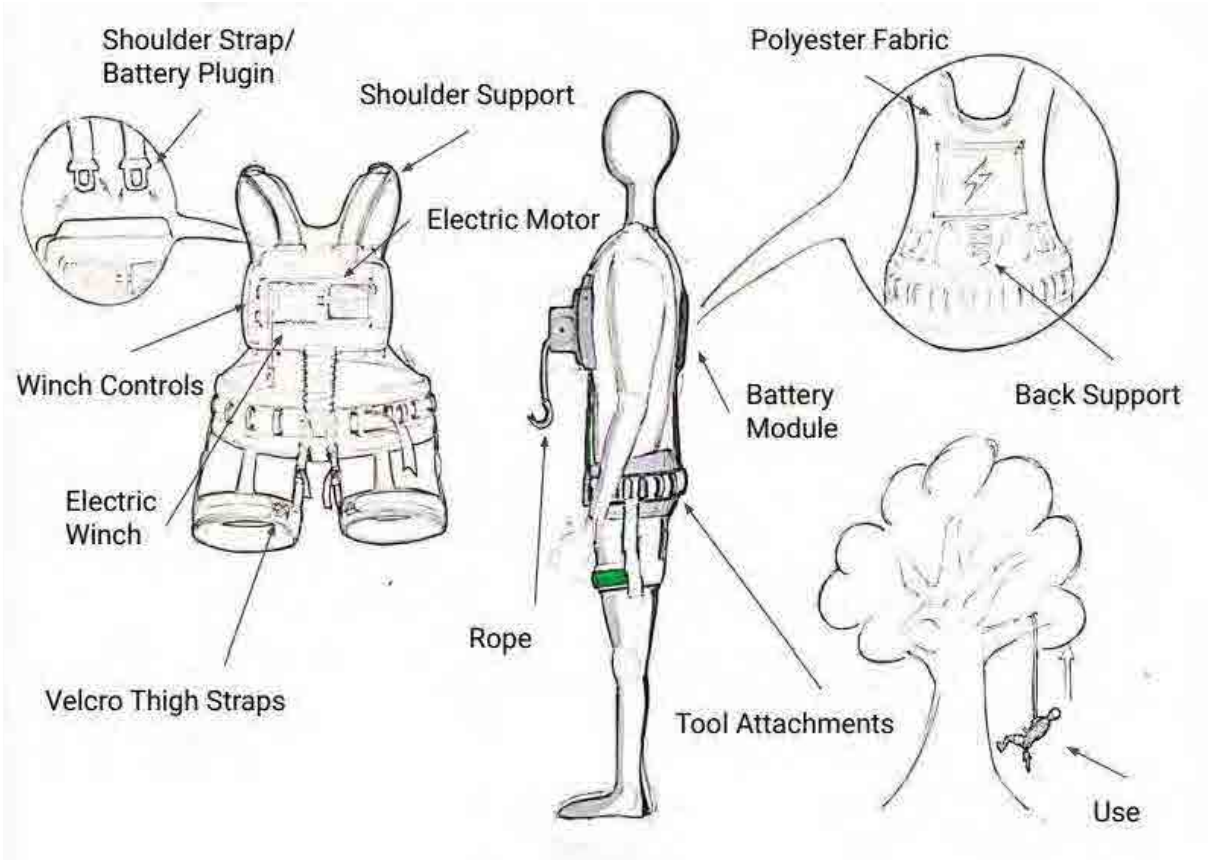

Figure 40 – Figure 40 - Concept 1

4.2.2 « Concept Two »

This design aims to mitigate the danger of workers being hit with branches within the drop zone. It is also designed to remove the physical burden of the worker responsible for controlling the ropes. This feature is crucial because it will improve workers' safety, efficiency, and ability to control branches while falling into the drop zone. This design is for use in outdoor environments and can operate in most weather conditions.

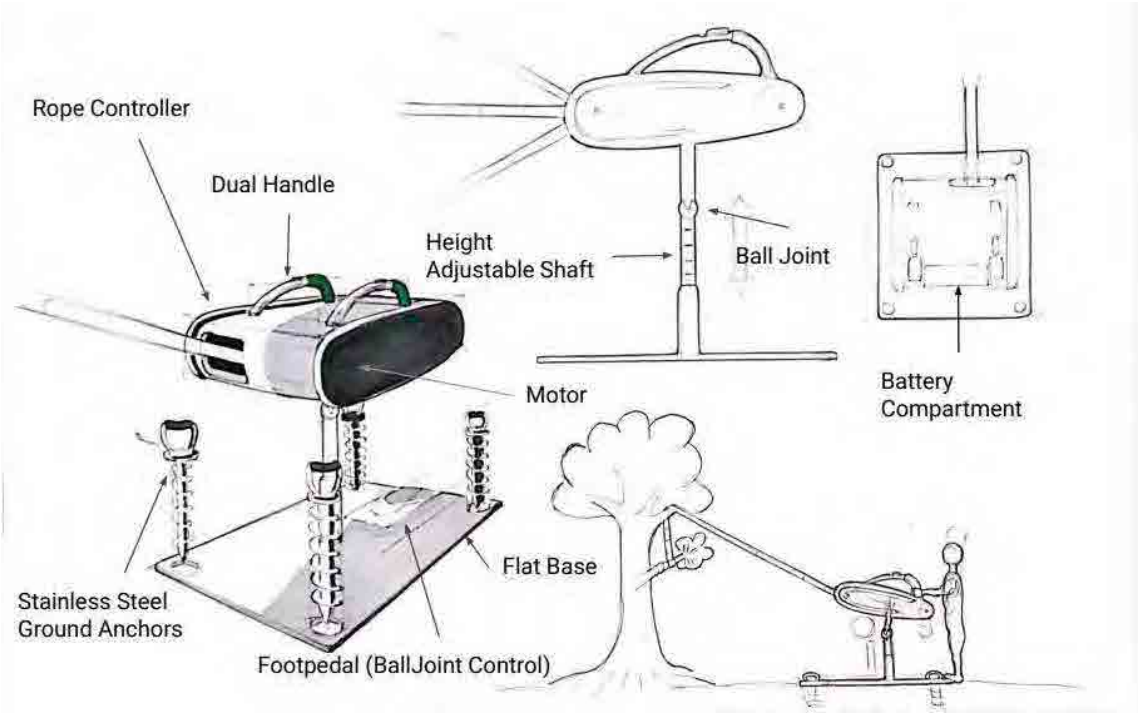

Figure 41 – Concept 2

4.2.3 « Concept Three »

This design aims to increase the functionality of the traditional chainsaw to better suit the needs of an arborist and provide improved safety on the job. This design is crucial because it will improve the worker's efficiency, the ability to access more hard-to-reach branches and user comfort. It is designed to be used in outdoor environments and can operate in most weather conditions.

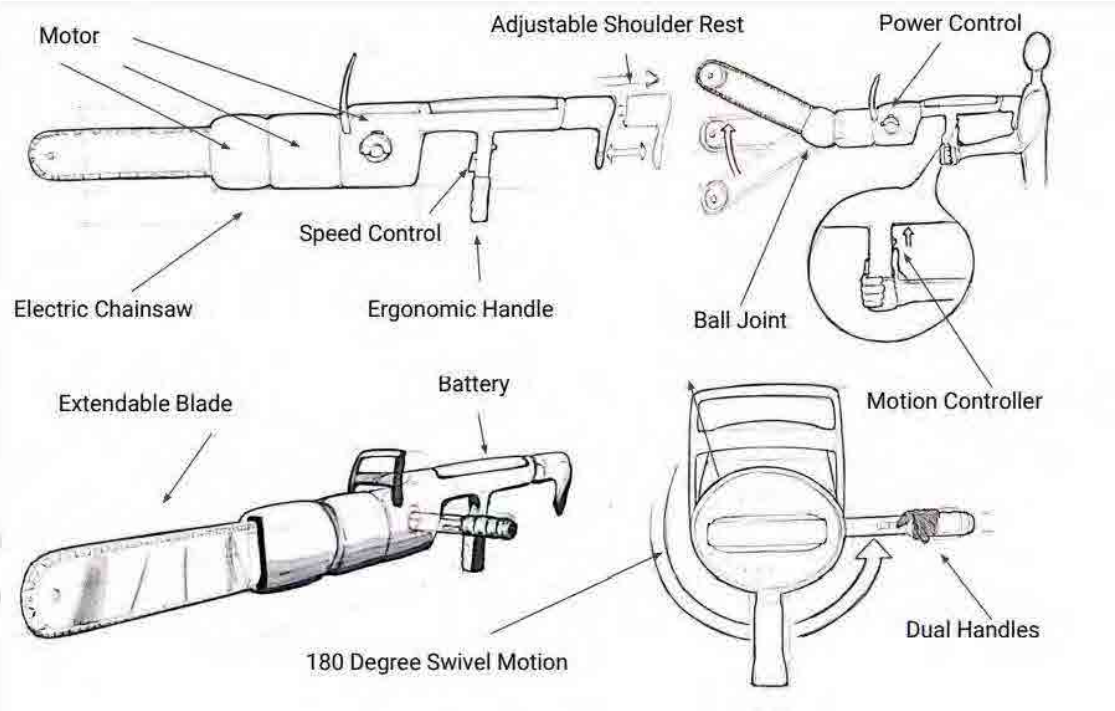

Figure 42 - Concept 3

4.3 « Concept Strategy »

Concept direction and Product Schematic Profile One

Out of the three developed concepts, two were selected to be further refined as they showed the most potential for improving the user's safety. The insights and data gathered during this stage would help decide which design would be selected as the final.

4.3.1« Concept Direction and Product Schematic Profile One »

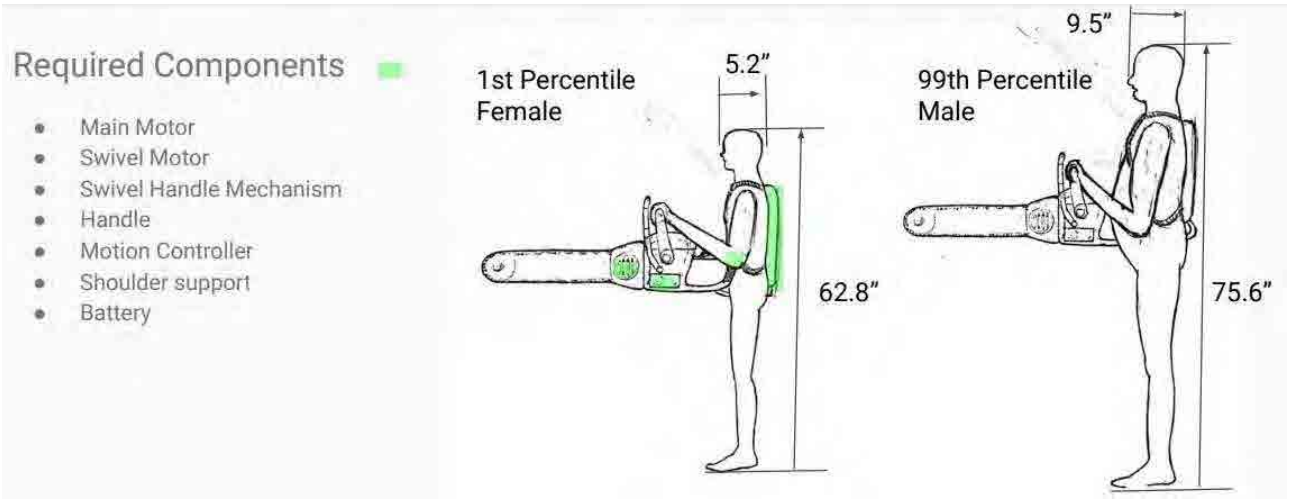

Figure 43 – Concept Direction & Product Schematic One

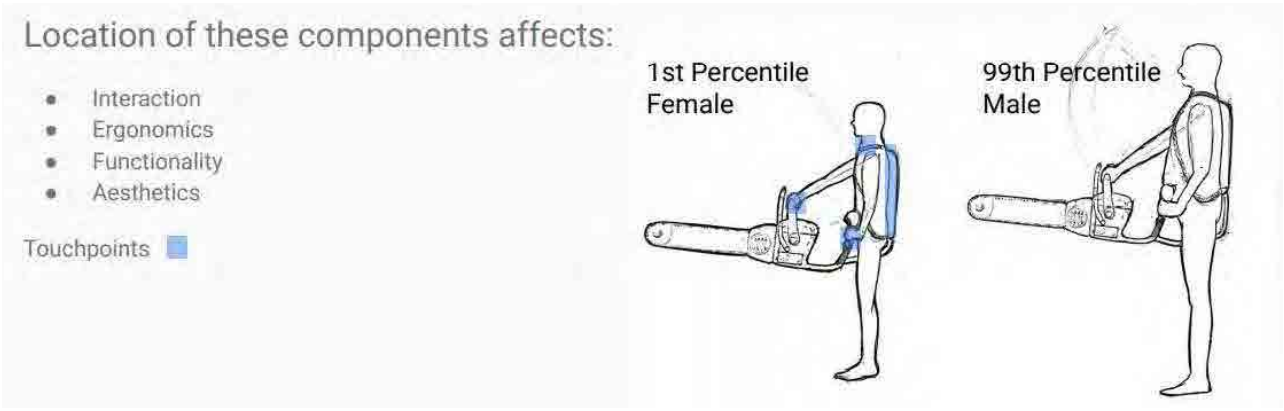

Figure 44 – Concept Direction & Product Schematic One

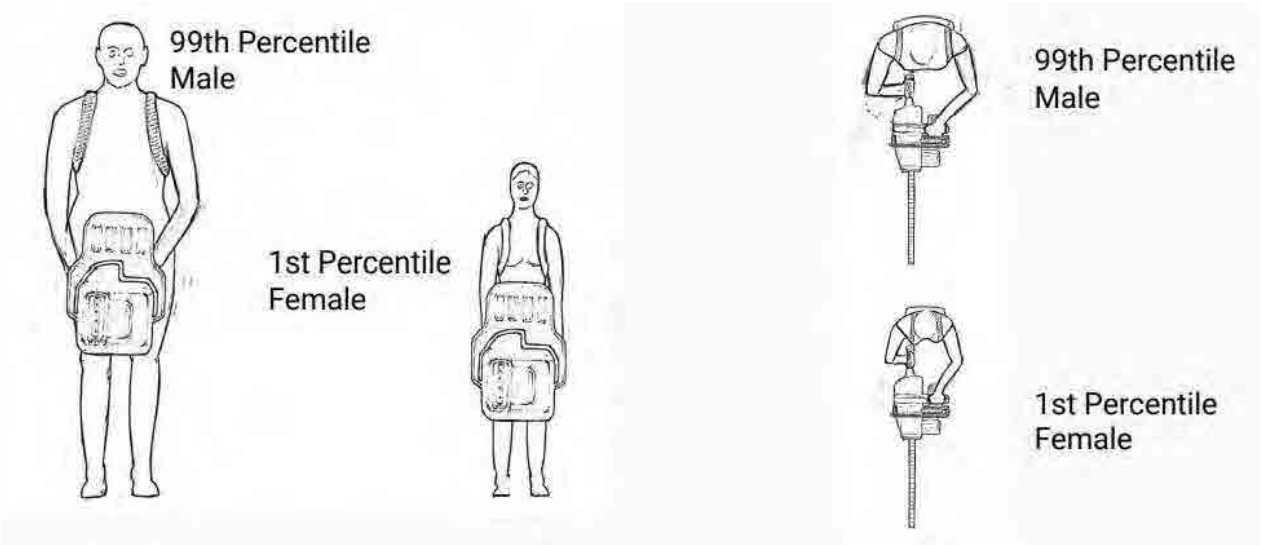

Figure 45 – Concept Direction & Product Schematic One

4.3.2 « Concept Direction and Product Schematic Profile Two »

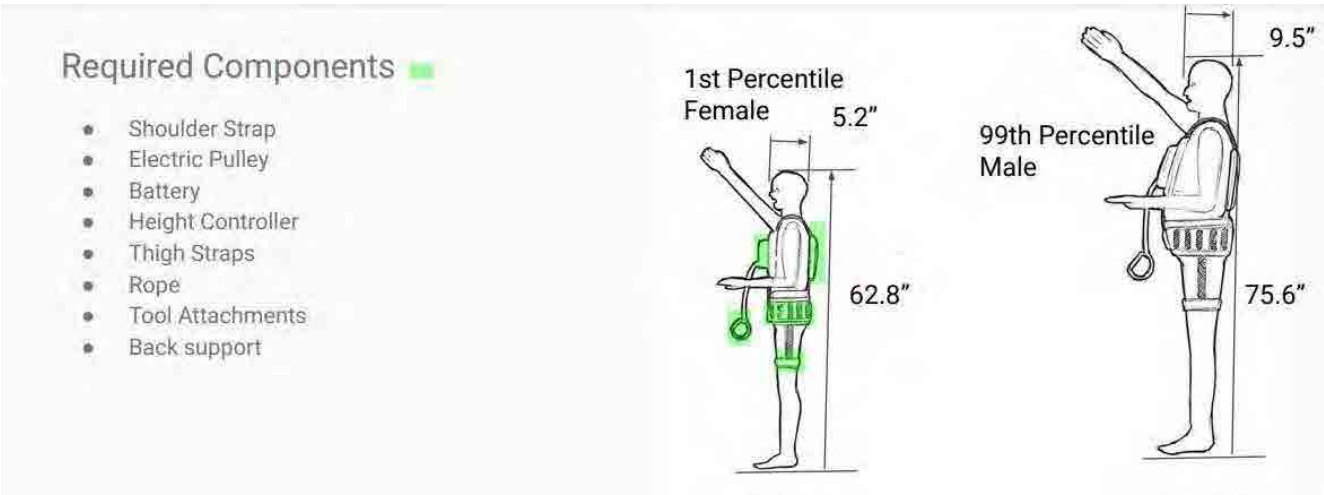

Figure 46 – Concept Direction & Product Schematic Two

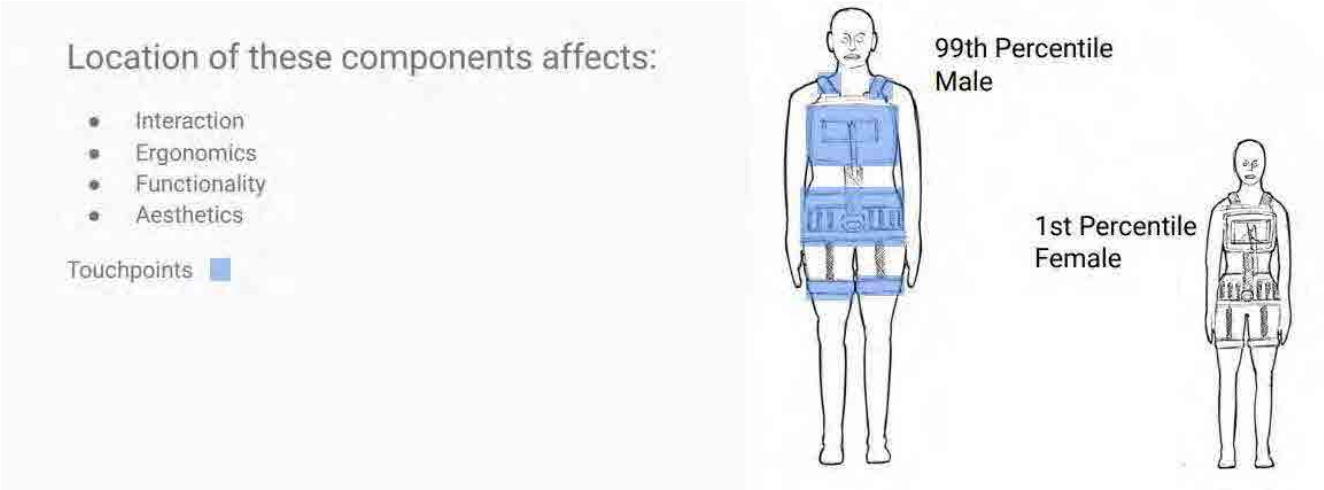

Figure 47 – Concept Direction & Product Schematic Two

4.4 « Concept Refinement & Validation »

After comparing both concepts, concept one was chosen because it proved to have the most potential to improve worker safety. A sketch model was made to understand the design's ergonomics and measurements and how users interact with these touchpoints. After completing the sketch model, the information gathered was used to finalise the concept one design.

4.4.1 « Design Refinement »

Defining the Design Brief

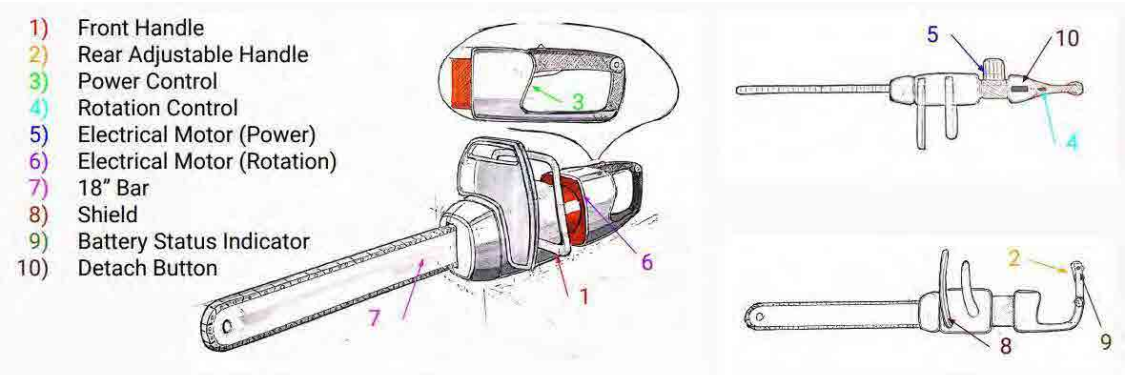

Figure 48 – Design Refinement

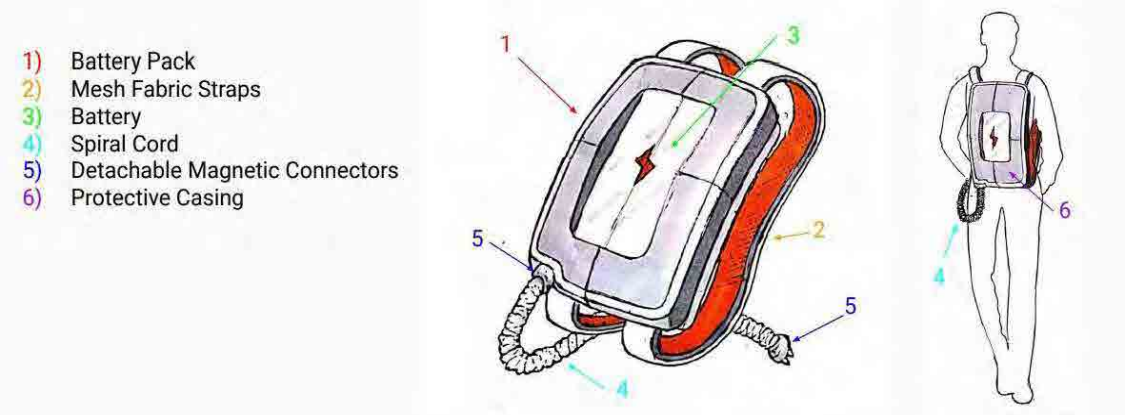

Figure 49 – Design Refinement

4.4.2 « Detail Development »

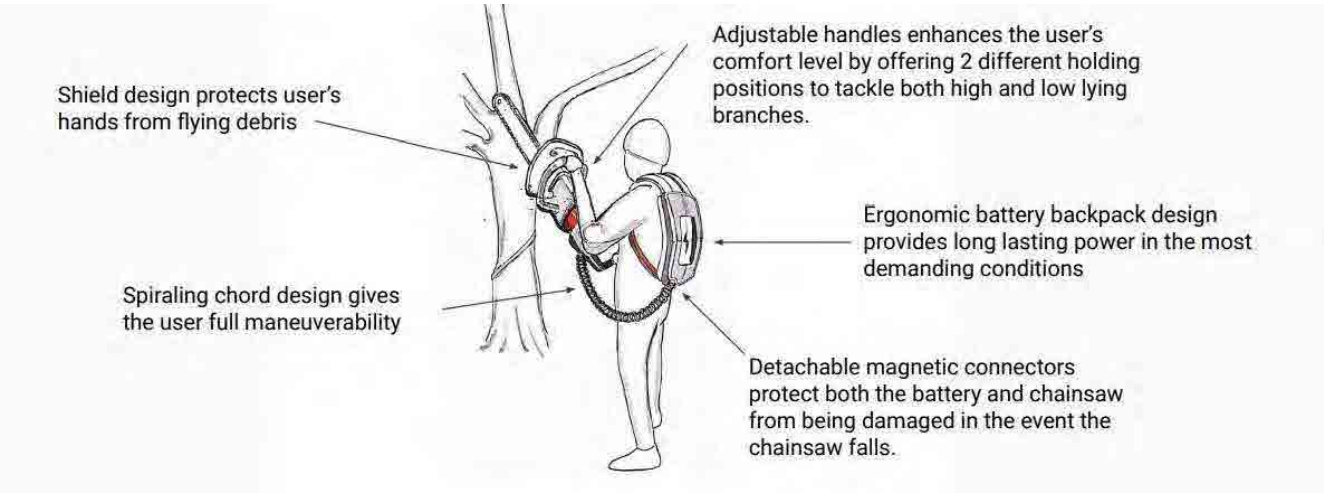

Figure 50 – Detail Development

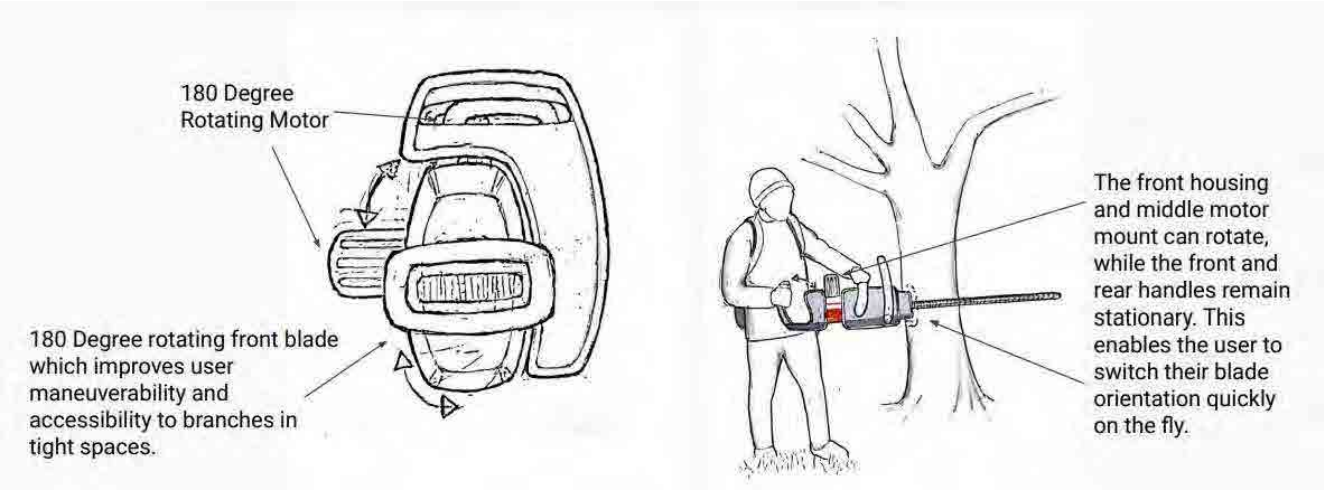

Figure 51 – Detail Development

4.4.3 « Refined Product Schematic & Key Ergonomics »

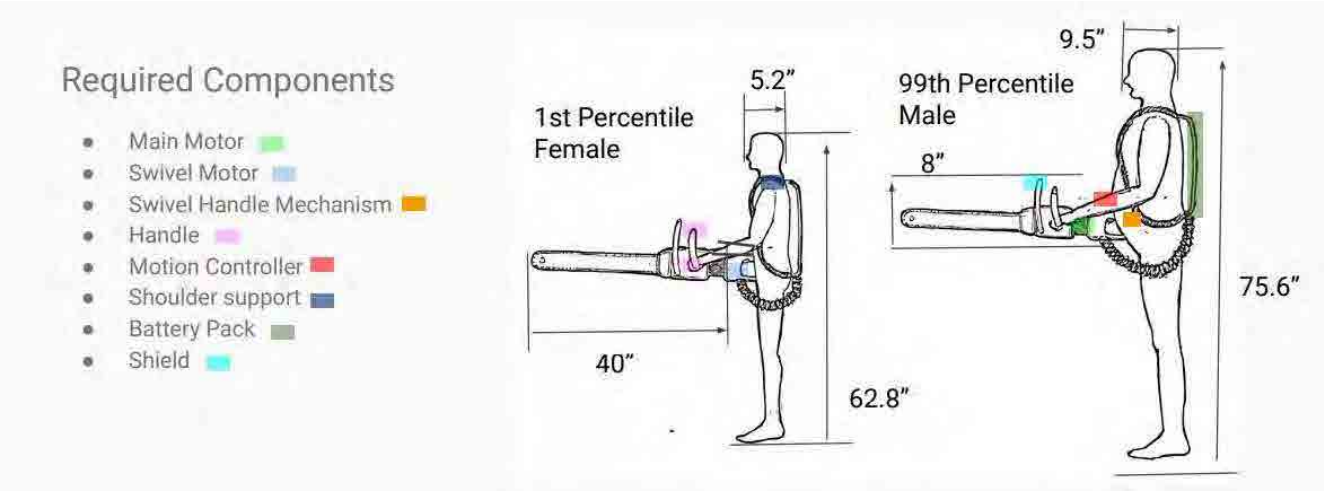

Figure 52 – Refined Product Schematic

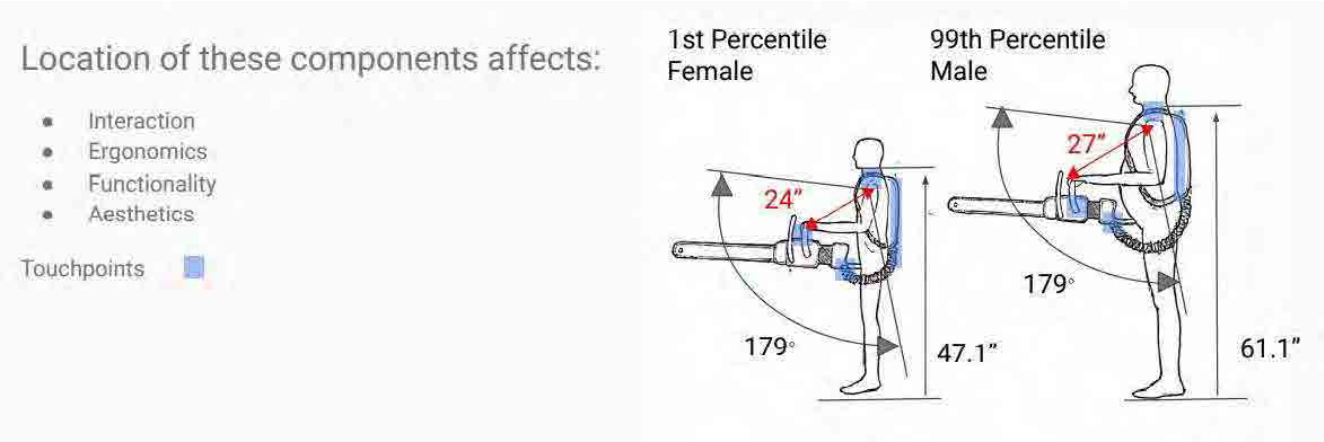

Figure 53 – Refined Product Schematic

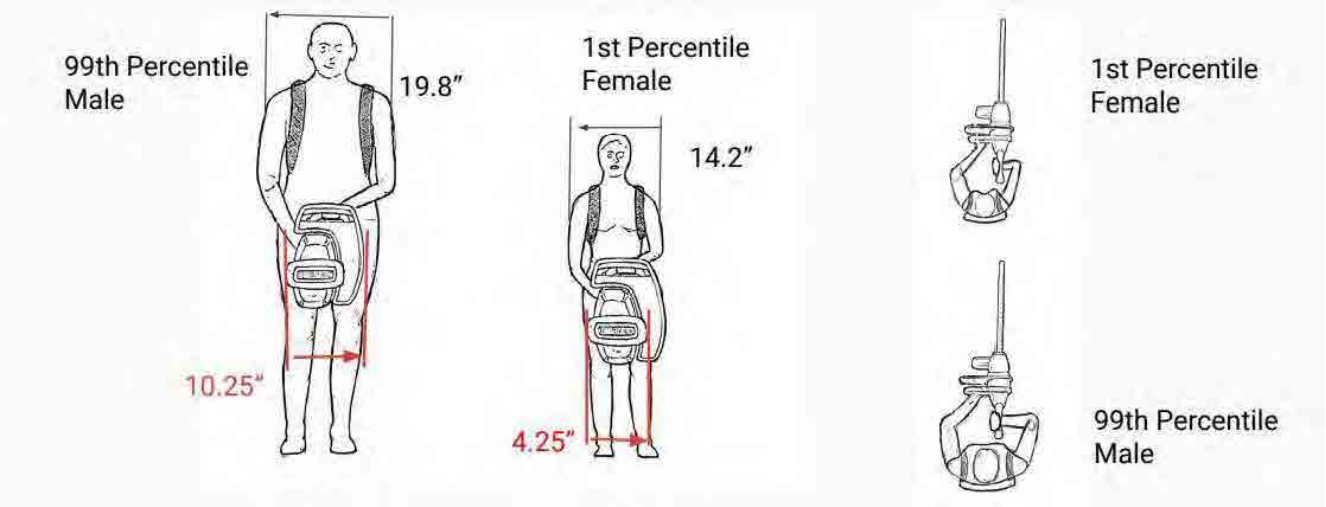

Figure 54 – Refined Product Schematic

4.5 « Concept Realization »

4.5.1 « Design Finalization »

To resolve the safety issues caused by current chainsaws, proper ergonomics and dimensioning were considered whilst creating the final design. This ensures that forestry workers are well protected from dangers while performing their daily tasks. In the figures below, the SpinSaw is divided into different color-coded sections that explain the required components and how the location of these components affects the end user. Below are detailed configuration layouts demonstrating how the 99th percentile male and the 5th percentile female can use the chainsaw's features.

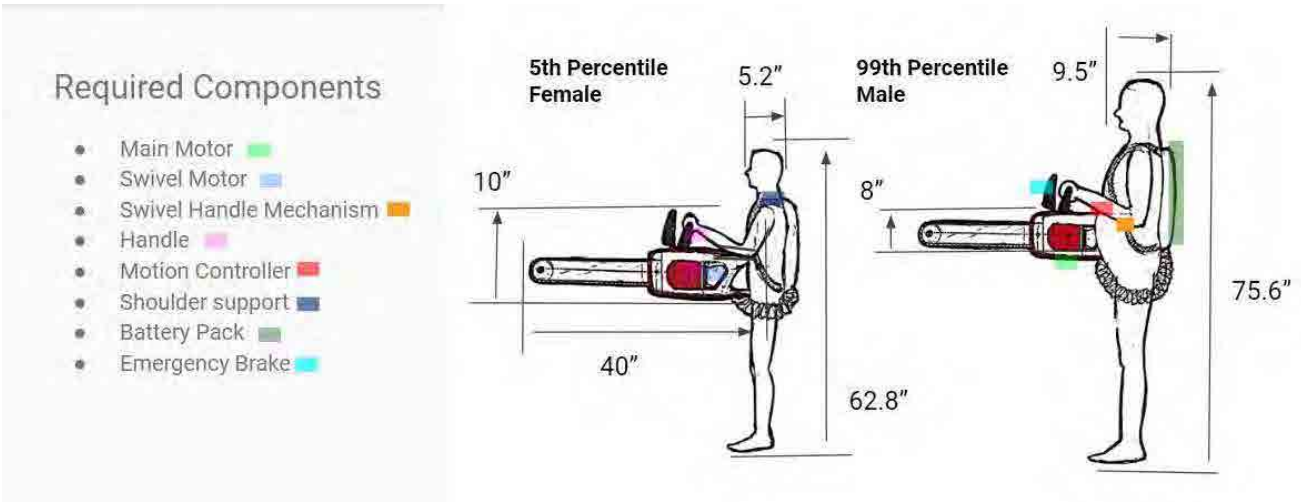

Figure 55 – Configuration Diagram

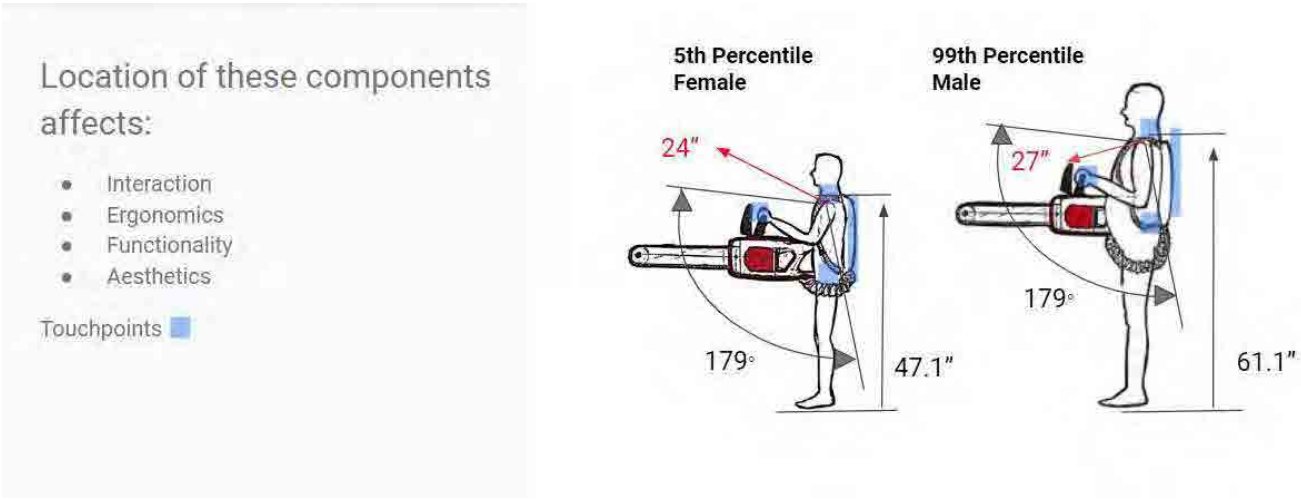

Figure 56 – Configuration Diagram

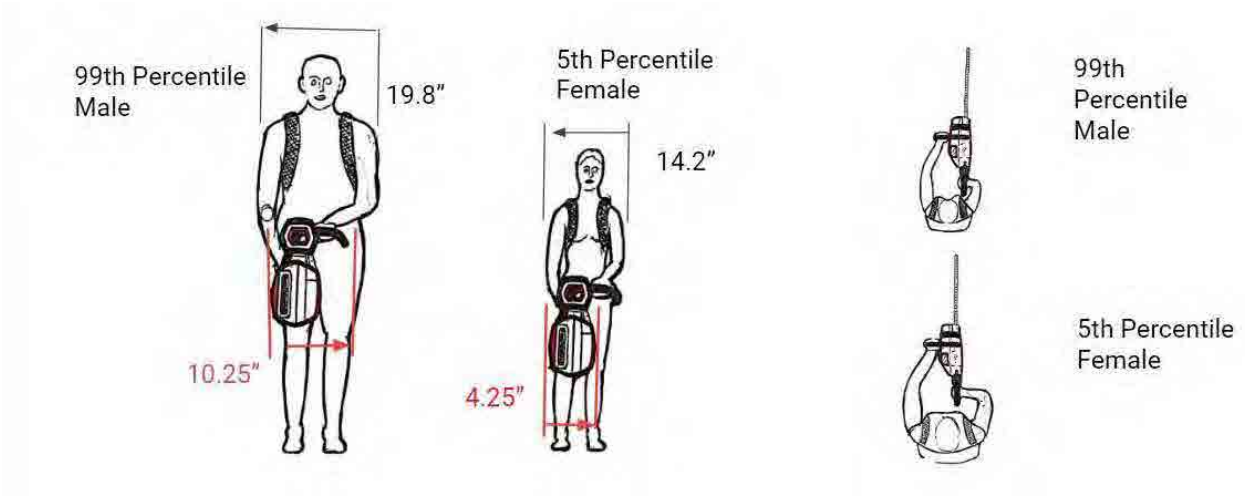

Figure 57 – Configuration Diagram

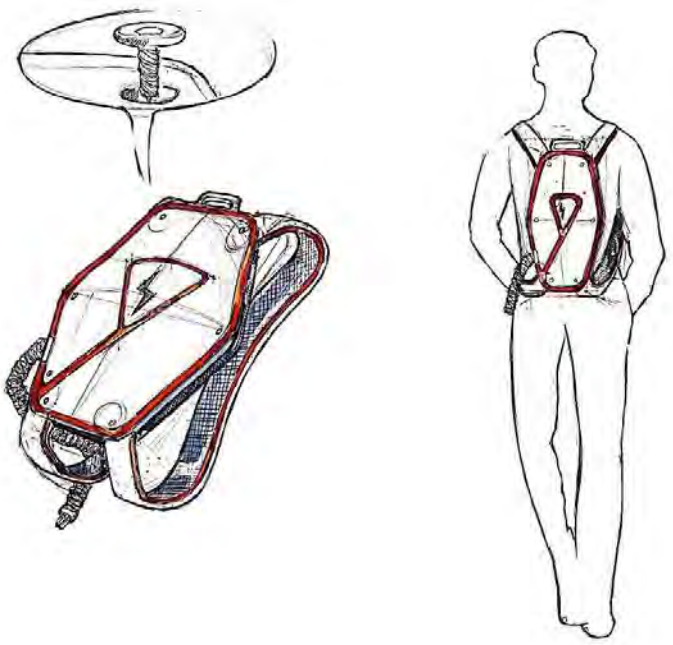

Figure 58 – Refined Sketches

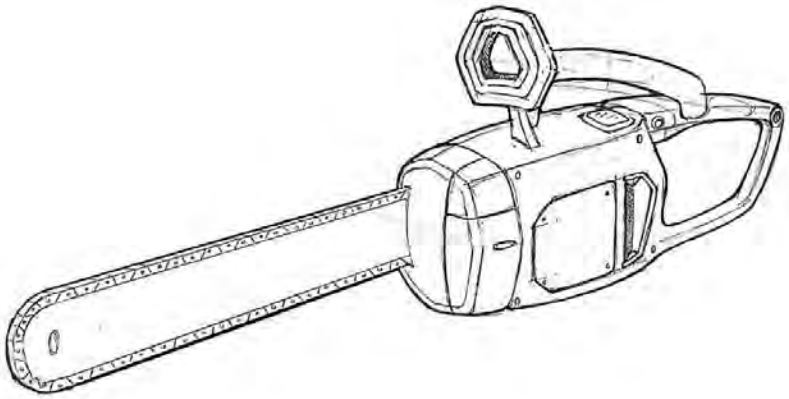

Figure 59 – Refined Sketch

4.5.2 « Physical Study Models »

A sketch model of the chainsaw was fabricated to understand the design's mechanics and dimensions better. The model was created out of pink styrofoam and cardboard at a 1:1 scale. The proper proportions and ergonomics were implemented on the sketch model to ensure a wide variety of users could adequately utilize the device's features. The model provided crucial insight into the development process for the CAD model, including how the exterior surfaces should be built and what parts may be troublesome to build.

Figure 60 – Chainsaw Study Model

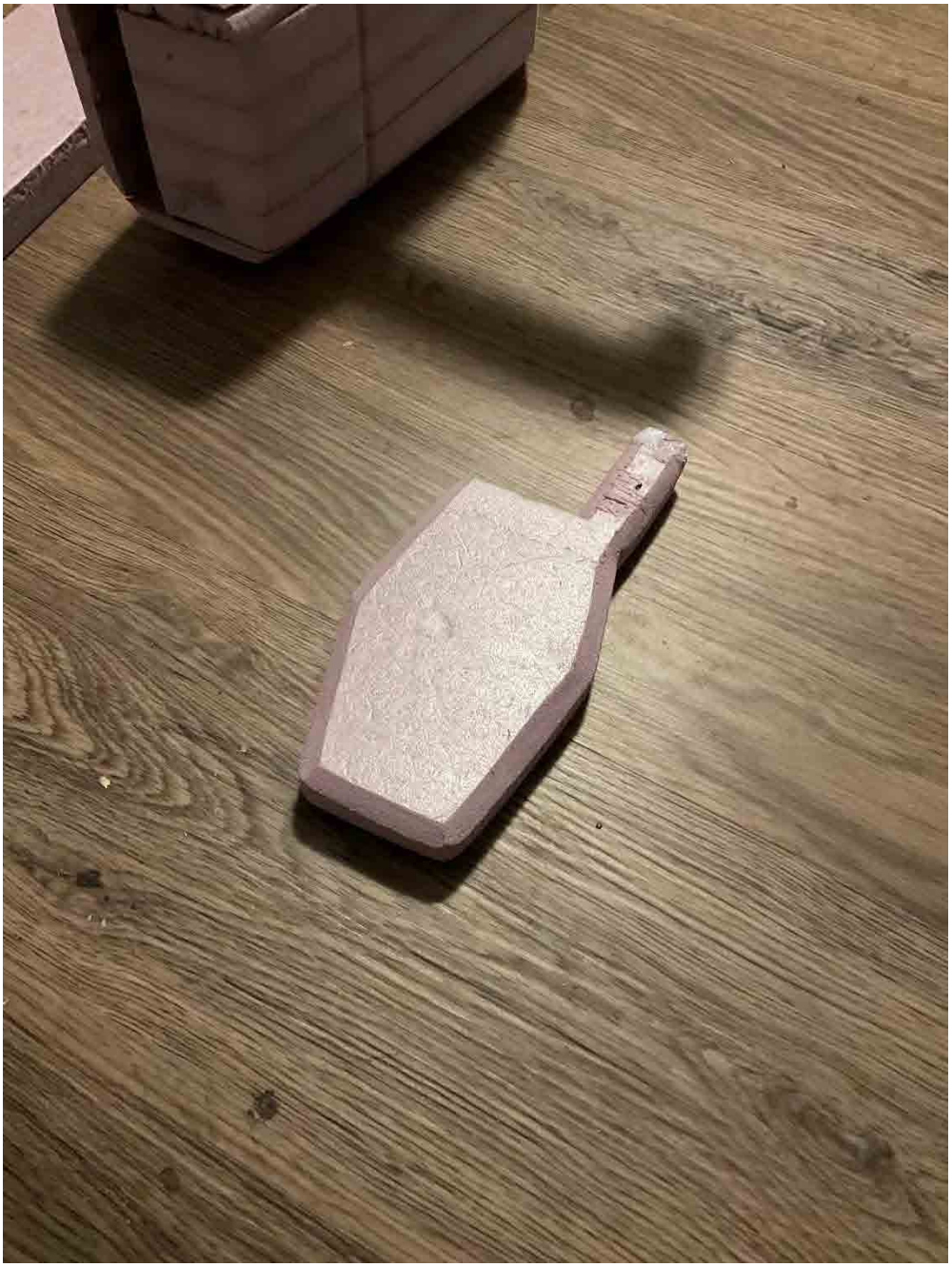

Figure 61 – Chainsaw Study Model

Figure 62 – Chainsaw Study Model

Figure 63 – Chainsaw Study Model

Figure 64 – Chainsaw Study Model

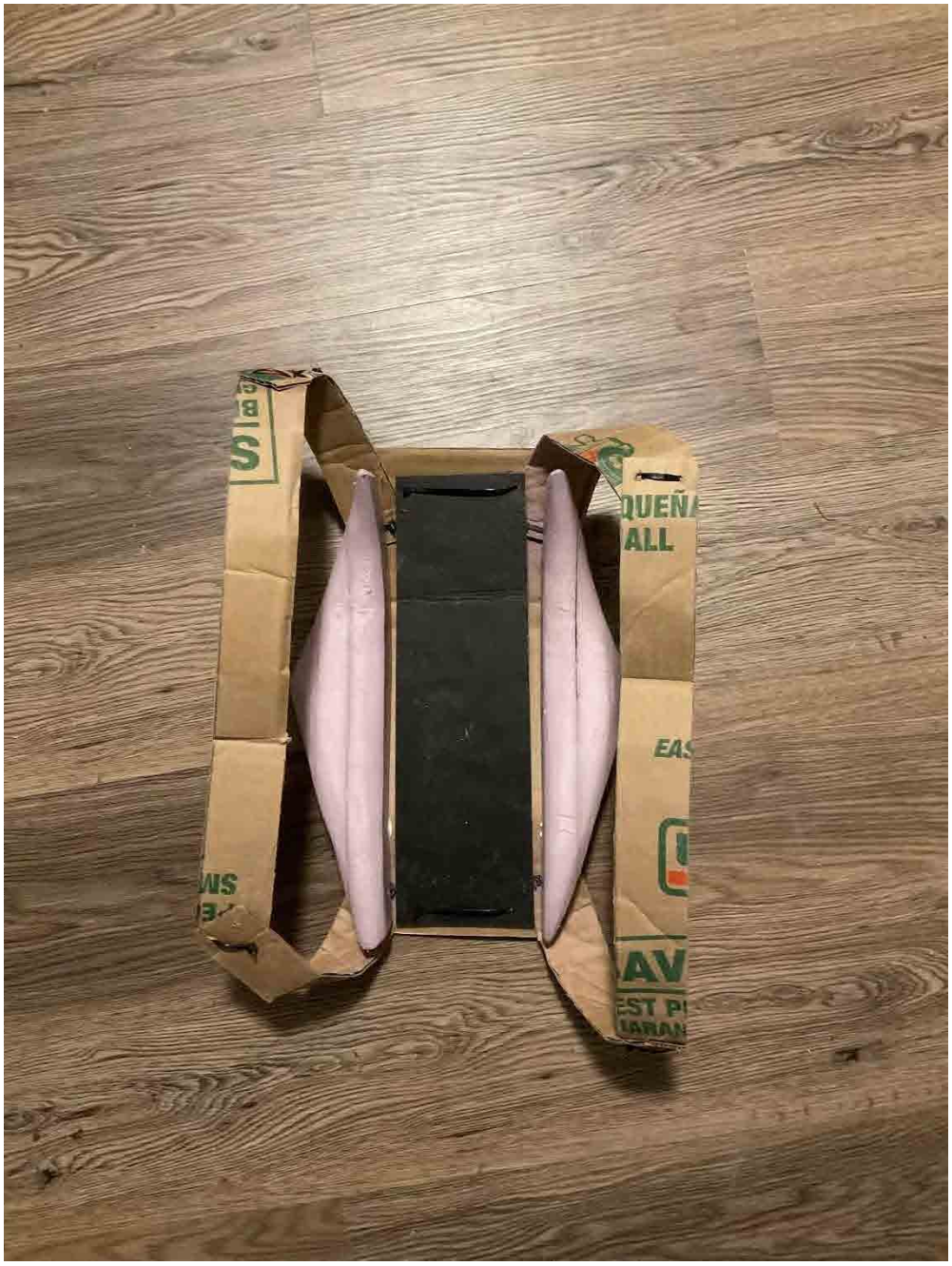

Figure 65 – Power Pack Study Model

Figure 66– Power Pack Study Model

Figure 67 – Study Model

Figure 68 – Power Pack Study Model

4.6 « Design Resolution »

The SpinSaw's final design considers the pain points experienced by forestry workers to ensure that they operate safely while completing their daily tasks. Developing musculoskeletal disorders from exposure to long periods of bodily vibration, and muscle strain due to stooping repetitively for long periods, were two major pain points that needed to be addressed. Throughout the design process the design's ergonomic touchpoints were constantly refined, changing from its initial angular shape to a more organic form as more data was collected from conducting further research and tests on the sketch model. The design of the rear handle was purposely placed on the right side of the chainsaw to make the device easier to hold and operate. The SpinSaw's aesthetics changed from a slim elongated cylindrical shape in the beginning phases of the design, into a hexagonal shape with an organic, streamlined form. This gives the design an aesthetically pleasing look and enough room to house all the necessary electronics. This sketch represents the final design direction before moving into the CAD development phase.

Materials & Considerations

Chainsaw – Matte grey Polycarbonate plastic

Power Pack – Matte Grey + Medium Gloss Black Polycarbonate plastic + Nylon

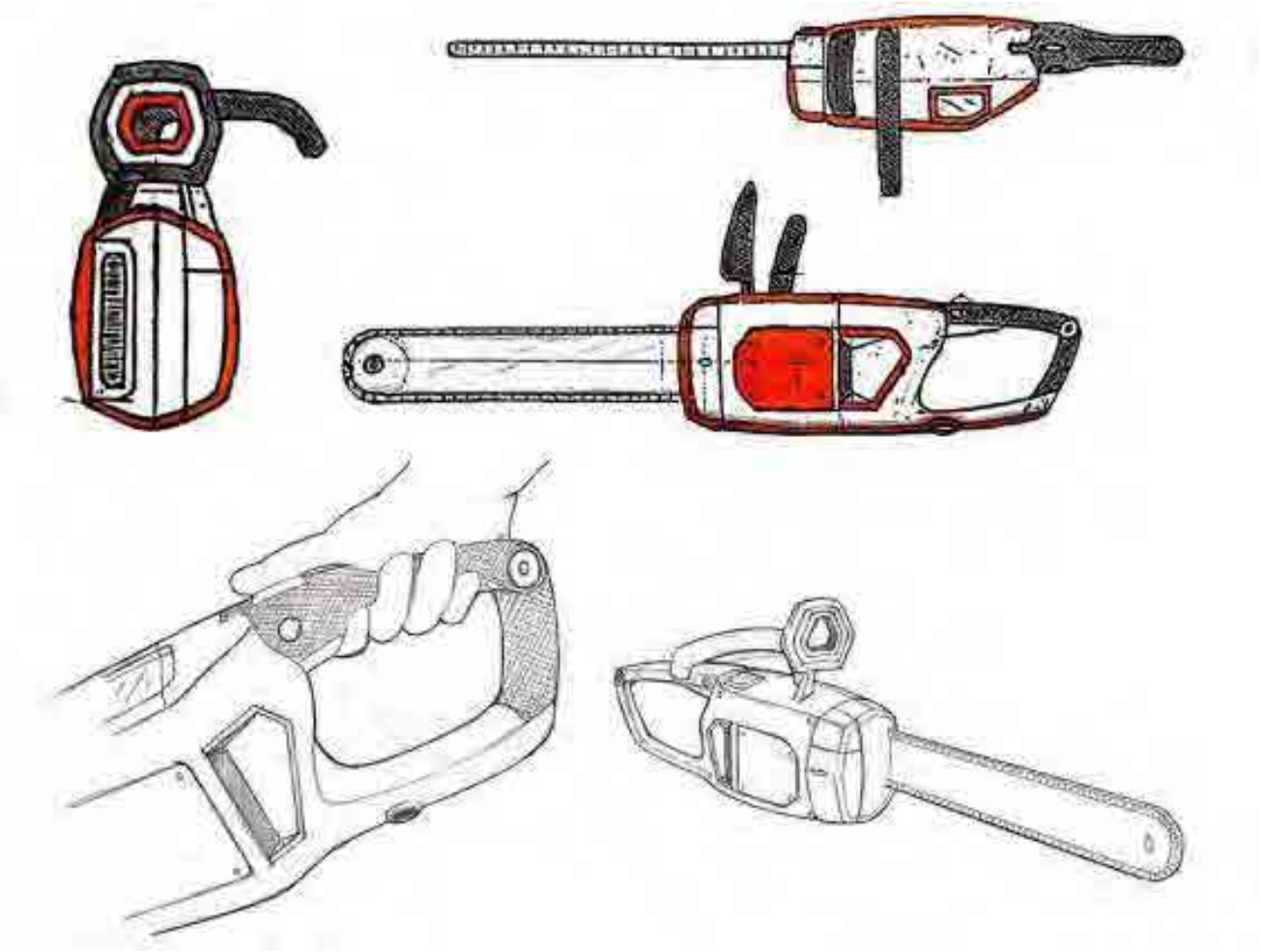

Figure 69 – Design Resolution

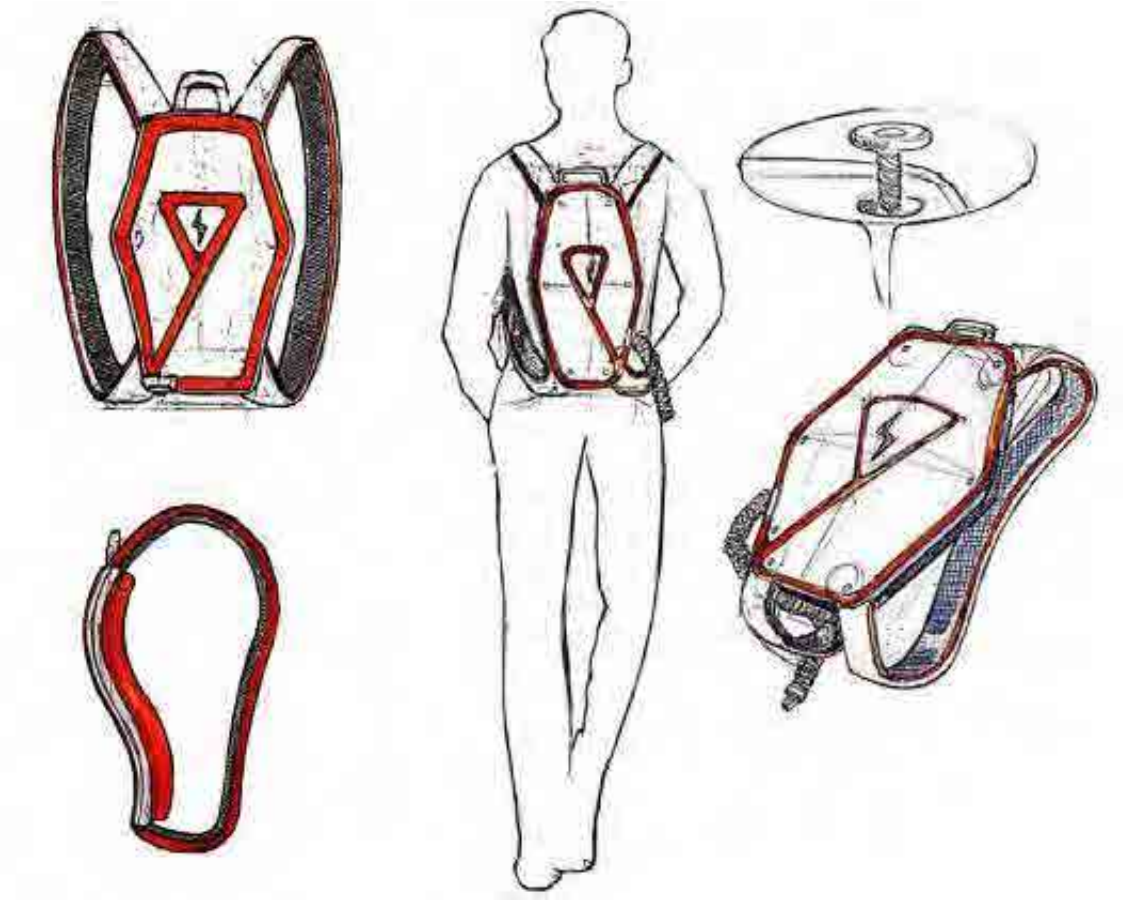

Figure 70 – Design Resolution

4.7 « CAD Development »

The figures below illustrate the development of the CAD model. The process began by inserting the sketch pictures of the model into Solidworks. A wireframe was built around these sketch pictures to form the outer frame of the model. Once this was established, more intricate detailing and features were added. Solid bodies were used to construct the model as opposed to using surfaces because its construction process is more straightforward and involves fewer errors. The entire modelling process took approximately four weeks to complete.

Figure 71– Chainsaw CAD Development

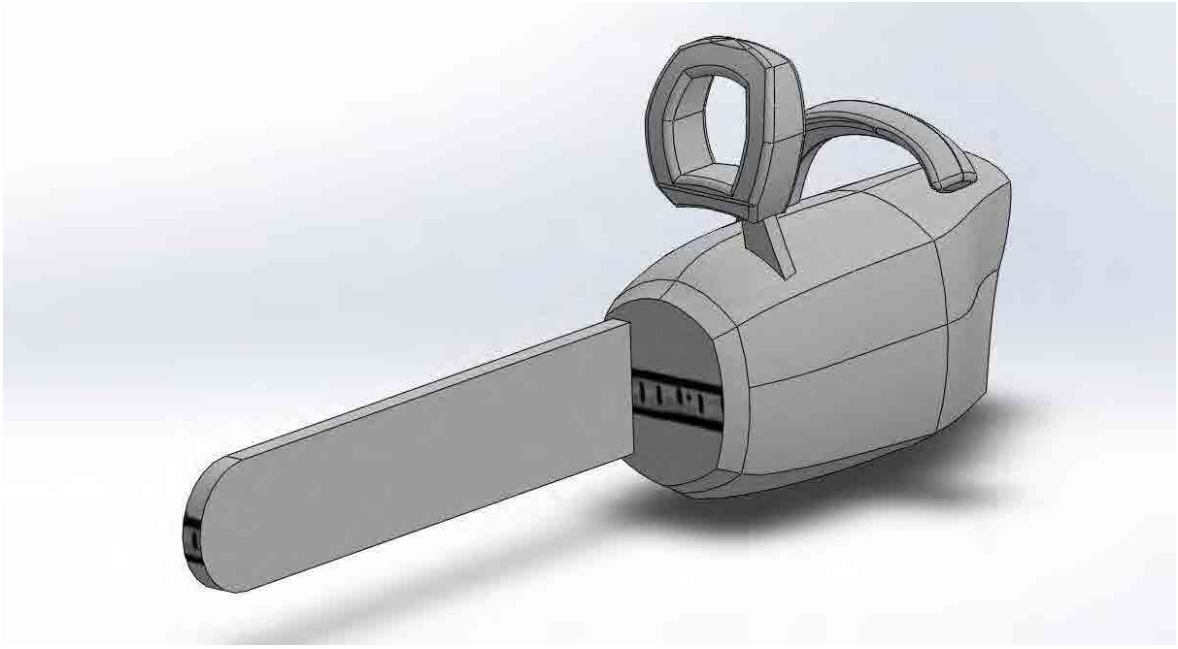

Figure 72 –Chainsaw CAD Development

Figure 73 – Chainsaw CAD Development

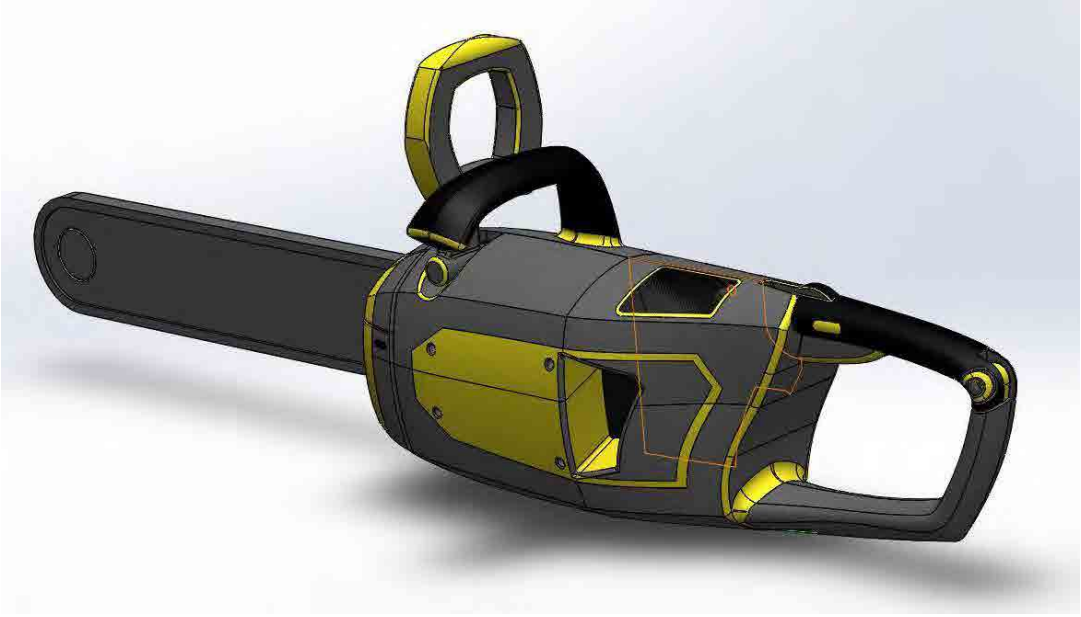

Figure 74 – Chainsaw CAD Development

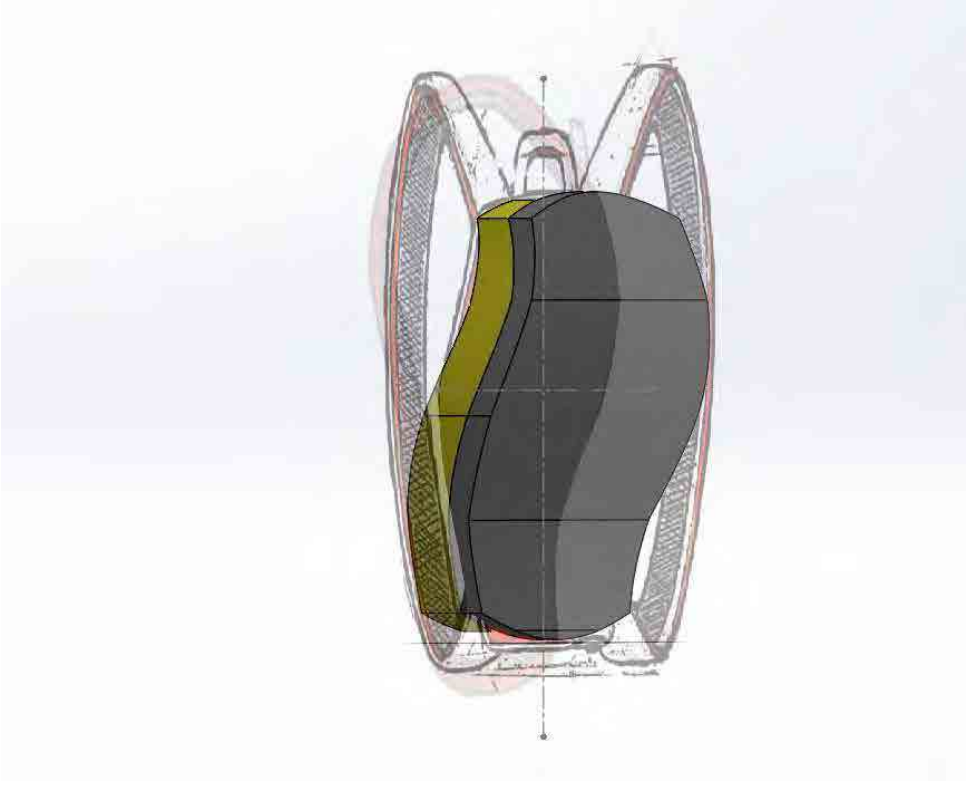

Figure 75 – Power Pack CAD Development

Figure 76 – Power Pack CAD Development

Figure 77 – Power Pack CAD Development

Figure 78 – Power Pack CAD Development

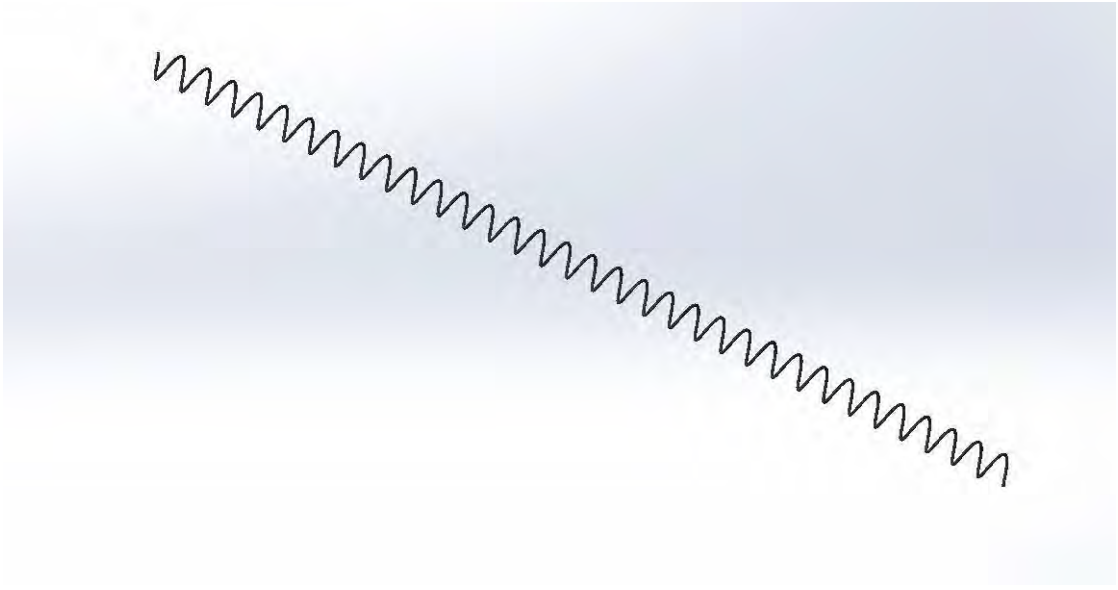

Figure 79 – Power Chord CAD Development

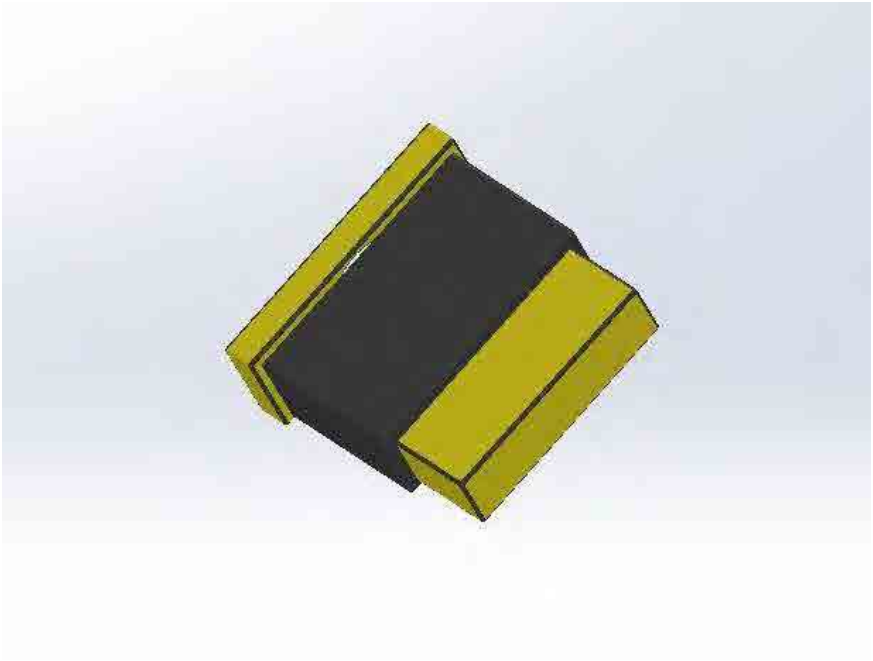

Figure 80 – Power Chord CAD Development

Figure 81 – Power Chord CAD Development

4.8 « Physical Model Fabrication»

The final model construction was outsourced to a 3D manufacturer. Due to the nature of the design, the model had to be SLA printed. To minimise manufacturing errors, finalising the design's dimensions was first discussed with the 3D manufacturing company and then addressed on Solidworks before printing commenced. The manufacturing material used for both the chainsaw and the power pack was a combination of polycarbonate plastic and rubber. The final adjustments to the model only took two days, and the final 3D printed model was manufactured and delivered in three days. The painting process proved to be very challenging. The models started with four coats of grey primer. Then they were taped accordingly to add black paint. The chainsaw received black paint on the inside of the model, and the power pack's front face was painted black. Three coats were used for each model. Once the paint dried, the model was taped again to add three coats of yellow paint for detailing. Lastly, three coats of clear paint were used to add a protective layer to the paint job and give the model a medium gloss finish.

Figure 82 - Physical Model Fabrication

Figure 83 – Physical Model Fabrication

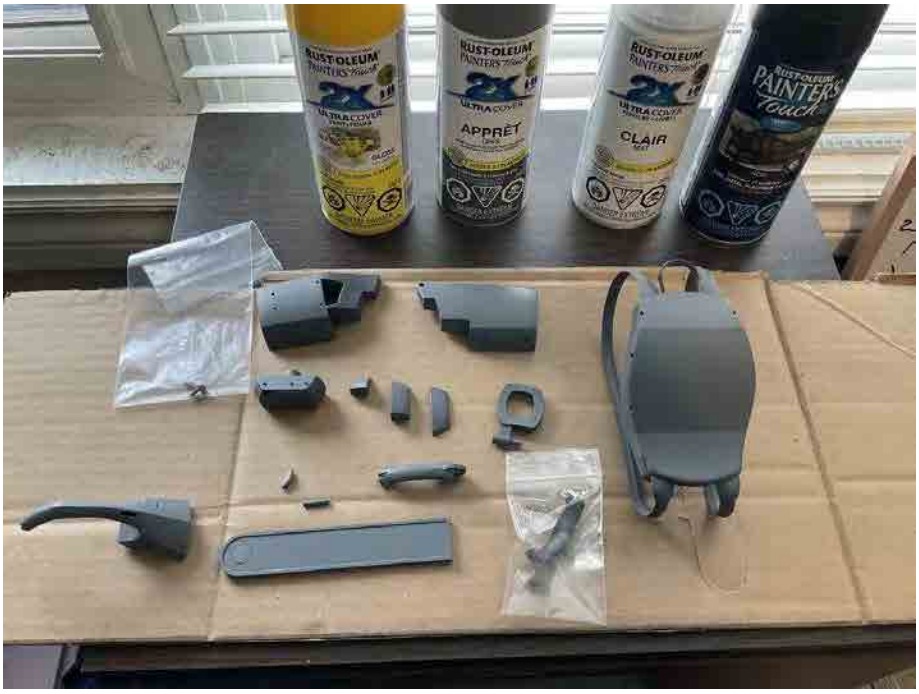

Figure 84 - Physical Model Fabrication

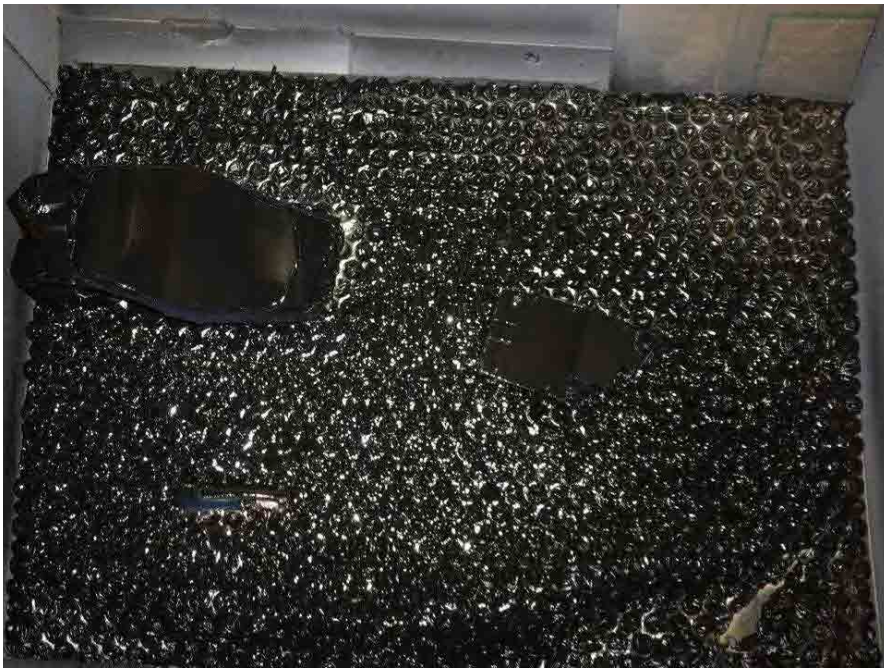

Figure 85 - Physical Model Fabrication

Figure 86 - Physical Model Fabrication

Figure 87 – Physical Model Fabrication

CHAPTER 5 - Final Design

5.1 « Summary »

Figure 88 – Man felling a tree

The SpinSaw 360 is a powerful and versatile electric chainsaw designed to better suit the needs of forestry workers, provide improved safety on the job, and increase the functionality of the traditional chainsaw. This design is important because it allows users to fell, trim and prune trees safely and efficiently. The device is designed to operate outdoors in most weather conditions.

Explanation

Tree care in the forest industry is widely known to be a dangerous activity. Therefore, user safety was an essential factor that was integrated into the design through a combination of styling and function cues. Control and mastery of the chainsaw were identified to be directly related to the forestry worker's performance, comfort, and safety on the job.

Benefits

The SpinSaw's top benefits are comfort, efficiency, power and versatility. In the context of comfort, the SpinSaw has a silicone rubber front handle that reduces the chainsaw's recoil and the motor's vibrations while in use. Both increase the user's sense of safety and security on the job. In terms of efficiency, the SpinSaw is equipped with a separate high-capacity cobalt-free, lithium-ion battery that minimizes the downtime on the job improving user efficiency because they have more time for other tasks. The powerhouse of the SpinSaw is a heavy-duty brushless motor that provides sufficient power to tackle multiple types of wood varying in hardness. This makes the user feel more skilled and accomplished by further reducing their downtime on the job.

The SpinSaw is versatile because it has a rotating blade feature that allows users to access branches in confined spaces. This feature also gives the user the ability to cut trunks comfortably and consistently at the desired angle instead of bending, twisting and straining the body with a conventional chainsaw. The rear handle of the chainsaw is adjustable and allows a wide variety of user percentiles to operate the device in different holding positions.

5.2 « Design Criteria Met »

5.2.1 « Full Bodied Interaction Design »

Throughout the SpinSaw 360's design process, full-bodied interaction design techniques were used. The SpinSaw 360 has a total of six touchpoints and interacts with three major body part areas. They are known as the shoulders, arms, and back region. The SpinSaw 360's design meets the minimum requirements for a full-bodied ergonomic study. The study was conducted using measurements of a 99th percentile male and a 5th percentile female in order to properly locate and size the device's features for effective use. These measurements were essential to developing a user-centred design that improves the efficacy of the physical interaction between the user and the device.

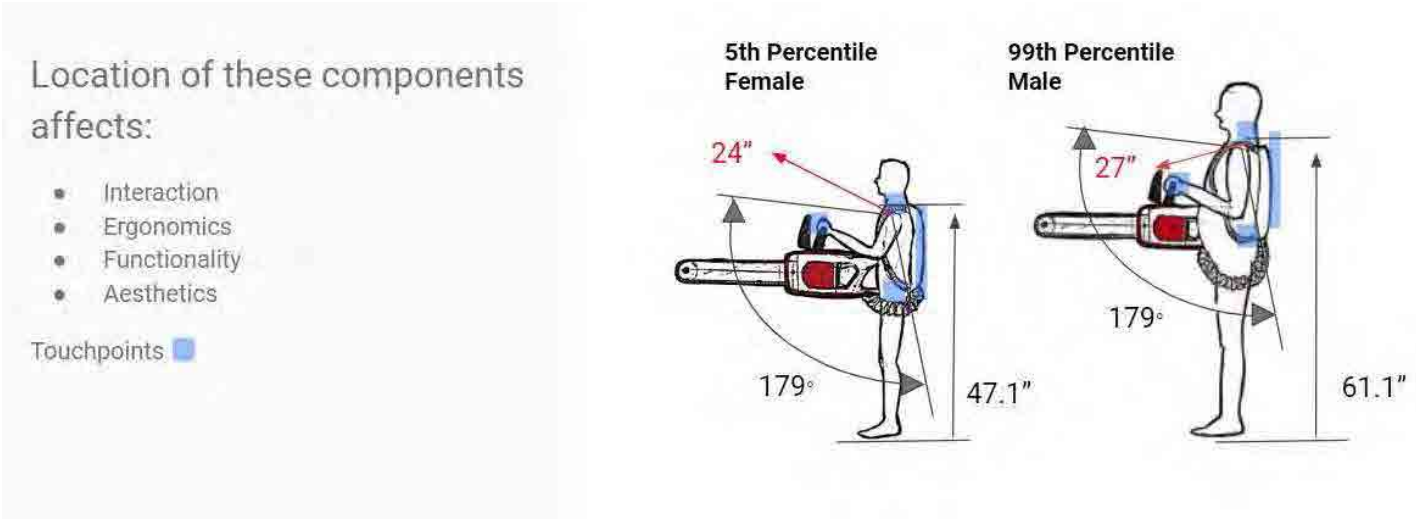

Figure 89 – Full Bodied Interaction Design

5.2.2 « Materials Processes and Technology»

Weight and durability were the two major factors that influenced the material selection process. These factors were very important because they directly affect the device's portability, versatility and ease of use. All components of the chainsaw, excluding the front and rear handle and the power port connector, will be made of injection-moulded polycarbonate plastic. This material was chosen because it's lightweight, durable and recyclable. The front handle will be manufactured out of extruded silicone rubber because of its anti-vibrational properties and the rear handle will be made of cold-forged stainless steel. Stainless steel was chosen for the rear handle because it will be rotating about a hinge and would therefore require additional strength to perform under stress.

The two major material choices for the power pack are nylon and polycarbonate plastic. The nylon will be used for the lumbar pads, shoulder straps, and handle. These features will be manufactured via the process of webbing. This material was chosen because it Is light, robust, durable, and easy to produce.

5.2.3 « Design Implementation»

The total cost of the materials and manufacturing will require further study as the project progresses. As technology advances, the overall prices of electronics become cheaper. Based on online research and comparing manufacturing costs of current electric chainsaws, a bill of materials was produced.

Parts	Materials	Description	Color	Manufacturing Methods	Cost $
18" Bar	Stainless Steel	Chain guide	Metallic Grey	Laser Cut	$2,500
Chain	Tungsten Carbide Tipped	Material Remover	Metallic Grey	Stamping	$1,500
Oil Reservoir	Polycarbonate plastic	Chain Lubricator	Yellow + Light grey	Injection Moulded	$750
Chain Tensioner	Polycarbonate plastic + Steel	Tension & Timing chain controller	Yellow + Light grey	Injection Moulded + Cold Forging	$750
Electronic Controls	Various	Power & Rotation control	Various	Various	$2,500
Swivel Motor	Iron, Nickel, Cobalt	Power source	Silver	Outsourced	$1,500
Power Motor	Iron, Nickel, Cobalt	Power source	Silver	Outsourced	$3,500
Emergency Brake	Polycarbonate plastic	Safety mechanism	Yellow + Light grey	Injection Moulded	$1,000
Front Handle	Silicone Rubbber	Grip & Control	Black	Extrusion	$1,250
Rear Handle	Polycarbonate plastic + Stainless Steel	Grip & Control	Yellow + Light grey	Injection Moulded + Cold Forging	$2,500
Motor Panel	Polycarbonate plastic	Maintenance	Yellow	Injection Moulded	$750
LED Panel	Clear polycarbonate plastic	Power Indicator	No color	Injection Moulded	$750
Power Connector	Neodyium Magnets	Power Distributor	Light Grey	Powder Metallurgy	$1,000

Power Pack

Parts	Materials	Description	Color	Manufacturing Methods	Cost $
Battery	Lithium Ion Phosphate	Power Supply	Black	Outsourced	$5,000
Lumbar Pads	Memory foam + Nylon	Back padding	Yellow	Outsourced	$1,000
Shoulder Straps	Nylon	Webbed	Yellow + Light grey	Webbing	$500
Chest Strap	Nylon	Securing Straps	Yellow + Light grey	Webbing	$500
Handle	High Density Memory Foam + Nylon	Webbed	Yellow + Light grey	Webbing	$1,000
PowerPack Pack Frame	Polycarbonate plastic	Mounting Frame	Light grey	Injection Moulded	$2,500
Power Cord	Chlorosulfonated Polyethylene + Neodyium Magnets	Power Distributor	Yellow	Outsourced	$500
Power Connector	Neodyium Magnets	Power Distributor	Light Grey	Powder Metallurgy	$1,000
Total					**$32,250**

Figure 90 – Bill of Materials

5.3 « Final CAD Rendering»

Figure 91 – CAD Renderings

Figure 92 - CAD Renderings

Figure 93 – CAD Renderings

Figure 94 - CAD Renderings

Figure 95 – CAD Renderings

5.4 « Physical Model »

The physical model was 3D printed in polystyrene using an SLA 3D printer.

Figure 96 – Physical Model

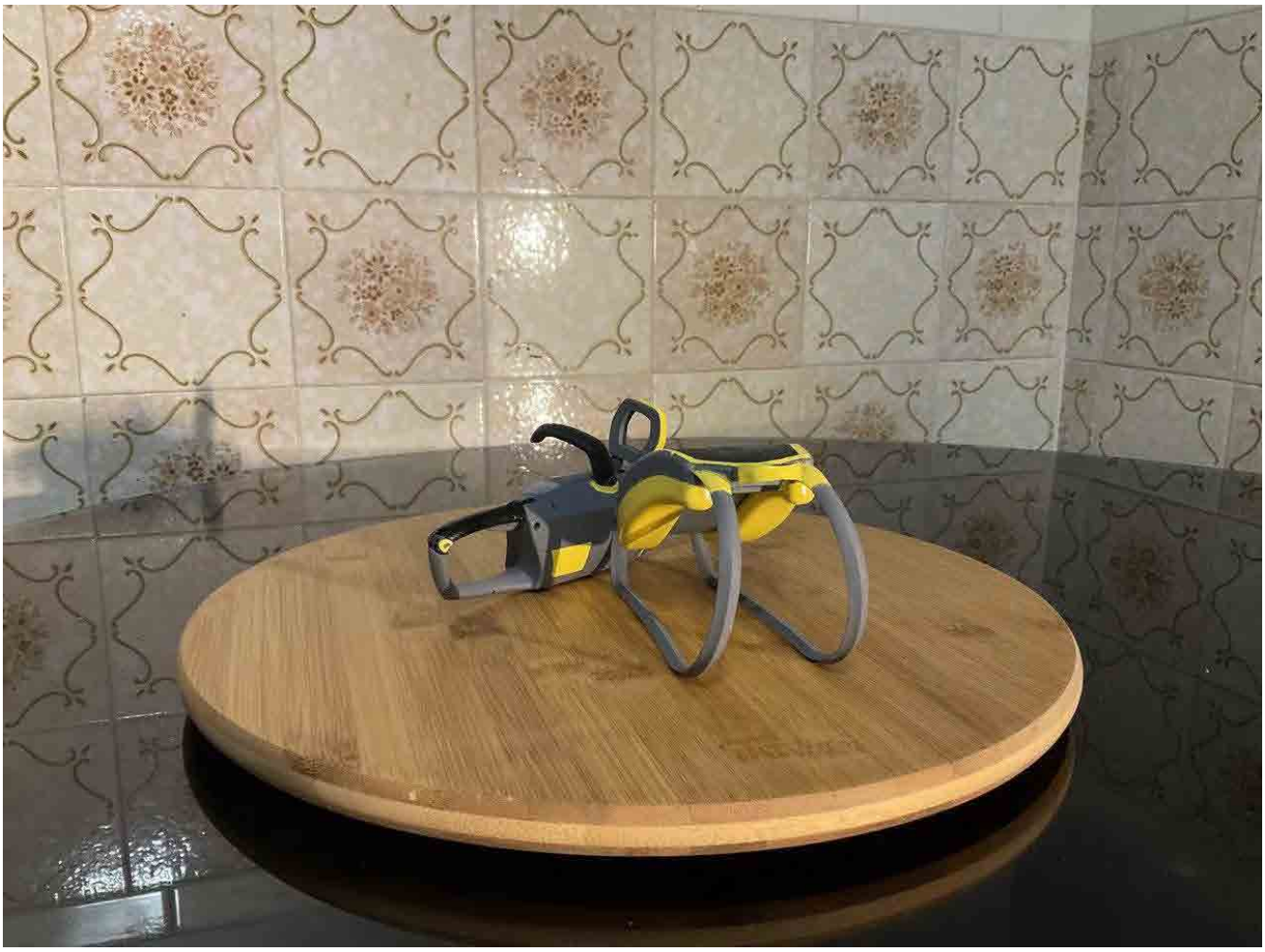

Figure 97 – Physical Model

Figure 98 – Physical Model

Figure 99 – Physical Model

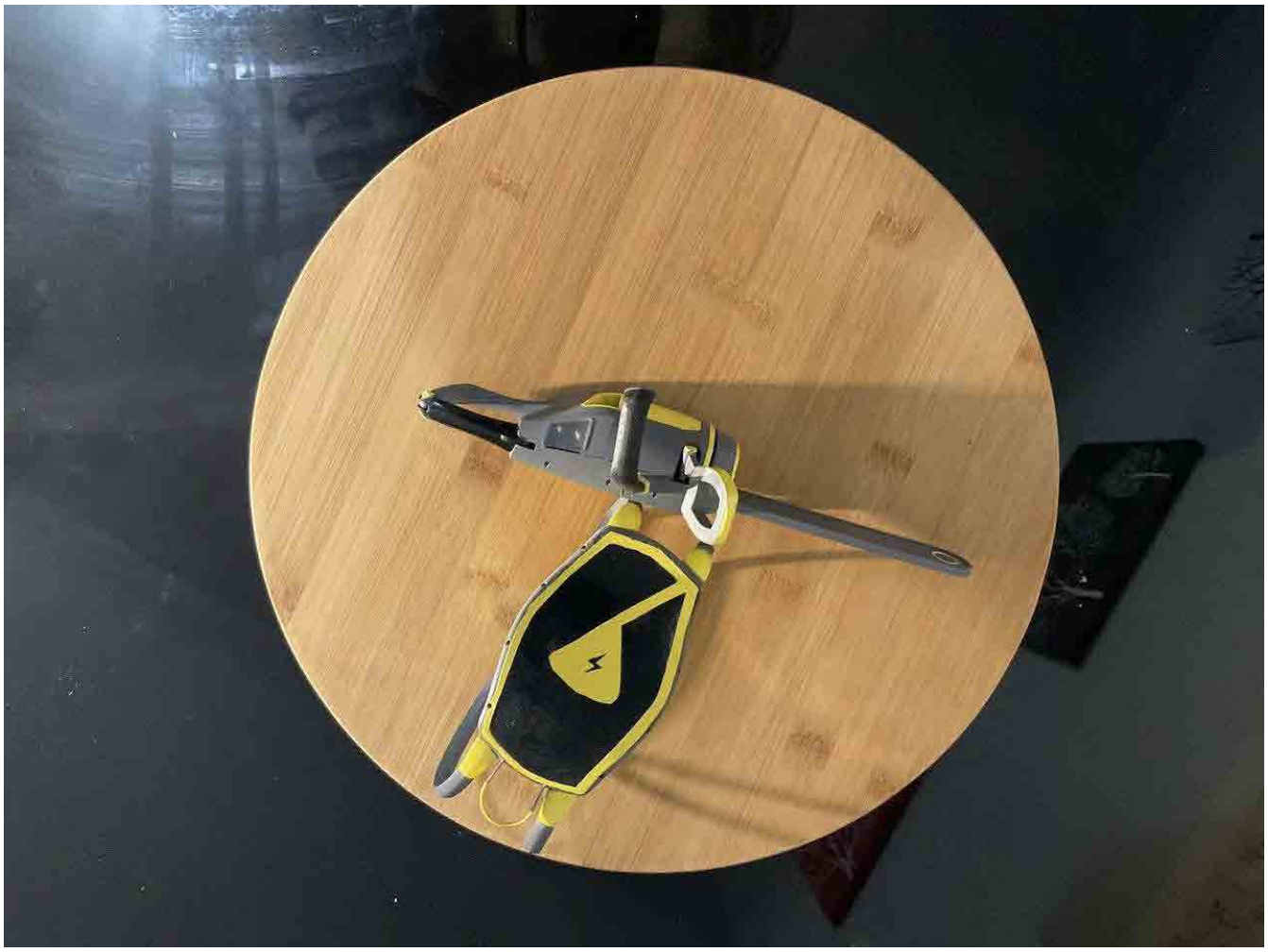

Figure 100 – Physical Model

5.5 « Technical Drawings

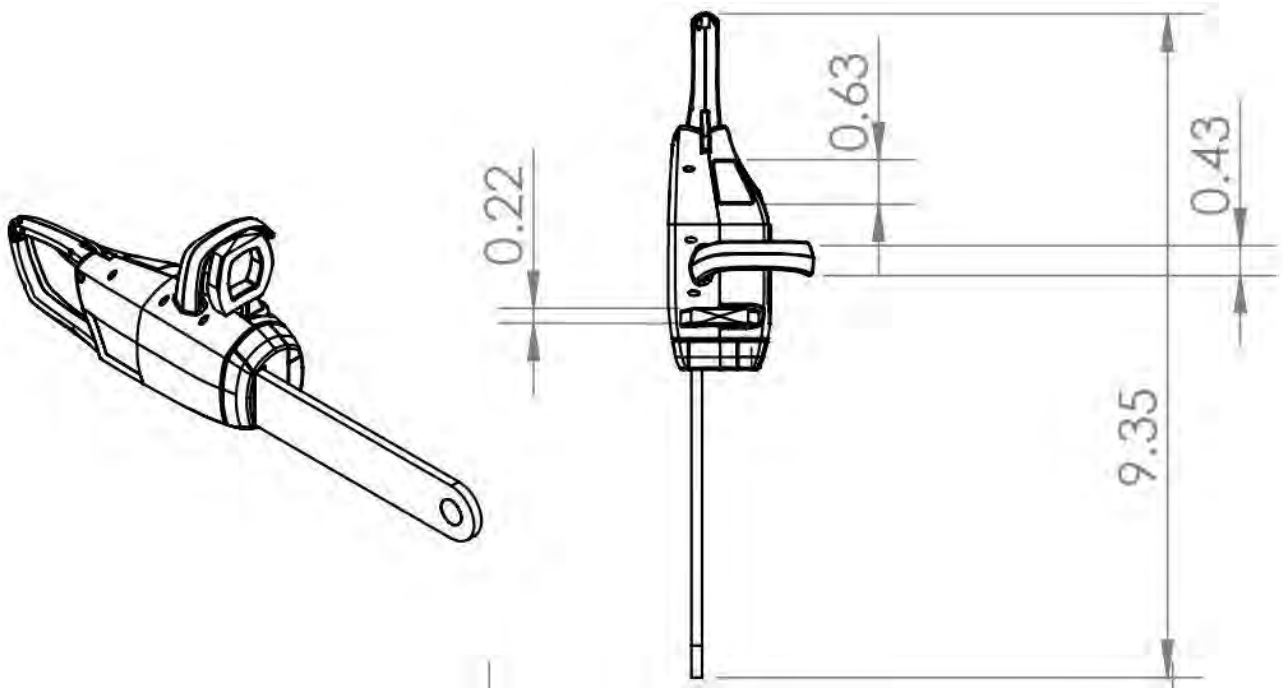

Figure 101– Technical Drawing 1

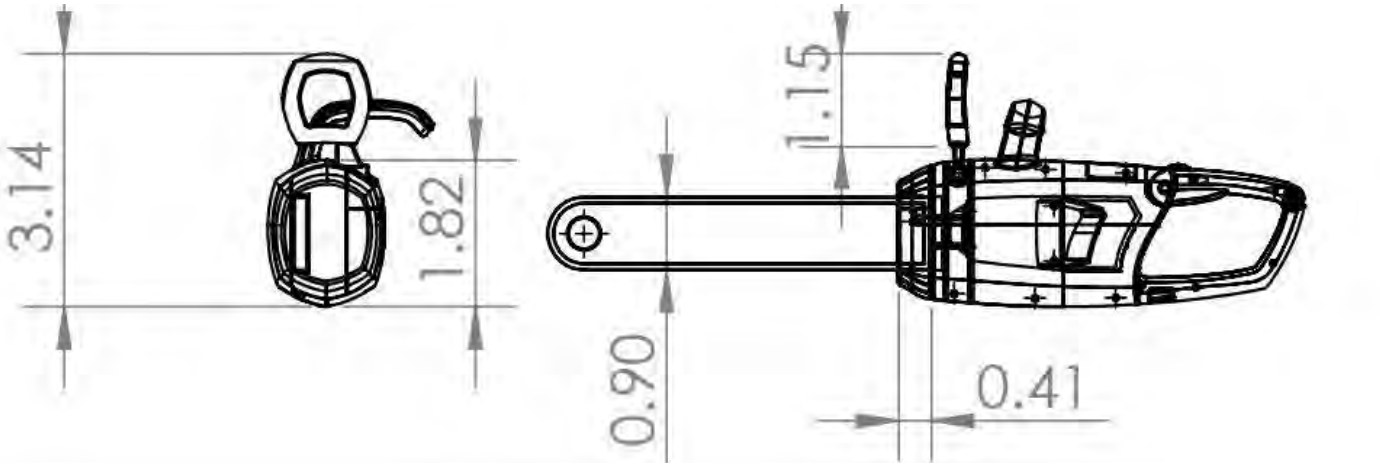

Figure 102 – Technical Drawing 2

5.6 « Sustainability »

Introduction,

This section of the report, will give a synopsis of the sustainability aspects taken into consideration for the Thesis project. These aspects include material and manufacturing, a business model of sustainability efforts, user health and safety, and environmental initiatives. In the Forestry Industry, sustainability is a necessity as it directly impacts the health of the surrounding environment. Sustainable forest management gives forests long-term health and social and economic benefits to locals.

Literature Review

« Sustainable forestry involves the continuous maintenance and efficient management of forests to provide natural resources such as wood and water to meet the needs of today and the future. Sustainability in forestry also involves smaller plants, wildlife, their habitats, the soil, and the natural landscape. Forests need to be sustainably managed to be protected from wildfires, diseases, pests, and abnormal use. This design intends to further add to the aspect of Forest sustainability by reducing air pollution and improving the forester's ability to manage forests. According to the Ministry of Northern Development, Mines Natural Resources and Forestry publicly owned Crown Lands, which represent 44% of Ontario's forests, are managed sustainably. Ontario's forests have benefited by remaining healthy, productive, and supportive of a strong forest industry through these sustainable initiatives. This is done by reducing the buildup of greenhouse gases, providing jobs and forest products to the market, and helping to conserve biodiversity through the enhancement or protection of wildlife, their habitats and watersheds.

Materials and Manufacturing

« The SpinSaw utilizes the environmentally friendly material, High Impact Polystyrene (HIPS). This plastic has chemical properties that make it very versatile, cost-effective, impact-resistant and recyclable. It can be easily blow moulded into different shapes, making it ideal for large-scale manufacturing.

Sustainability

« The SpinSaw utilizes the latest in electrical technology, including brushless motors and a high-capacity, cobalt-free, lithium-ion wearable battery. This high-capacity battery allows the SpinSaw to be used in heavy-duty applications just as well as gasoline-powered chainsaws. The battery also increases the device's run time, allowing it to be used for long periods without the need to be refuelled constantly. Due to the device's electrical nature, it is emission-free, and its noise pollution level is significantly lower compared to gasoline-powered chainsaws.

Sustainability Statement for Final Design

« This device would help foresters and forest and conservation technicians improve the environmental sustainability of forests by enhancing their land management, conservation and rehabilitation efficiency. For example, dead, dry trees are considered an extreme fire hazard because they can potentially start and/or help spread wildfires quickly. With the SpinSaw, these trees can be felled at a much more efficient rate compared to current chainsaws on the market.

« In conclusion, the SpinSaw has a very positive impact on Forest sustainability. Workers can remove unwanted trees much more efficiently and operate for extended periods of time without the need to refuel. Its electrical technology makes it a quiet, zero-emission device. Additionally, its housing materials are made from High Impact Polystyrene (HIPS) which is easily recyclable and can be repurposed at the end of the product's lifecycle.

CHAPTER 6- Conclusion

Figure 103 – In - Situ

Within the forestry industry, worker-related injury has become an alarming concern. Dangers such as exposure to prolonged bodily vibration, exposure to loud noises for long periods, overexertion and being struck by branches are just a few of the incidents that represent a high percentage of injury. Although there is some advancement of innovation within the industry, the proposed solutions have not been effective at improving the worker's safety on the job and their efficiency. The SpinSaw 360 provides an effective creative solution for the

forestry industry. It is a powerful and versatile all-electric device designed to help workers safely fell, prune and trim trees. The materials, features and technology used in the device were designed to improve the forestry worker’s performance on the job.

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Appendix A – Discovery

How may we improve the safety of Forestry workers in Canada?

Forestry workers spend most of their time outside, maintaining, and conserving parks and forest land. In the 20th century it focused mainly on managing land, monitoring plants for insects and diseases and collecting forest data. However, recently forest health has also included clearing excess trees brush and managing forest fires. In Canada, Land and forestry is ranked as the most dangerous industry. Forest workers face many hazards on the job including falling trees and branches, falls while working on slippery, uneven terrain, heat stress, exposure to extreme weather and musculoskeletal disorders due to moving heavy loads and vehicular accidents. Falling from ground level accounted for 13% of injuries in the industry. This industry is littered with opportunities to design a solution that can improve the safety of forestry workers, reduce their exposure to risks and improve their working conditions.

a) Tabulate the data collected for challenges of each sub-domain as follows:

USER ***Primary, Secondary and Tertiary*** ***(current challenges, indicate min 10 items)***		***PRODUCT*** ***Benchmarked Products*** ***(current challenges, indicate min 10 items)***	***ENVIRONMENT OF USE*** ***Various Environments of Usage*** ***(current challenges, indicate min 10 items)***
Categorize by job-title/position, job-functions, caretakers etc. and list the challenges faced by each category		Categorize by current product types or compatible products and list the challenges of each product section	Categorize by different scenarios used by different users or type of products and list the challenges of environment of usage
Primary Users			
Conservation Scientists ● *Physically Demanding* ● *Long walking Distances* ● *Rough Terrain* ● *Harsh Weather Conditions* ● *Work alone*		***Increment Borer-*** *Longer time required for coring,* *Trees may be too large for the borer to reach the pith* *Borer may miss the pith* *Difficult to insert into trees with dense wood*	*Rain- Makes handling of borer difficult.*
Foresters ● *Exposed to extreme weather conditions* ● *High risk of accidents* ● *Physically demanding* ● *Exposed to Insects/Wild animals*	 	***Delimbers***- ● *Most machines require a loader* ● *Tree cutting limited by machine size.* ● *Normally used at the landing (because of space issues), which can be far from the work site.* ***Feller Bunchers***-	*Rain – Loosens soil and increases risks of machine accidents and worker injury* *Snow- Creates a soil texture that bogs down machinery. Makes traversing through terrain difficult.*

		• *Ground and tree conditions can affect the slope at which equipment can operate.* • *Tracked machines with self leveling cabs are limited to operating on slopes of 50%. Tracked machines without self leveling cabs are limited to operating on 40% slopes.* • *Wheeled feller bunchers are limited to 25% slopes* • *Rough broken ground or many ground obstacles limit the slope to less than maximum* • *Larger trees reduce operating slope due to their mass* • *Wheeled equipment are prone to rutting and compaction* • *Broken cutting teeth from Hotsaw heads can be thrown very far at very high speeds which can injure nearby workers*	
Forest and Conservation Technicians • *High risk of injury or illness* • *Long working hours* • *Heavy lifting* • *Exposed to working extreme conditions. (eg. Battling forest, fires)*		*Bulldozers* • *Long use can cause noise induced hearing loss* • *Vehicular vibrations can lead to musculoskeletal damage over time.*	*Rain – Bulldozers can become bugged down in intense rain* *Snow- Can cause bulldozers to lose traction which can lead to accidents and worker injury* *Hot- Can suffer from dehydration or heat stress*
		***Logger***	*Rain – Loggers without tracks can Lose grip or become bogged down in mud*

Forest and Conservation Workers ● *Exposure to extreme weather* ● *Long work hours* ● *Physically demanding*		● *Increases the impact of flooding* ● *Muscoskeletal damage* ● *Debris can strike nearby workers causing injury or death*	*risks of machine accidents and worker injury* *Snow- Loggers without tracks can get stuck in sludge Which makes traversing through the terrain difficult.*
Secondary Users			
TigerCat (Equipment Manufacturer)			
Truckers		***Log Truck*** ● *Improper loading* ● *Poor Maintenance* ● *Driver Error*	*Muddy- Mud caused by rains can cause trucks to get stuck* *Rain & Snow- Can create slippery roads That cause accidents*
Tertiary Users			
Wajax (Distributor/Servicer) *RedHead Equipment LTD* (Distributor/ Servicer)		*Safety boots for Service Technician* ● *Heavy weight can lead to lower back and knee problems.* ● *Loses grip on slippery surfaces* ● *Inadequate arch support that an lead to foot injuries such as plantar fasciitis.*	*Snow- Shoes can get bogged down in snow because of weight. Decreases worker manoeuvrability.* *Rain- Can create slippery surface conditions leading to falls.*

Appendix B – Contextual Research (User)

Product Benchmarking

How May We?

How may we improve the safety of forestry workers?

Tigercat 470 Mulcher

Rugged and compact, the 470 mulcher is a 245 kW (328 hp) carrier. With ultra low ground pressure, the 470 is ideal in the most challenging soft soil applications.

Overview: Tigercat mulcher carriers offer superior build quality, greater hydraulic efficiency, better operator ergonomics and easier access to components and daily service points than competing mulcher carriers. The result in greater uptime, higher productivity — essential in time sensitive ROW clearing projects.

The 470 mulcher is an agile, low ground pressure machine best suited to tough terrain and sensitive site ROW, pipeline maintenance and exploration projects.

KEY BENEFITS

- Large attachment pump. High flow to the mulching head
- Closed loop drive system provides optimal balance of speed and tractive effort for high performance and efficiency in extreme terrain
- Counter-rotate function (CRF). Turn on a dime at the touch of a button
- Extremely low ground pressure. Low impact in sensitive sites

- High-lift boom geometry, improved performance on sloped terrain
- Efficient, high-capacity cooling system with variable pitch fan and automatic reversing cycle

INNOVATIONS

As an engineering focused company, Tigercat is continually innovating in an effort to increase efficiency and productivity. Find out more about Tigercat innovations and key technologies.

Tigercat Power

Tigercat FPT power solutions. Stage V, Tier 4f, Tier 2 and Non-certified engine configurations to cover emissions requirements worldwide.

RemoteLog: Off site Access to Telematics

Be connected to your forestry operation from almost anywhere – all you need is RemoteLog™ and a device with internet connectivity.

Mulcher Benefits and Features

Benefit	Examples of Benefits
Reduces pain points	1. Reduces weed growth by keeping light from reaching the soil surface. 2. Reduces water loss from the soil surface, which helps maintain soil moisture. 3. Moderates soil temperatures, keeping it warmer on cold nights and cooler on hot days. 4. Eliminates hard-to-reach hindrances 5. Produces paths that serve as wildfire prevention
Enhances the user experience	Adds value to property
	Saves you time and effort

Using a mulcher as a specific product, examples of features would include:

Benefit	Examples of Benefits	Example of Features (mulcher) for those Benefits
Reduces pain points	1. Decreases physical workload	The staggered tooth design reduces stalling and jamming
	2. *Easy maintenance*	Access internal components quickly and easily with bolt-on service panels
	3. Quickly clears a wide trail	Variable torque hydraulic piston motor
Enhances the user experience	*Improves workflow*	Multiple rotor types to fit different jobs: – Standard – rotor with teeth only – Bite limiter – rotor with teeth separated by ribs to help prevent rotor stalling and creates finer shredded materials
	Improves safety	Hydraulic Mulching door keeps the work environment and equipment safe by dispersing materials according to your application and surroundings

Benchmarking Products

1	2	3	4	5	6
BARKO 930B 	PRENTICE 2864 	SUPERTRAK SK190RTL 	C200R FORESTRY MULCHER 	PRINORTH M700 	TIGERCAT M726G MULCHER 
BENEFITS					
-Powerful Engine -Loading Sensing Hydraulics -Hydraulics attachment drive -Travel system -Articulate joint -High strength construction -Bolt on cylinder glands - Cover Plates - Centralized Lubrication - Service Access - Operator Cab	-Lower Owning and Operating Cost - Powerful Performance - Clean, Cool Operation - Easy maintenance - Comfortable cab - "Stuck-to-the-Ground" Stability	-Front halogen work lights -Emergency engine shut down system -Electronic engine management system -Lexan front windshield -Complete guard/debris - Enclosed cab with air conditioning and heat -Adjustable seat -Superior sealing and noise abatement -Optional rear view camera system	- Hydraulic Cab tilt - Certified ROPS/FOPS/OPS Cab -Rooftop escape hatch and backup camera - High Output LED lights -20" wide rubber tracks - Heavy duty rubber track undercarriage, operating weight less than 20,000 pounds, 2 speed ground travel -20 000 lb capacity hydraulic rear winch	- Turbo coupling prevents sudden speed changes or rotor standstills that have a negative effect on the drive change, the carrier vehicle, and its engine. -Synchronization control: W-Kinematics prolongs the transmission and driveshaft Hydraulic follow -up shredding flap controls the mulcher's density grade according to user requirements -Height adjustable skids can be adjusted according to required operating conditions	- Large attachment pump. High flow to the mulching head -Optional multi-function mulcher/feller buncher hydraulic system and quick attach boom adapter for increased versatility -Boom float system. The mulching head automatically follows terrain contours -High-lift boom geometry. improved performance on sloped terrain - capacity cross-flow cooling. Automatic variable speed for improved fuel efficiency, automatic reversing cycle -Compartmentalized layout separates the cooling system, engine, and hydraulic components

		Engine over speed protection -Air Precleaner -Scavenger System Air Cleaner -2 Stage Air Cleaner				(1,143 lbf-ft) @ 1,500 rpm -AIR FILTRATION Precleaner and 2-stage engine air cleaner -COOLING Cross-flow side-by-side aluminum radiator, oil cooler, charge air cooler and A/C condensor -FAN Hydraulically driven; Automatic variable speed with automatic reversing cycle -FUEL CAPACITY usable 570 L (150 US gal) -DEF CAPACITY Tier 4f 80 L (21 US gal)
Powertrain	- All wheel drive planetary axles - **Front-** Rigid with hydraulic differential lock - **Rear-** Oscillation type with hydraulic differential lock	-Cat Axles - Front and Rear Differential Locks -HD Drivelines	Hydraulics -22gpm @ 3400psi separate loader hydraulics -50gpm @ 5500psi closed-loop hydraulics dedicated to custom mulcher head	-TRAVEL SPEED HIGH-4.8 mph, 7.7 km/h TRAVEL SPEED LOW-2.7 mph, 4.3 km/h	-Power belt -Oil cooled turbo clutch	TRANSMISSION 2-speed mechanical shift, variable speed hydrostatic Piston motor, infinitely variable -AXLES Tigercat IB15, inboard planetary, barrel differential Front fixed; Rear oscillating +/- 15° -DIFFERENTIAL LOCKS Independent front and rear
Hydraulic System	-Travel System- Hydrostatic; variable displacement pump and motor with pilot operated foot controls, combined with two-speed transfer case -Lift/Tilt/Steer Pump- Variable displacement piston pump - Attachment Pump- Variable displacement piston pump producing 100 GPM (378 LPM) @ 5,000 PSI (33,095 kPa)	-PowerDirect Plus System -Load-Sensing Hydraulics with Variable -Displacement Main, Attachment, Hydrostatic and Fan Pumps -High Performance Multifunctioning -Main Control Valve -Cat ToughGuard Hoses		-HYDRAULIC TANK-20 gallons, 75.7 L -HIGH FLOW HYDROSTATIC-66.1 gpm • 5,800 psi, 250 L/min • 400 bar	Adjustable hydraulic counter rake.	PUMP, DRIVE Piston -PUMP, ATTACHMENT- Piston -PUMP, BOOM- Gear -PUMP, STEERING- Gear -PUMP, FAN- Gear -RESERVOIR - 186 L (49 US gal) -FILTRATION- (4) Spin-on, 7 micron full flow (1) Water absorbing -CYLINDERS, BOOM (4) 115 mm (4.5 in) bore lift and tilt

	- Attachment Return Filter- High pressure 20 micron - Hydraulic Reservoir- 74 gal (303 L) - Oil Cooler- High capacity, anti-clog type with reversing fan integrated with radiator and charge air cooler					-CYLINDERS, STEER (2) 75 mm (3 in) bore
Brakes	-Service/Emergency Brake- Hydrostatic-dynamic front axle internal wet disc brake with foot pedal in cab -Parking Brake- Switch operated control on dash with wet disc brakes, located on drive line at transmission	-Brakes Enclosed -Disc Service Brakes -Hydraulically Released and Spring Applied -Parking Brake	N/A	N/A	N/A	-DYNAMIC BRAKING - Hydrostatic -SECONDARY BRAKE Enclosed, oil cooled -PARK BRAKE Driveline mounted wet disc Spring applied, hydraulic release
Tires	-Standard (8' 11" machine width) 28L–26 20 ply with 25 x 26 reinforced wheels	28L x 26 16 PR, NOAW Offset	Rubber tire	Tracks	Skidders	-STANDARD-30.5Lx32,26 -OPTIONAL-: 28Lx26,20; 67x34-25,22; 73x44-32,20
Electrical	-Starting System/Alternator- 12-volt with ignition key; 150 amp - Power View Display- Engine oil pressure, engine RPM, engine load %, hour meter, engine temperature, volt-meter, aftertreatment indicators - Visual Warning System- Engine oil pressure, engine temperature - Analog Audio/Visual Warning System- Hydraulic oil temperature, low hydraulic oil level, park brake, differential lock engaged, high pressure filter service	-24-Volt Electrical System -130-Amp Alternator -Maintenance Free (2-1,000 CCA) Batteries -Cat Jump Start Receptacle -Dual Bulb Halogen (6 total) Working Lights - Main Disconnect Switch -Diagnostic Connector -Warning Horn -Product Link Ready	-Electrical system: 12 volt (1 battery)	Not specified	-Height sensors -Hydraulic Sensors -Sync control	-BATTERY (2) 12 v -ALTERNATOR 110 amp, 24 v -SYSTEM VOLTAGE 24 v

	attachment pump filter service, fuel level	- IQAN MD3 Full Function Control System -Working Lights -Radio Ready Package				
Operator's Station	ROPS and FOPS certified, the tightly sealed, vibration-isolated floating cab features sound insulation and an adjustable bucket seat with 4-point harness. Climate controlled with air conditioning and heating with defroster, the cab includes dual joystick controls, pilot operated foot travel and brake pedals, and various control buttons.	-Reverse Slope 3-piece Windshield -High Capacity HVAC System -Knee Action Air Suspension Seat -Headliner -Non Permeable Removable Floor Mat -Dome Light -Rearview Camera -Dual 12V Outlets -Two (2) Beverage Holders	Cab -Enclosed cab with air conditioning and heat -Adjustable seat 1/2 inch Lexan front and rear windshield -Superior sealing and noise abatement -Optional rear view camera system	-CAB CERTIFICATIONS-ROPS ISO 8082 • FOPS ISO 8083 • OPS ISO 8084/WCB G603	N/A	- CAB Insulated, pressurized and isolation mounted; (2) doors with sliding tempered glass windows and hinged steel mesh screens; Removable steel and polycarbonate skylight; A/C, heater, defroster and pressurizer; Forward sloping polycarbonate windshield; AM/FM digital stereo with CD player; Bluetooth® audio and hands-free calling 12 v power point; 24 v lighter; LED lighting -SEAT Air ride suspension, fully adjustable, heated and cooled -OPERATOR CONTROLS Hydraulic pilot; Joystick for boom and steering (2) Foot pedals for forward/reverse travel
Other Standard Equipment	N/A	Not specified	Cooling system -High debris individual radiator, aftercooler and oil coolers all with temperature controlled reversing fans.	-PREDATOR MULCHER HEAD MODEL – STANDARD-FM200-BDR	N/A	Pressurized water system; Back-up alarm Fuel gauge; Hydraulic oil hand fill pump; Fire extinguisher; Fire detection system; Drive speed limiter control; Rear camera; Boom float system Air compressor with 24,5 L (6.5 US gal) tank LogOn™ local wifi machine monitoring system
Optional Equipment	-hydraulic tank heater -Engine block heater -Joystick travel control -Mulcher head terrain float system	MACHINE ATTACHMENTS -AM/FM/CD/Sirius-Satellite Radio Package -Safety Lights -Attachment Float Control Arm Control	Fecon BH85 DCR Drum Mulcher	N/A	-BCS ROTOR SYSTEM -UPTs ROTOR SYSTEM -UPT ROTOR SYSTEM	High output LED lighting package; CB radio Fire suppression system; Multi-function mulcher/ feller buncher hydraulic system with quick attach boom adapter; Diesel-powered cold weather aids RemoteLog® telematics system

Appendix C – Field Research (Product)

PANEL ON RESEARCH ETHICS
Navigating the ethics of human research

TCPS 2: CORE

Certificate of Completion

This document certifies that

Jaaziel Codogan

has completed the Tri-Council Policy Statement:
Ethical Conduct for Research Involving Humans
Course on Research Ethics (TCPS 2: CORE)

n01316348

Date of Issue: **28 September, 2021**

Appendix D – Result Analysis

1:1 Interview questions

1. Can you tell me about your background?
2. What are your day to day tasks like?
3. Is there a specific Physical layout of the job site?
4. What sort of tools do you use on the job?
5. What goes on in your head while you are completing a task?
6. What are the sequence of steps you do when completing a job?
7. Where do you usually go to get tool or equipment supplies? Why do you go to these specific places?
8. Do you remember any remarks people have made about the job?
9. What are the typical things you hear while on the job?
10. Describe the fears, frustrations, anxieties you feel while doing this task
11. What is the most common cause of injury on the job based on your experience?
12. Is there anything you find frustrating while completing a task? If so, why?
13. What are some goals you have achieved in your field?
14. How do you feel when you have completed a job?
15. What do you enjoy about you job. What was once situation where you found enjoyment/ satisfaction when completing a job.
16. Describe anything that would make your job easier and less stressful
17. Describe anything that would make this job more productive.

1:1 Interview Responses

1. I have been an arborist for 10 years. I've have work experience in both small and large companies but now I conduct my own business. As of now i do contract climbing for different companies in the Ontario area.
2. Normally I get contacted by clients to do a job. Typically for tree removal or trimming. I usually update my team on the job we are performing and we meet at the sight. We identify possible hazards on the job site and ensure that everyone has their standard PPE before working which is standard. After the job has been completed we pack up for the day.
3. Yes. When we arrive at the job site the 1st thing we do is set up general traffic control. The general foreman is responsible for arranging additional precautions prior to the job starting. Teams get together to understand the job briefing at the mobile on site office. Our equipment and tools are stored separately. Transportation vehicles are located at the jobsite entrance.
4. Chainsaws, Positioners, Snake tail, Pickup truck, Utility trailer, Logger, Saddles, Helmets, Radios, Gloves, Eye protection, Straps, Spurs
5. Am I hydrated? How am I feeling? What's the most efficient way to cut down this tree? I hope the weather does not change for me. I should be wary of these branches.

6) Jobsite briefing with team. Jobsite walk around. In the walk around we identify the major hazards, obstacles. Plan tasks that need to be performed and positioning workers. Check equipment and ensure that workers have the correct PPE. Once the work commences it is

essential we keep communication with workers. So we utilize a command/response communication protocol. Emergency preparedness is a top priority so I ensure that the correct equipment and protocol are provided.

7) I usually go to Universal field supplies for equipment. They have a wide variety of products and offer very competitive prices. In the case where I need to get machinery parts I usually run to Triad machinery. I love to work with them because of their exceptional customer service.

8) People who see me working often tell me that I'm very brave for doing such dangerous work. Children who pass by enjoy the sight of the heavy machinery at work and sometimes feel me how cool they are.

9) On the job i normally hear statements like : Have you hydrated yourself? How are you feeling today? Make sure your gear is working before you start the job? Chainsaws, Trucks running, Workers talking.

10) I fear getting injured on the job and not being able to work. I am very anxious when removing power lines from trees because I can get electrocuted if I’m not careful. Standing near heavy equipment while in operation makes me a bit anxious because there is a high risk of getting hit by taking branches of flying debris. A major frustration for me is getting bad weather when on a job. It makes my working conditions a-lot more dangerous and increases the chances for workers to get injured. It is very common to fall on the job and bad weather just increases those chances.

11) Falls, Being struck by falling branches, Biological hazards, Rough terrain, Bad weather, Kickback from chainsaws.

12) A major thing i find frustrating while completing a task is dealing with broken equipment. This is very frustrating for me because the equipment would need to be serviced which is very time consuming and prolongs the job. Another major frustration is working in extreme weather conditions. This also slows the completion time of the job and makes working conditions more hazardous.

13) Learning how to operate the logger. Becoming a foreman on the job. Creating my own tree service business.

14) When I first started this job I quickly realized that there were always new challenges and there was always something new to learn. Most of the time my team and I have had to improvise or create new solutions to solve a problem. When we complete tasks like these, we always get a sense of satisfaction that we completed the job and did it right. Additionally, it’s a good feeling when none of your team members get injured on the job as these injuries are very common.

15) What i enjoy most about the job is seeing new recruits get excited about the industry. I enjoy helping them understand the safety precautions and sharing personal knowledge and experiences to add to their skillset. I love to see people recognize this great industry.

16) One thing that would help make my job become less stressful is getting protective great that would significantly reduce my risk of being hit with falling objects or debris from machines.

17) Real time data collection would be very helpful. This would allow me to collect data about tree height, diameter, trimming status, diseases and other variables in real time. Having this data would allow me to work more efficiently because I would have insight into the status of the greenery on my work site as well as its maintenance status.

Who

Arborist
ages 35-40
Working in position for 10 years

Persona

What do they need to do

Setup Traffic control
Job briefing
Site walk thru
Inspect tools and heavy machinery
Prune trees
Fell trees
Remove trees
Replant trees
PPE check

What do they see?

Equipment
Heavy machinery
Forested area
Other workers
Wildlife
Word Hazards

Pains

Extreme weather conditions
Falling objects
Flying debris
Steep sloping areas
Falls
Physical exhaustion
Machinery Noise
Uneven terrain

Gains

Improves curb appeal
Ensures long term tree health
Enhanced property protection
Clean forested areas

What do they hear?

Heavy cutting equipment
Trucks running
Workers communicating
Wildlife

What do they do?

Prunes trees
Fertilizes trees
Monitor trees for insects or diseases
Transplanting trees
Removing trees

Thoughts and feelings

These power tools are very loud
Am I properly hydrated?
I hope the weather does not get bad.
I hope i do not fall on this slippery terrain
Today I will be going home in one piece.

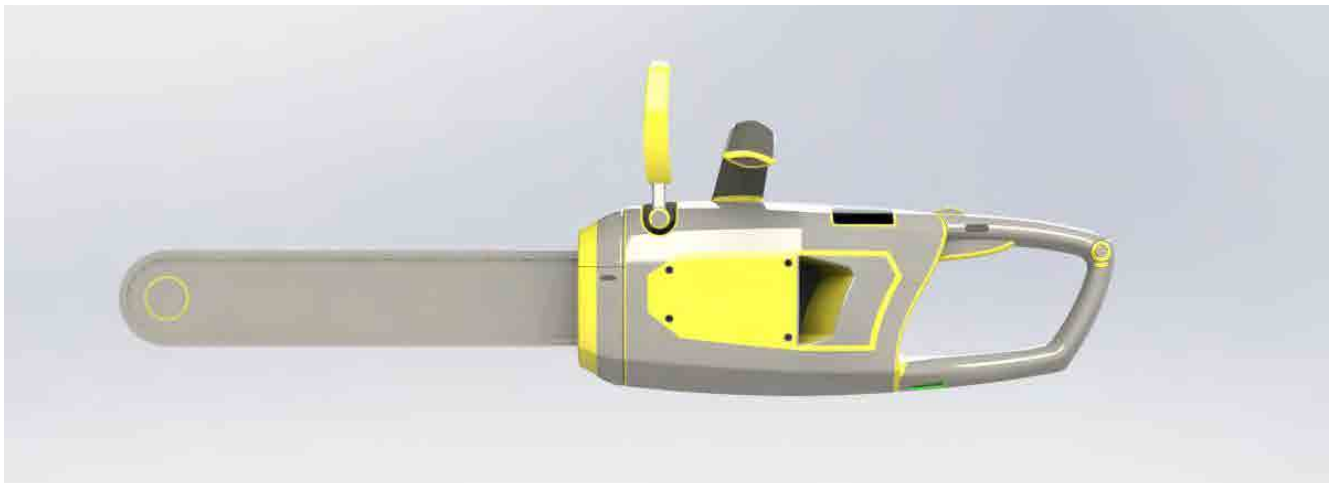
What do they say?

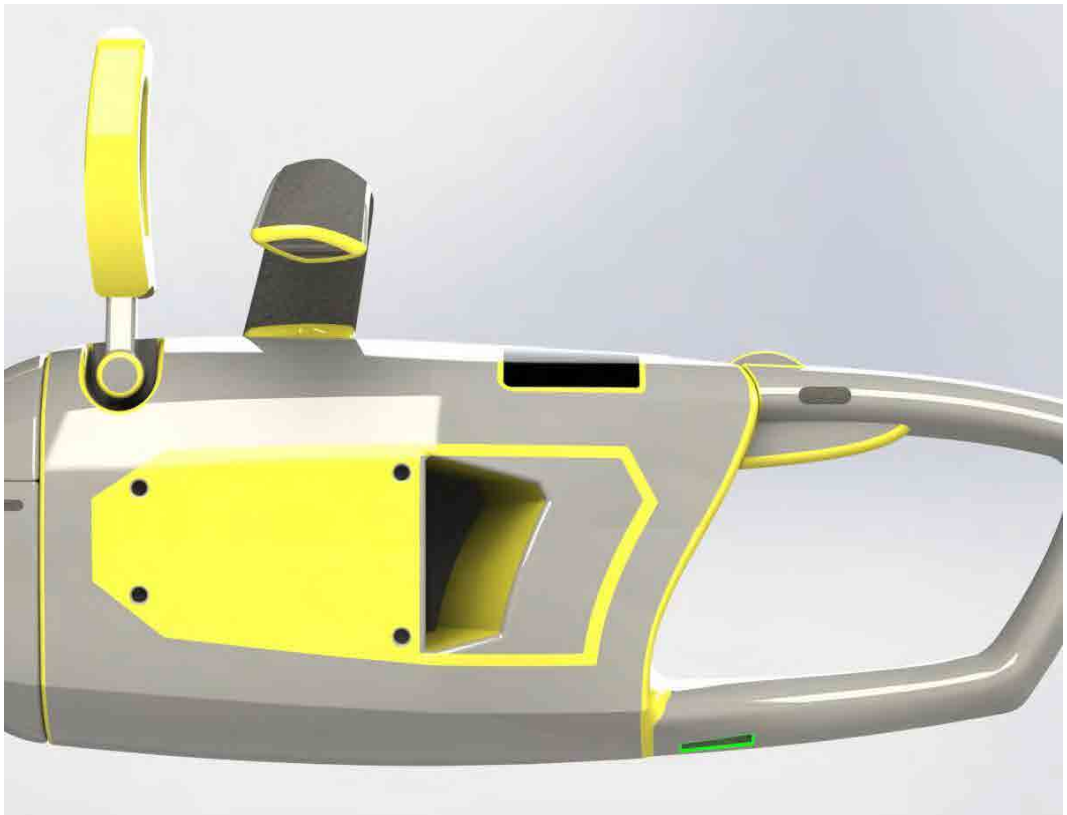
Ensure your gear works before we start
Has anyone inspected the trucks?
Mark out all the potential hazards on the job site
This task is exhausting
The weather is very hot today

My findings based on my interviews included:

- Worker safety is the biggest concern on the job
- Rainy, Snowy weather has a significant negative impact on productivity
- Workers do not have sufficient protection against falling objects
- Rough terrain can cause worker injuries and make it extremely difficult for vehicles to operate effectively
- The most common cause of injury on the jobsite is falling.
- Vehicular vibrations can lead to physical injury in the lower back area

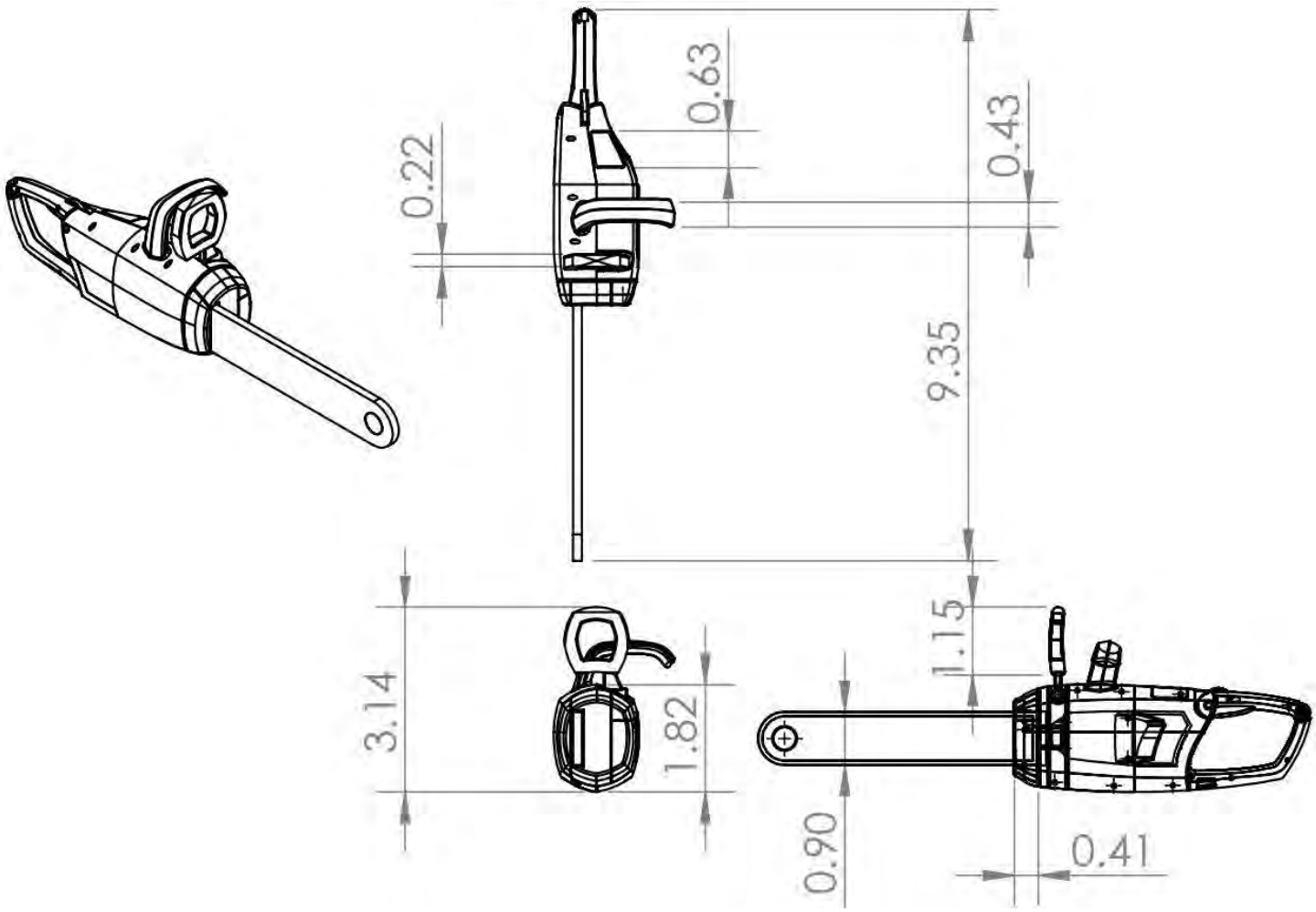
Appendix E - CAD Development






Battery Supply
Shoulder Pads
Battery Status Indicator
Magnetic Power Port

Appendix F – Technical Drawings



Appendix G – Bill of Materials

Parts	Materials	Description	Color	Manufacturing Methods	Cost $
18" Bar	Stainless Steel	Chain guide	Metallic Grey	Laser Cut	$2,500
Chain	Tungsten Carbide Tipped	Material Remover	Metallic Grey	Stamping	$1,500
Oil Reservoir	Polycarbonate plastic	Chain Lubricator	Yellow + Light grey	Injection Moulded	$750
Chain Tensioner	Polycarbonate plastic + Steel	Tension & Timing chain controller	Yellow + Light grey	Injection Moulded + Cold Forging	$750
Electronic Controls	Various	Power & Rotation control	Various	Various	$2,500
Swivel Motor	Iron, Nickel, Cobalt	Power source	Silver	Outsourced	$1,500
Power Motor	Iron, Nickel, Cobalt	Power source	Silver	Outsourced	$3,500
Emergency Brake	Polycarbonate plastic	Safety mechanism	Yellow + Light grey	Injection Moulded	$1,000
Front Handle	Silicone Rubbber	Grip & Control	Black	Extrusion	$1,250
Rear Handle	Polycarbonate plastic + Stainless Steel	Grip & Control	Yellow + Light grey	Injection Moulded + Cold Forging	$2,500
Motor Panel	Polycarbonate plastic	Maintenance	Yellow	Injection Moulded	$750
LED Panel	Clear polycarbonate plastic	Power Indicator	No color	Injection Moulded	$750
Power Connector	Neodyium Magnets	Power Distributor	Light Grey	Powder Metallurgy	$1,000

Power Pack

Parts	Materials	Description	Color	Manufacturing Methods	Cost $
Battery	Lithium Ion Phosphate	Power Supply	Black	Outsourced	$5,000
Lumbar Pads	Memory foam + Nylon	Back padding	Yellow	Outsourced	$1,000
Shoulder Straps	Nylon	Webbed	Yellow + Light grey	Webbing	$500
Chest Strap	Nylon	Securing Straps	Yellow + Light grey	Webbing	$500
Handle	High Density Memory Foam + Nylon	Webbed	Yellow + Light grey	Webbing	$1,000
PowerPack Pack Frame	Polycarbonate plastic	Mounting Frame	Light grey	Injection Moulded	$2,500
Power Cord	Chlorosulfonated Polyethylene + Neodyium Magnets	Power Distributor	Yellow	Outsourced	$500
Power Connector	Neodyium Magnets	Power Distributor	Light Grey	Powder Metallurgy	$1,000
Total					**$32,250**

Appendix H– Approval Forms & Plans

THESIS TOPIC APPROVAL:

Student Name:	Jaaziel Codogan
Topic Title:	How may we improve the safety of forestry workers in Canada?

TOPIC DESCRIPTIVE SUMMARY (Preliminary Abstract)

According to an article published on the Canadian Occupational Safety website, forestry is regarded as one of the most industries in Canada. In 2018 the industry suffered eleven fatalities, one thousand three hundred and twenty-four injury claims. According to an article published by the International Journal of Environmental Research and Public Health extreme weather conditions subject workers to extreme cold and heat conditions which lead to reduced work capacity, heat stress and dehydration. Treacherous terrain and site factors such as slopes and soil types pose serious dangers to workers and lead to machinery accidents. Falling trees and branches and tree hang-ups pose serious risks to workers. The combination of shocks, whole-body-vibration and noises can be generated by both outside and inside sources and are known to have a great impact on worker's comfort. The impact of these vibrations can transfer to the feet through the floor of the vehicle and can lead to vascular diseases in the lower limbs. This thesis proposes an in-depth study of daily processes and challenges facing forestry workers using data collection methods such as observational studies, interviews and surveys. A one-to-one scale ergonomic model would be developed to understand ergonomics and human scale as well as to evaluate the feasibility of the design. A solution will be developed to improve the safety of forestry workers by enhancing their protection in hazardous working conditions and provide workers with a more relaxed working environment.

Student Signature(s):	
Date:	26 / 09 / 2021

Instructor Signature(s):	
Date:	07 October 2021

IDSN 4502
SENIOR LEVEL THESIS TWO

Humber ITAL / Faculty of Applied Sciences & Technology
Bachelor of Industrial Design / WINTER 2022
Catherine Chong / Sandro Zaccolo

CRITICAL MILESTONES APPROVAL FOR CAD DEVELOPMENT & MODEL FABRICATION

Student Name:	Jaaziel Codogan
Topic / Thesis Title:	IMPROVING SAFETY FOR FORESTRY WORKERS

THESIS PROJECT – DESIGN APPROVAL FORM

Design is reviewed and approved to proceed for the following: [X] **CAD Design and Development Phase**

Comment:
- Initial CAD started reasonably well as of week #7/February 22nd. continue with detailing and refinement require to start CAD for the battery pack.
- Refinement CAD progress well as of week #8/March 8th

Design is reviewed and approved to proceed for the following: [X] **Model Fabrication Including Rapid Prototyping / 3D Printing and Model Building Phase**

Comment:
- Once CAD is completed, can move forward to model fabrication from week #9 onward.

Instructor Signature(s):

Date:	8th March, 2022

Chong, Kacpen, Thomson, Zaccolo

Appendix I – Advisor Meetings and Agreement Forms

HUMBER

IDSN 4002 / 4502

SENIOR LEVEL THESIS ONE & THESIS TWO

INFORMATION LETTER

Research Study Topic: How may we improve the safety of Forestry in Canada?

Investigator: Jaaziel Codogan / 647-853-2844 / codogan@gmail.com

Sponsor: Humber ITAL, Faculty of Applied Sciences & Technology (IDSN 4002 & IDSN 4502)

Introduction

My name is Jaaziel Codogan, I am an industrial design student at Humber ITAL, and I am inviting your participation in a research study on various problems that affect the safety of forestry workers in Canada. Forest workers face many hazards including falling trees and branches, falls while working slippery, uneven terrain, heat stress, exposure to extreme weather and musculoskeletal disorders due to moving heavy loads and vehicular accidents. Falling from ground level accounted for 13% of industries in the industry. The results will be contributed to my Senior Level Thesis project.

Purpose of the Study

This study is being conducted as an aid in designing a product that can improve the user's safety while performing tasks on the work site. The product to be designed will be inspired by the numerous safety hazards while working on the job site. With your assistance, I plan to address the safety problems that workers face on a regualar basis in the forestry industry. This study is primarily based on understanding ergonomics, human interaction design activities, and user experience aspects of the research area.

Procedures

If you volunteer to participate in this study, your activities in interacting with a machine/ equipment/ vehicle will be observed and documented. Your activities will be documented by means of a digital camera / video camera while operating the machine/ equipment/ vehicle. You will also be asked questions pertaining to the machine /device /equipment /vehicle and how you use it.

Confidentiality

Every effort will be made to ensure confidentiality of any identifying information that is obtained during the study. In the case of being recorded visually, your face will be masked /blurred or hidden. The information and documentations (photographs) gathered are all subject to being used in the final presentation of the study.

Participation and Withdrawal

Your participation in this study is completely voluntary and you may interrupt or end the study and the session at any time without giving a reason or fear of being penalized.

If at any point during the session, you feel uncomfortable and wish to end your participation, please let the moderator know and they will end your participation immediately.

Humber Research Ethics Board

This research project /course has been approved by the Humber Research Ethics Board. If you have any questions about your rights as a research participant, please contact Dr. Lydia Boyko, REB Chair, 416-675-6622 ext. 79322, **Lydia.Boyko@humber.ca**

HUMBER
Faculty of Applied Sciences & Technology
Bachelor of Industrial Design / FALL 2021 & WINTER 2022

IDSN 4002 /4502

SENIOR LEVEL THESIS ONE & THESIS TWO

INFORMATION LETTER

Conditions of Participation

- ✓ I understand that I am free to withdraw from the study at any time without any consequences.
- ✓ I understand that my participation in this study is confidential. (i.e. the researcher will know but will not disclose my identity)
- ✓ My identity will be masked.
- ✓ I understand that the data from this study may be published.

☑ **I have read the information presented above and I understand this agreement. I voluntarily agree to take part in this study.**

Click or tap here to enter text.		2021-10-21
Jesse Zunti		
Participant's Name	Participant's Signature	Date

Project Information

Thank you very much for your time and help in making this study possible. If you have any queries or wish to know more about this Senior Level Thesis project, please contact me at the followings:

Phone: 647-853-2844

Email: codogan@gmail.com

My supervisors are:

Prof. Catherine Chong, **catherine.chong@humber.ca**

Prof. Sandro Zaccolo, **sandro.zaccolo@humber.ca**