Earthquake Search and Rescue Solution

By

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Abstract

Earthquakes are unpredictable and unpreventable natural disasters that can cause catastrophic damage to cities, and their inhabitants around the world. Mountainous regions are affected greatly by these earthquakes because of their geographical location. Severe damage is caused to communities, and the lives of the people living there are greatly endangered. How can we make rescue missions in these mountainous regions more efficient? Rescue workers undergo tremendous amounts of stress throughout these search and rescue missions. Making their jobs easier and more efficient can result in a greater amount of lives saved by them. An in-depth study on the challenges that these rescue workers face will be conducted. Data will be collected through observational studies, interviews, and surveys. Analysis of this data will focus on improving the efficiency of rescue workers, and eliminating any problems that they currently face.
A one to one model will be developed to better understand proper human factors and full-bodied human interaction design. This study will result in a design solution that will enhance the efficiency of rescue workers, and increase the odds of saving individuals lives who are negatively impacted by earthquakes in mountainous regions.

Acknowledgements

I would like to thank the teaching faculty at Humber, for the wonderful support and guidance they have provided throughout these past four years. Thank you to Catherine Chong and Sandro Zaccolo for being great thesis professors and always believing in the work that we were capable of accomplishing. I would also like to thank my advisor, John Davidson, for his excellent insight into the search and rescue field that led me in the right direction to complete this project. I would like to give a huge thank you to the graduating class of 2021 for their companionship and comradery, and I wish all of you the best as we end our journey through the Industrial Design program. Lastly, I would like to give a thank you to my parents for their constant support and positivity towards my work. Without you, none of this would have been possible.

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Figure 1.1 - Chitrakar, N. Earthquake damage in Khumjung. Retrieved from https://www.pri.org/stories/2016-03-04/nepal-has-yet-spend-billions-dollars-pledged-after-2015-earthquakes

Figure 1.2 - Retrieved from https://www.cnn.com/2016/10/30/world/gallery/italy-earthquake-1030/index.html

1.1 PROBLEM DEFINITION

Earthquake search and rescue workers undergo tremendous amounts of stress and strain during a search and rescue mission. Making their jobs easier and more efficient can result in reduced strain on the job. Ultimately, it will also result in a greater number of lives saved by these workers.

This report will examine how structural collapse workers interact with their tools and equipment, as well as the procedures and techniques they utilize during an earthquake search and rescue mission. The research and content of this report is aimed at developing a design solution that enables structural collapse workers to carry out their missions to be safer, more efficient, and less strenuous.

1.2 RATIONALE & SIGNIFICANCE

To gain an understanding of how rescue workers operate their equipment and carry out their missions, several tools will be used to assemble relevant data and information.

Research questions will be conducted that attempt to better understand the process and steps carried out during an earthquake rescue mission, as well as what tools and techniques are used during these missions.

This thesis will use the following questions, information, and research tools to gather data and information that the final design will be based on.

Questions:	Information areas:	Research tools:
How can we decrease the strain of rescue workers?	Current products used in the industry	Literature review
What procedures to rescue workers follow?	User interaction with tools and equipment	Information search
How can current products be improved?	Target user demographics	Benchmarking existing rescue practices & solutions
What are the current pain points during structural collapse rescue?	Structural collapse rescue procedures	User interview & observation
		Video analysis
		Ergonomic studies

Table 1.1 - Investigative Approach

The data and information gained from these research tools will assist in the development process of a product solution that satisfies the necessary sustainability, ergonomic, and functional requirements of this thesis.

1.3 BACKGROUND, HISTORY, & SOCIAL CONTEXT

Earthquakes are unpredictable and unpreventable natural disasters that can cause catastrophic damage to cities, and their inhabitants around the world. Mountainous regions in particular are affected greatly by these earthquakes due to their geographical location. The damage zones of nine out of ten major disasters in recent decades involve mountainous areas (Hewitt, 1983). Severe damage is caused to communities. The lives of the people living in these communities are greatly endangered.

Rescue workers are assigned anywhere between 6 to 12 hour shifts, depending on the weather and environment. These long work hours can take a toll on the user's body. Between always being on their feet and having to carry around heavy tools and equipment. Combine this with the high stress environment of a disaster zone, these workers undergo a tremendous amount of both physical and mental exhaustion.

CHAPTER 2

RESEARCH

Figure 2.1 - Retrieved from https://m.washingtontimes.com/multimedia/image/ap_3d2baaa3d5f5d712740f6a7067004ca8jpg/

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2.1 User Research

The objective of this thesis user research is to investigate the chosen research topic using scholarly and popular research searchtools. The chosen research topic is analyzing how challenges that rescue workers face during earthquake search and rescue missions can be reduced or solved, in order to enhance the quality of research conducted. To gain an in-depth understanding of this research topic, and the problems that are associated with it, the search tools that will be used include the Humber Library search engine, Library Databases, and Google Scholar. The areas that this research will focus on include benchmarking existing products, understanding user needs, user demographics, user surveys and interviews, as well as a potential full bodied human interaction design analysis.

2.1.1 User Profile/Persona

Figure 5 - Santana, W. Firefighters search for victims. Retrieved from https://www.theatlantic.com/photo/2011/03/japan-earthquake-rescue-recovery-and-reaction/100024/

Name	*Li Feng*
Age	38
Occupation	Rescue Worker
Education	Bachelor’s Degree - Medicine
Family	Married, 1 Child
Location	Taiwan, China
Frequency	Responds to approx. 6 emergency calls/month
Duration	6-12 hour shifts
Social/Solitary	Works in a team with 30 other rescue workers
Other Activities	Cycling, Swimming, Weight Training

Table 2.1 - Fictitious User Profile

A rescue worker persona is developed. This is a fictitious person who fits the relevant demographic, motivations, and background based on demographic research. This persona aims to focus the design intent for the product. A fictional breakdown of the user profile is described below.

“Li Feng is a 38 year old Asian male. He has a bachelor’s degree in marketing and earns a yearly salary of about $54,000. Being a rescue worker is his career, and has been working for 11 years. Li Began his career at the age of 27. He decided to pursue this field because he wanted

to help save the lives of victims who are affected by earthquakes. He takes great pride in ensuring that he can positively impact people's lives. Li Feng is a 38 year old Asian male. He has a bachelor's degree in marketing and earns a yearly salary of about $54,000. Being a rescue worker is his career, and has been working for 11 years. Li Began his career at the age of 27. He decided to pursue this field because he wanted to help save the lives of victims who are affected by earthquakes. He takes great pride in ensuring that he can positively impact people's lives."

According to research, based on firefighter statistics, ages vary greatly. The ages range from 20 years of age, to older than 60. The average age for both males and females is approximately 35-39 years old.

Most rescue workers are male. Males make up about ~75% of the population. While men are very dominant in the field, women also make up a respectable percentage of workers, accounting for an average of ~25%.

Earthquake rescue workers must respond to various different types of emergencies and scenarios which require different solutions. Typically, rescue workers take part in 12 hour rotating shifts when on a mission. Recently, shifts have been reduced to 5-6 hours long. This is to ensure that the rescue workers perform at their best and can ultimately work more hours in total.

A survey of frontline workers during the 2011 Canterbury earthquake shows that the most common level of completed education for these workers is university. Technical college and Secondary school are the next highest completed educations.

Rescue workers need to stay in peak physical condition in order to perform well during their missions. Because of this, these individuals' lifestyles should reflect what their job requires. Rescue workers are extremely active people; they spend time exercising and performing cardio to improve their stamina and strength. These individuals enjoy hobbies with physical activity when they're not on the job.

Earthquake rescue workers can consist of both professionals, and volunteers. It is difficult to identify an income level for volunteer workers as they may not have the same qualifications or experience that a professional would have. They also may not work as many hours as a professional. Rescue worker volunteers can come from many different countries. Volunteers are able to offer valuable physical or emotional assistance, regardless of their various backgrounds. That being said, the average national salary for firefighters is $53,888/year.

Due to the cooperative nature of the job, rescue workers must be very vocal with their partners/ squad. Communication is vital for rescue workers to effectively do their job. When rescuing trapped civilians, rescue workers must be able to effectively communicate the steps of what must be done. Care must also be given when communicating with civilians in danger. They must be kept calm in these high stress situations.

Earthquake rescue workers conduct multiple activities and operations during a rescue mission. Some of these operations include gaining knowledge from locals to help search for survivors, using specialized sound equipment to detect faint noises, using extendable, flexible video cameras to squeeze through gaps in rubble to help locate survivors, and operating heavy machinery such as diggers and hydraulic jacks to shift large amounts of rubble and concrete out of the way. (Nepal earthquakes: How does the search and rescue operation work, 2015).

Personality		Cognitive Aspect	
‘Locus of control’	↑	Technical Skill	↑ ↑
Self-Efficacy	↑ ↑	Pre-req. Content knowledge	↑ ↑ ↑
Changeability	↑		
Uncertainty Avoidance	↑ ↑		

Table 2.2 - Cognitive Importance

Primary User

Primary users can be described as Emergency Rescue Workers, Victims, and Fire fighters.

Secondary User

Secondary users can be described as Engineers, and Civilians.

Tertiary User

Tertiary users can be described as Construction workers, Police officers, and helicopter pilots.

2.1.2 User Observation

The purpose of gathering all this data is to aid in receiving a better understanding of the multiple uses and product scenarios experienced by rescue workers. This research helps to understand why and how they use particular tools and equipment, and the context in which they are used. This information and research will inform the design process for the solution that is being developed.

Rescue workers often work in confined spaces. Because of this, The equipment they use consist of small hand tools and larger power tools. Large machinery such as an excavator or an hydraulic jack is rarely used because of its size, and its inability to be used in small areas. There are also various safety concerns for victims when using large machinery. This is why it is best for a worker to use smaller tools.

User research was conducted in the form of in-person interviews and online user observation with the use of explanatory training videos.

An interview was conducted with John Davidson at the HUSAR (Heavy urban search and rescue) training building in Toronto. John is the Captain of special operations and Coordinator for Toronto HUSAR. John was generous enough to provide a tour of the HUSAR building, as well as sit down and conduct an interview to discuss his career, and what steps go into conducting a structural collapse rescue mission, from planning, to clean up.

Name	**Email**	**Basis of expertise**
John Davidson	John.I.Davidson@Toronto.ca	Captain of special operations & Coordinator at Toronto HUSAR

Table 2.3 - User Interview Contact

Questions were prepared in advance prior to the interview. These questions were aimed at understanding the procedures taken during structural collapse missions, and the techniques and operations performed during these missions.

The questions of this interview were specified towards both the interviewee directly, as well as the rescue worker profession as a whole. Some of the questions asked during the interview are listed below.

1. *What is your career background? And what is your current role with HUSAR?*

2. *What goes into preparing for a structural collapse rescue mission? What steps are taken from start to finish?*

3. *How do you communicate with others during a mission?*

4. *Do you experience any difficulties during these missions?*
5. *Have these missions ever caused you grief, or sadness? What, if anything would help to cope with these feelings?*
6. *Would anything make the job easier or more efficient? Would anything make operations more enjoyable?*
7. *What goes on in your head when carrying out a given plan or task?*
8. *Do you look or listen for anything in specific during rescue missions? How important is audible and visual feedback during missions?*
9. *What is achieved from performing these missions?*
10. *What is most enjoyable about your line of work?*

The questions were asked between the interviewer and the interviewee, John Davidson. The interview was done in a very casual manner. The exact phrasing of these questions changed slightly during the interview. The key takeaways which assisted in developing this thesis solution are listed below. The full interview with questions and responses are located in Appendix B.

Key Takeaways - John Davidson Interview
Structural collapse technicians experience various different types of collapsed building (V, pancake, A frame, etc). They need to know what techniques are required to save victims from every different type. The workers break through rubble and create paths into collapsed buildings to locate and save victims. Breaching into buildings can be done various different ways, with various different tools (Dirty breach, Clean breach, etc).
Secondary collapse is very dangerous for both rescue workers, and victims. Workers need to know how to respond to a potential secondary collapse. Auditory feedback from wooden support structures, and alarms notify workers when they are in potential danger.

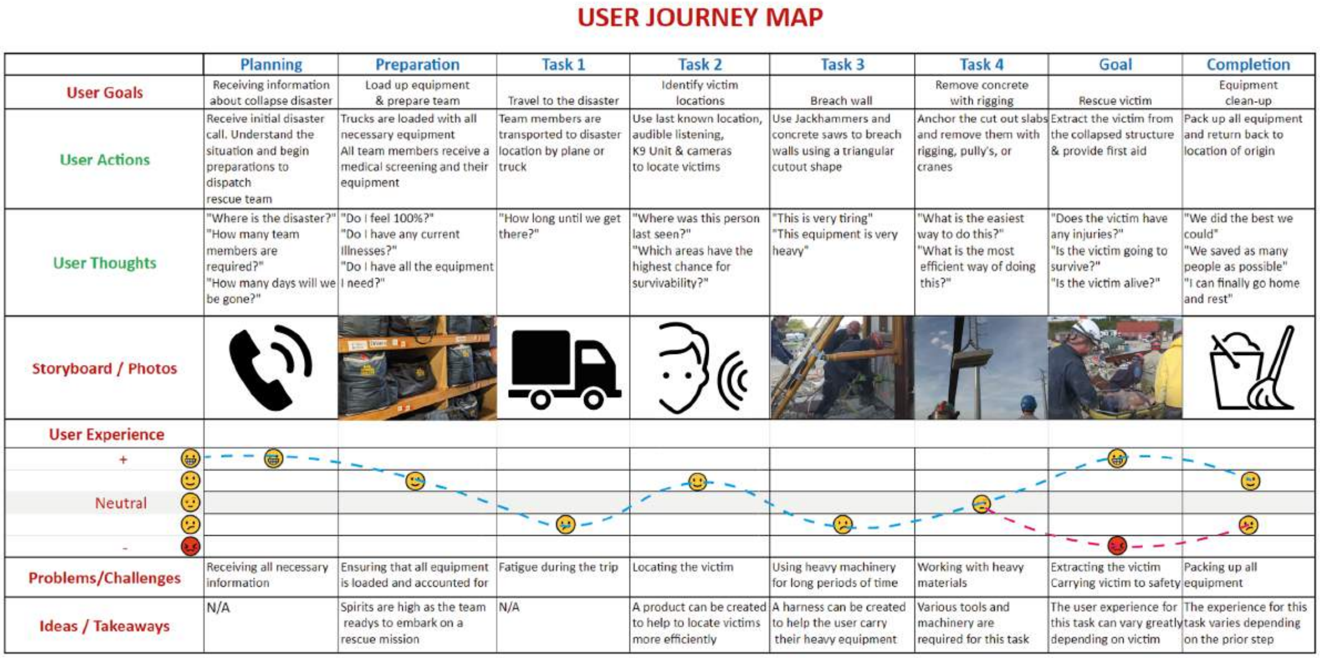
The tools and equipment that rescue workers use are often very heavy and require the worker to exert a lot of energy to operate them correctly. Improving the efficiency of carrying around these heavy tools would help workers to maintain their energy and potentially work longer shifts.
The primary pains during structural collapse missions can include carrying around heavy equipment, high levels of stress, long work hours, little amounts of sleep, and grief/sadness. The primary gains for these missions include saving the lives of people in need, helping to make others' lives better, providing a unique service, and solving complex problems.

Table 2.4 - Key Takeaways

2.1.3 Activity Mapping

Information and data from the activities conducted were gathered and organized to develop potential improvements in the user experience of a rescue worker.

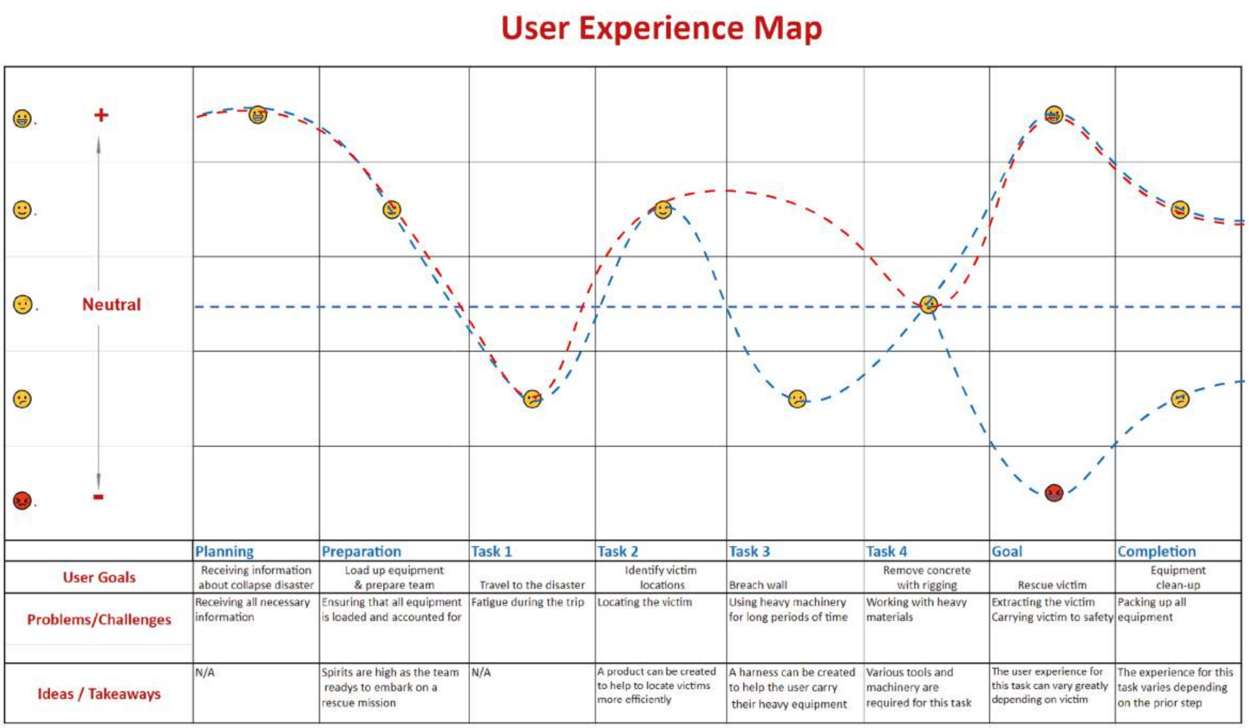
- Receiving initial disaster call - Understand the situation and begin preparations to dispatch a rescue team.
- Trucks are loaded with all necessary equipment. All team members receive a medical screening and their equipment.
- Team members are transported to disaster locations by plane or truck.
- Use the last known locations, audible listening, K9 unit & cameras to locate victims.
- Use jackhammers and concrete saws to breach walls using a triangular cutout shape
- Anchor the cut out slabs and remove them with rigging, pulleys, or cranes.
- Extract victims from the collapsed structure & provide first aid.
- Pack up all equipment and return back to the location of origin.



USER JOURNEY MAP

	Planning	Preparation	Task 1	Task 2	Task 3	Task 4	Goal	Completion
User Goals	Receiving information about collapse disaster	Load up equipment & prepare team	Travel to the disaster	Identify victim locations	Breach wall	Remove concrete with rigging	Rescue victim	Equipment clean-up
User Actions	Receive initial disaster call. Understand the situation and begin preparations to dispatch rescue team	Trucks are loaded with all necessary equipment All team members receive a medical screening and their equipment	Team members are transported to disaster location by plane or truck	Use last known location, audible listening, K9 Unit & cameras to locate victims	Use Jackhammers and concrete saws to breach walls using a triangular cutout shape	Anchor the cut out slabs and remove them with rigging, pully's, or cranes	Extract the victim from the collapsed structure & provide first aid	Pack up all equipment and return back to location of origin
User Thoughts	"Where is the disaster?" "How many team members are required?" "How many days will we be gone?"	"Do I feel 100%?" "Do I have any current Illnesses?" "Do I have all the equipment I need?"	"How long until we get there?"	"Where was this person last seen?" "Which areas have the highest chance for survivability?"	"This is very tiring" "This equipment is very heavy"	"What is the easiest way to do this?" "What is the most efficient way of doing this?"	"Does the victim have any injuries?" "Is the victim going to survive?" "Is the victim alive?"	"We did the best we could" "We saved as many people as possible" "I can finally go home and rest"
Storyboard / Photos								
User Experience								
+								
Neutral								
-								
Problems/Challenges	Receiving all necessary information	Ensuring that all equipment is loaded and accounted for	Fatigue during the trip	Locating the victim	Using heavy machinery for long periods of time	Working with heavy materials	Extracting the victim Carrying victim to safety	Packing up all equipment
Ideas / Takeaways	N/A	Spirits are high as the team readys to embark on a rescue mission	N/A	A product can be created to help to locate victims more efficiently	A harness can be created to help the user carry their heavy equipment	Various tools and machinery are required for this task	The user experience for this task can vary greatly depending on victim	The experience for this task varies depending on the prior step

Figure 2.3 - User Journey Map



User Experience Map

	Planning	Preparation	Task 1	Task 2	Task 3	Task 4	Goal	Completion
User Goals	Receiving information about collapse disaster	Load up equipment & prepare team	Travel to the disaster	Identify victim locations	Breach wall	Remove concrete with rigging	Rescue victim	Equipment clean-up
Problems/Challenges	Receiving all necessary information	Ensuring that all equipment is loaded and accounted for	Fatigue during the trip	Locating the victim	Using heavy machinery for long periods of time	Working with heavy materials	Extracting the victim Carrying victim to safety	Packing up all equipment
Ideas / Takeaways	N/A	Spirits are high as the team readys to embark on a rescue mission	N/A	A product can be created to help to locate victims more efficiently	A harness can be created to help the user carry their heavy equipment	Various tools and machinery are required for this task	The user experience for this task can vary greatly depending on victim	The experience for this task varies depending on the prior step

Figure 2.4 - User experience Map

2.1.4 Ergonomics (Existing Products)

An ergonomic study was conducted using existing tools that are used by structural collapse technicians to breach buildings. These tools include Concrete saws, Spreaders, Jackhammers, and Hammer drills. This ergonomic research will include analysis between 5th percentile females and 95th percentile males.

The products used by search and rescue workers are specifically designed to cut through tough materials. These products are not specifically designed for rescue workers, rather they are originally designed for the construction industry, and are used by rescue workers. These products are not very ergonomic when they are used in environments that they were not originally intended. These tools are primarily designed with functionality as their most important feature.

2.1.5 Safety & Health

Rescue workers are put into disaster environments to do their job. Because of the nature of these environments, there is always danger, however minor, to the rescue worker. Many accidents can occur from mishandling equipment, from exhaustion, or environmental complications. Because of these factors, health and safety of the worker during a rescue mission is of top priority.

Current safety issues with structural collapse include: the heavy weight of equipment, secondary collapse, concrete falling through cutouts, low visibility.

Potential injuries that can be caused include: Muscular strain, fractures, crushing, death. Additional causes for these injuries include user error, exhaustion, machine ergonomics, and environmental complications

The larger and heavier the equipment, the more dangers and safety risks that come with them. Smaller tools do not have much adjustability for different percentiles which can also contribute to muscular strain for the user.

2.2 Product Research

The following section of this report examines various tools and equipment used by structural collapse technicians. The goal is to identify key benefits and features of each item, while also highlighting areas that can be innovated.

10 initial products were initially selected. 4 of these products have been chosen to be analyzed in this report.

Product Name	Product Image	Product Reference
Husqvarna K970-14” Gas Ring Saw		Retrieved from https://desertdiamondindustries.com/products/husqvarna-k970-14-gas-ring-saw
Spreader GSP 5240 EVO 3		Retrieved from https://www.holmatro.com/en/rescue/spreader-gsp-5240-evo-3

Bosch Breaker Hammer BH2760VC		Retrieved from https://www.rona.ca/en/bosch-breaker-hammer-bh2760vc-330009248
Bosch 1191VSRK Hammer Drill		Retrieved from https://www.boschtools.com/ca/en/boschtools-ocs/corded-hammer-drills-1191vsrk-33240-p/

Table 2.5 - Product Benchmarks

2.2.1 Benchmarking - Benefits & Features

The product benchmarking for this thesis relied on retrieving data from products that are commonly used during structural collapse rescue rescue procedures. These products were selected due to their function, and ergonomic attributes which can be innovated upon later in the development process. Using promotional materials provided from these existing products, features and benefits have been sorted and highlighted.

Key Benefits	Key Features
Comfort - Ergonomic Safety - Accident Prevention Efficiency - Less Downtime All Day use Extended Tool Life	Portability Easy access Increased tool speed Decreased Weight Emission Free

Table 2.6 - benefits & Features

2.2.2 Benchmarking - Functionality

The products chosen for benchmarking are used for a variety of different applications.

Each product has its own benefits, but each product has its own specialty use cases.

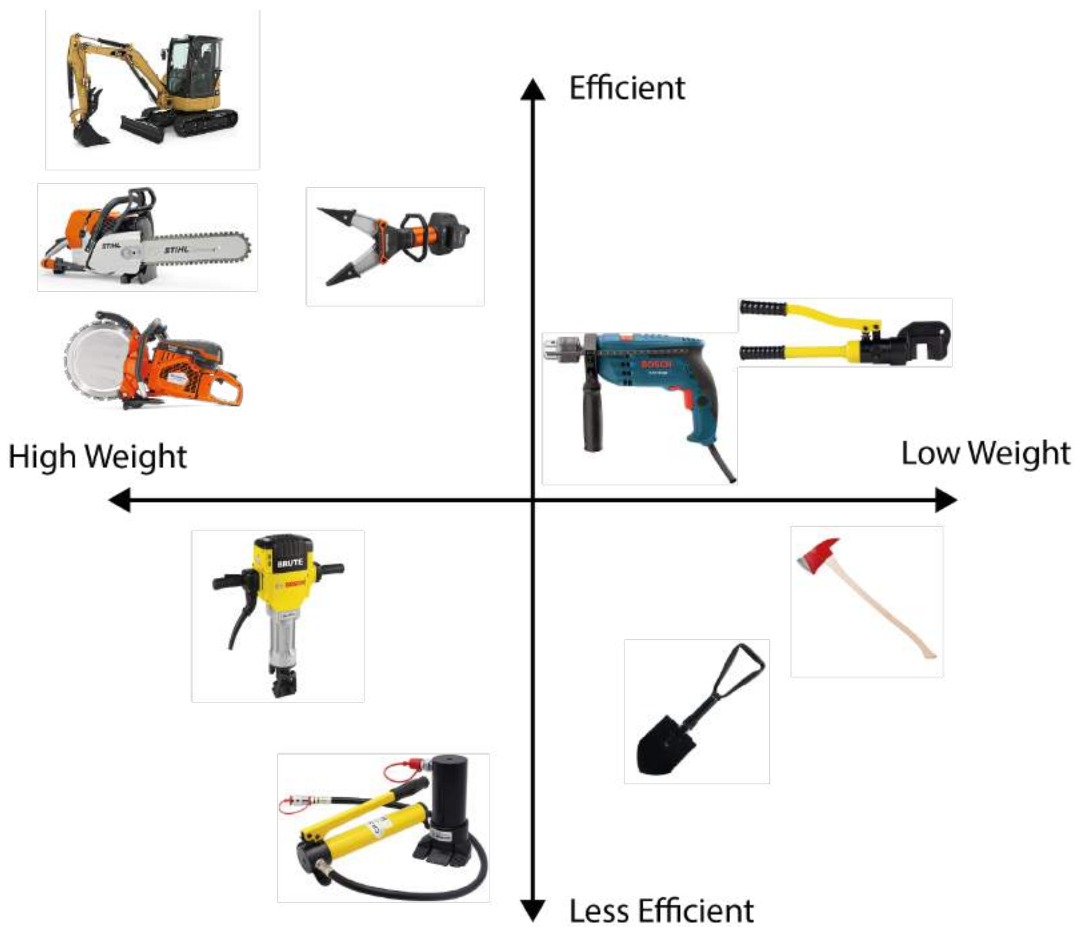


Figure 2.5 - Product Benchmarking Comparison 1

This equipment is used by rescue workers and enables them to effectively break through and clear rubble to reach trapped victims. This equipment offers minimal ergonomics to the user. According to the results from Figure 2.4 below, it is evident that there is a correlation between the efficiency of a piece of equipment, and it's heavy weight. Heavier equipment often tends to be more efficient than lighter equipment. The light weight tools are not as effective because they are not power tools. They do not provide the user with enough benefits to make their work easier. These observations show that there is potential for product innovation to make equipment both highly efficient, and low weight, as well as more ergonomic.

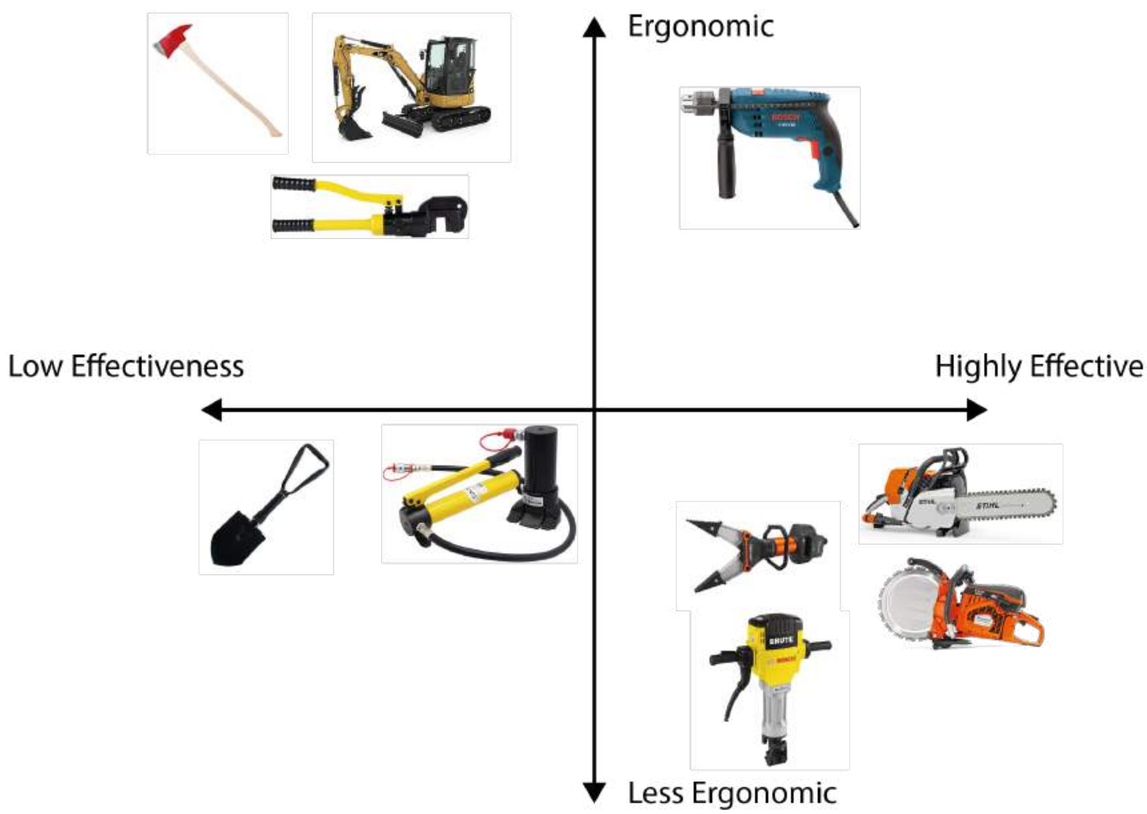


Figure 2.6 - Product Benchmarking Comparison 2

Key Findings

- Potential to reduce weight in equipment
- Durability is important
- Function is more important than ergonomics
- Safety is a top priority

2.2.3 Benchmarking - Aesthetics & Semantic Profile

Shape:

The equipment used by rescue workers is commonly angular and has a rugged styling. Since these tools are used in the construction industry as well, the styling makes lots of sense, as it fits in with the environments that they are used in. They are made to look like they can both deal damage to tough materials, as well as take a beating.

Size:

The size of these products range from small, hand held equipment, to large machinery that is controlled by a worker. The focus of this thesis is on the hand held products rather than the larger machinery. Hand held tools can be categorized into small and light tools that can be carried with one hand, and medium sized heavy tools that require the user to use both of their hands to carry and operate it.

Texture:

The equipment used by rescue workers often has textures that reflect its use scenarios. The handles of a tool, for example, would be heavily textured and have a rough grip so the user can effectively grip it with gloves on, even if the handle itself is dirty or wet. This equipment can also be very heavy and be dangerous if it was dropped. These rough textures prevent accidents like that from happening.

Semantic Profile:

Search and rescue equipment sport an aggressive, rugged appearance. The tools tend to be more geometric, rather than organic. This styling choice also helps to strengthen the tools materials. The materials chosen for these products tend to be high durability. These materials will help to increase the lifespan of the product. Because these products are exposed to a variety of extreme conditions and environments, rescue workers need to be able to trust that their equipment is reliable and can effectively meet the extreme use cases that are required from it.

2.2.4 Benchmarking - Materials & Manufacturing

Materials which appear in current benchmarked products are as follows:

Material	Benefits	Reference
Steel	Durability & Quality Design Flexibility Cost Efficiency Recyclability Low Emissions	https://teampacesetter.com/5-big-benefits-of-steel/
Polycarbonate	High Impact Resistance Versatile 25 Year Life Expectancy Offers UV Protection	https://www.milwoodgroup.com/the-benefits-of-polycarbonate/
High Impact Steel	High Tensile Strength Greater Flexibility Cushioning under Impact Increased Service Life	https://www.allfasteners.com.au/news-articles/driver-bits-the-differences#:

ABS	Impact Resistant Heat Resistant High Tensile Strength Shock Absorbance Scratch Resistance Low Cost	http://www.retlawindustries.com/Info/ABSPlastic
TPU	Extremely High Wear Resistance Resilience Durability Superior Tear Strength High Elasticity Excellent Process Ability	https://www.townsendchem.com.au/what-is-tpu#:

Table 2.7 - Benchmarked Materials Table

Material choice, and the manufacturing processes that go with materials are extremely important for tools that will be used in extreme conditions, such as during a natural disaster. Plastics like ABS are used for the outer shells of equipment. This material provides impact resistance, high tensile strength, shock absorption, and scratch resistance. All of these benefits are incredibly useful for the environment where it will be used. Other plastics like TPU are used for grips on equipment. The extremely high wear, high resistance, high resilience, and high durability provide the tools with a long lasting grip that can take abuse and reliably not wear out over time.

Steel is often used for the internal components of equipment and is the primary reason why equipment often has an extremely high weight. High impact steel is used for the bits that are used to break apart concrete. Its high tensile strength and Cushioning under impact ensure that the bits will not deform or shatter under use.

The steel components of equipment are casted and machined, or stamped, depending on the part being made at the time. These manufacturing processes are done by machine to ensure consistency and accuracy throughout the process. The plastic components are injection molded and then fastened together with screws.

2.2.5 Benchmarking - Sustainability

Equipment used by search and rescue workers is not often sustainable. The equipment that is used sometimes runs off fossil fuels. Recently, more and more of this equipment is converting to electric power. Fossil fuel allows more flexibility as it is easily obtainable in almost any part of the world. As electric batteries continue to improve, so does their usefulness for this equipment. Electric equipment can not be used for longer durations of time, and the power of electric motors can rival the power of a fossil fuel engine.

The primary concern for rescue workers during a mission is safety for both the trapped victims, as well as themselves. In order to achieve this standard of safety, the equipment they use needs to be effective and reliable. To ensure that this equipment is reliable, they are primarily designed to last long and undergo extreme stress.

CHAPTER 3

ANALYSIS

Figure 3.1 - Retrieved from https://news.sky.com/story/mexico-earthquake-who-are-the-hero-moles-of-mexico-city-11046008

3.1 Analysis - Need

Earthquakes cause severe damage and devastation to communities affected by them. Rescue workers work tirelessly to try and save victims from these disasters as efficiently and effectively as possible. These workers require suitable gear, equipment, and training in order to carry out their missions correctly.

Various challenges are faced by rescue workers during these stressful rescue missions. Their success relies on the reliability and usefulness of their equipment.

This section will explore the needs and benefits of existing products, as well as any needs that are not met by existing products. Analyzing this information will help to further develop a potential product solution.

3.1.1 Needs/Benefits not met by current products

Currently, a majority of the equipment used by rescue workers to assist them in structural collapse missions come from the construction industry. Tools such as jack hammers and concrete saws can easily perform their intended tasks. This equipment, however, has issues when it is used outside of a construction environment. The tools currently on the market are very heavy, and have poor ergonomics. This heavy equipment can be difficult to maneuver around a confined area, such as during a structural collapse mission.

3.1.2 Latent Needs

The latent needs of a product are needs currently not met by industry. These needs are also not specifically requested by the consumer. Most consumers do not realize that they have these specific needs. They are underlying desires driven by the fundamental needs that a user forgets about or takes for granted.

Figure 3.2 Maslow's hierarchy of needs Retrieved from https://www.simplypsychology.org/maslow.html

Latent Needs	Benefit Statement
Ergonomics	A potential solution should help the user reduce strain while operating the equipment. The equipment should require the user to use minimal effort to operate.
Safety	The environments in which structural collapse missions take place can be extremely dangerous because of threats like secondary collapse. A potential solution must not create any additional dangers for the user. The user the equipment.
	The first hours during a disaster are the most

Efficiency	important. Rescue workers must conduct their mission quickly, and effectively in order to rescue all trapped victims. A product solution must be efficient to operate. It must have minimal setup time. It must eliminate any time wasted during the search and rescue process.
Styling	Styling of current products on the market are made to be functional, rather than aesthetically appealing. The potential solution should be both functional, without having to sacrifice the aesthetics of the overall product system.

Table 3.1 - Latent Needs Table

3.1.3 Categorization of Needs

After gathering product benchmarking information, and user observations, immediate needs, latent needs, and the desires/wants of the user have been listed below. A solution to these needs will be implemented into a potential product solution.

Immediate Needs

- Decreasing the length of search and rescue missions
- Lighter, more efficient equipment
- Ease of use
- Modularity within product system

Latent Needs

- Ergonomics
- Safety
- Efficiency
- Styling

Wants/Desires

- Increased ergonomics
- Decreased weight
- Increased durability
- Increased maneuverability
- Improved efficiency

3.1.4 Needs Analysis Diagram

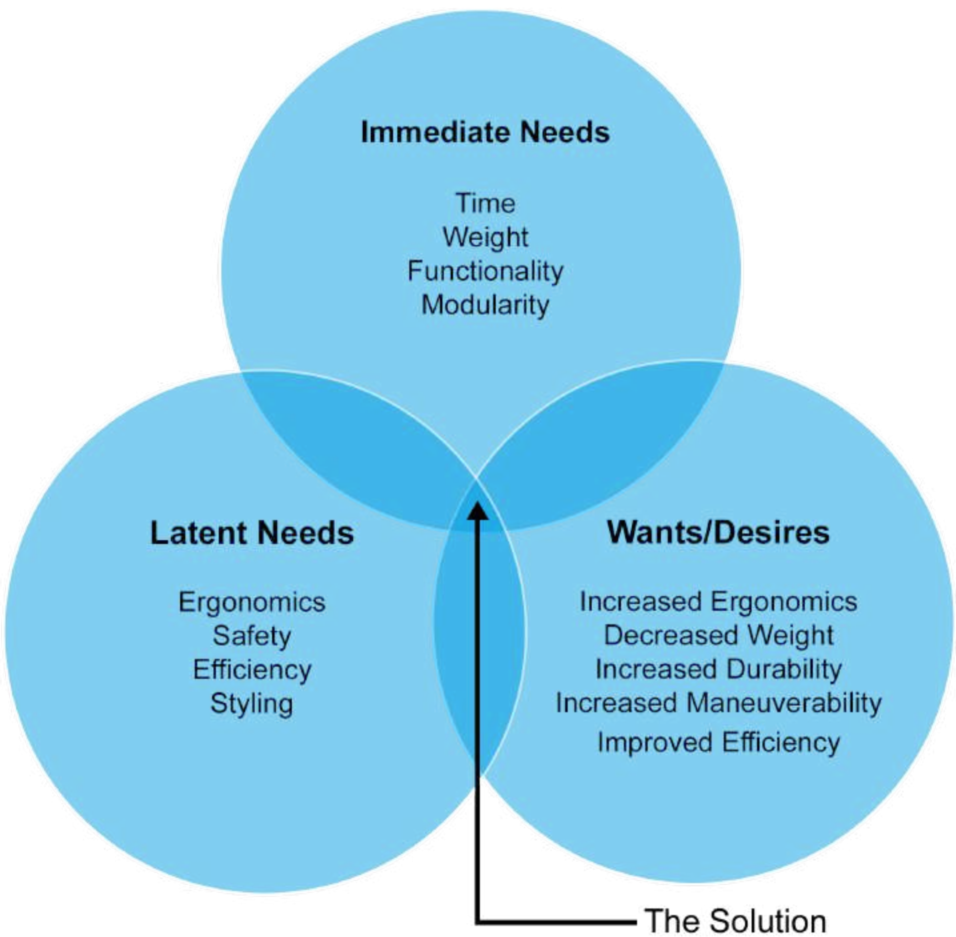


Figure 3.3 - Needs Analysis Diagram

With the use of this needs analysis diagram, a potential solution will be developed by combining the immediate needs, latent needs, and desires. The product solution will take the positive aspects from existing products on the market, and incorporate features that are currently missing from existing products, to create a more efficient and effective product solution.

3.2 Analysis - Usability

This section will analyze the activities and operations that rescue workers conduct during a search and rescue mission. These activities will be used to help with the development of a potential product solution.

3.2.1 Activity - Workflow Mapping

Below is a summary of the workflow of a rescue worker during an earthquake search and rescue mission. The key points during the rescue process are summarized for an easier analysis of activities.

1. Locating Victims with Cameras

2. Breaching the building

3. Removing large slabs with rigging

4. Locating and extracting the victim

Step 1 - Locating Victim with Cameras

The first activity that is conducted during the search and rescue process is locating victims with cameras. Workers also use other techniques to locate victims such as using last known location, audible listening, and K9 units.

Step 2 - Breaching the building

The second activity is breaching the building. Jackhammers and concrete saws are used to breach walls or floors using a triangular cutout shape. Triangular cutouts are made because a triangle is the strongest shape. The breach itself can be done in various different ways such as a dirty breach, or a clean breach. The workers have to ensure that the breach is large enough to carry potential victims through safely.

Step 3 - Removing large slabs with rigging

The third activity is removing large slabs with rigging. Once the cuts for the breach have been created, the large remaining section of concrete is often very heavy, and needs to be removed from the wall or floor. This concrete is removed using rigging. A hole is drilled in the center of the concrete so that it can be anchored. It is then secured and removed with the use of pulleys or cranes.

Step 4 - Locating and extracting the victim to safety

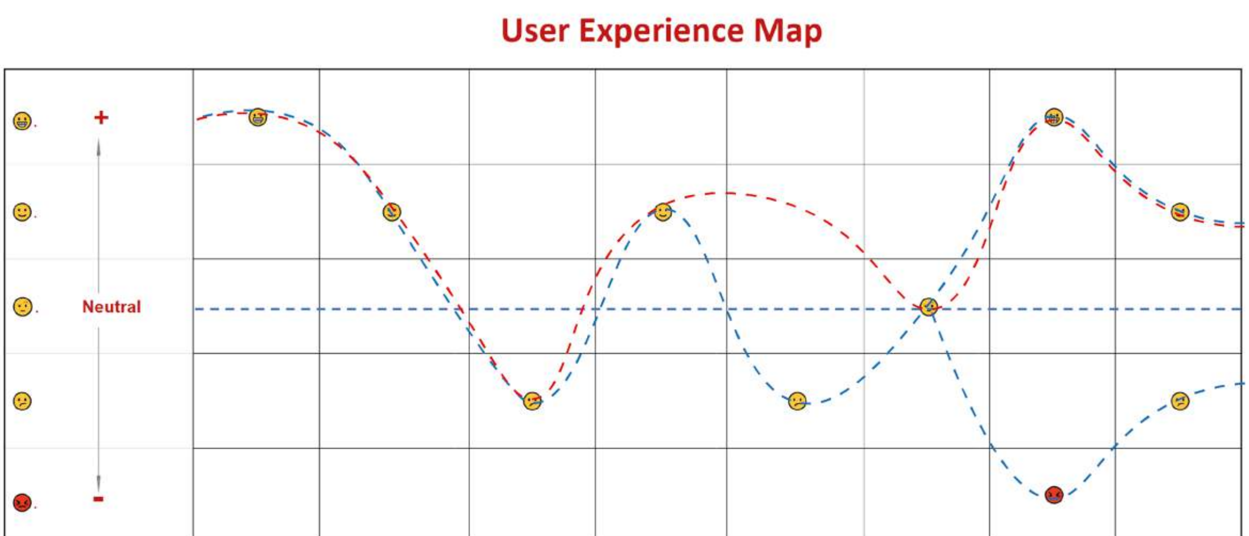
The fourth and final activity is extracting the victim to safety. Once the victim is located within the collapsed building, they are extracted from the building, placed in a rescue basket and removed from the disaster area. Once they arrive at a safe location, first aid is provided, and paramedics are able to assess the victim.

The equipment used during these rescue missions are vital to their success, and the safe recovery of victims. Current rescue workers are susceptible to over exhaustion and injury when working in these conditions. Because of this, there exists an opportunity for a product that can improve these structural collapse rescue missions, and can help to improve the overall experience for the user throughout their rescue process.

3.2.2 Activity - Experience Mapping

Experience mapping was a useful tool in the data analysis process. This data offered a visual representation of where the positive and negative aspects of search and rescue missions are located throughout the process. A user experience map was used to benchmark the average experience/emotion that a user may feel during the activity that they perform. This information can be used to analyze areas that can be improved for the user.

Shown below is a user experience map of a user performing a search and rescue mission, from panning, all the way to completion.



	Planning	Preparation	Task 1	Task 2	Task 3	Task 4	Goal	Completion
User Goals	Receiving information about collapse disaster	Load up equipment & prepare team	Travel to the disaster	Identify victim locations	Breach wall	Remove concrete with rigging	Rescue victim	Equipment clean-up
Problems/Challenges	Receiving all necessary information	Ensuring that all equipment is loaded and accounted for	Fatigue during the trip	Locating the victim	Using heavy machinery for long periods of time	Working with heavy materials	Extracting the victim Carrying victim to safety	Packing up all equipment
Ideas / Takeaways	N/A	Spirits are high as the team readys to embark on a rescue mission	N/A	A product can be created to help to locate victims more efficiently	A harness can be created to help the user carry their heavy equipment	Various tools and machinery are required for this task	The user experience for this task can vary greatly depending on victim	The experience for this task varies depending on the prior step

Figure 3.4 - User Experience Map

The user begins the rescue mission procedure feeling excited. Once the initial call is received, emotions are positive and adrenaline is rushing as these workers prepare to do the job that they have been training for up until this point. Preparation is slow and meticulous but the experience remains positive. Once the travel to the disaster begins, exhaustion starts to set in. The longer the travel, the more tiring it becomes. Once the workers arrive at the event, they begin to feel slightly discouraged from looking at all the destruction that has been caused from the disaster. A rescue plan is conducted, and emotions are positive again. They are anticipated to put the rescue plan in motion.

Once victims are located, the process becomes an emotional roller coaster. It can either be very positive, or very negative for the worker. If victims are found to be alive, emotions are positive. If, unfortunately, the victims are found to be deceased, emotions are negative. The workers begin to think if they could have done anything more to help. That something else could have been done so that the victim could have survived. Once the operation is over and clean up begins, the workers reassure themselves that they did their best and did as much as they were able to do. Sometimes not everyone can be saved, and they have to accept the outcome. Emotion for the completion phase of the search and rescue process are relatively neutral.

3.3 Human Factors

The tools used by rescue workers during structural collapse missions are often very heavy and cumbersome to transport and operate. These drawbacks can lead to unwanted physical stress and strain for the user. This report is an ergonomic study for a potential product that can solve the problems of the tools currently used by rescue workers. This solution is a harness worn by a user to help support the heavy tools that they operate and reduce overall stress on the user's body.

A secondary component to this product is a robotic assistant that follows the user around to carry any additional tools and equipment required for the rescue mission. This will further help to reduce strain on the user's body because they are able to bring additional tools along with them, without needing to carry them on their person. This report will focus on the ergonomics and user experience of this product during a rescue mission.

Literature Review:

The anthropometric data that will be referenced in this report is sourced from "The Measure of Man and Woman" (Dreyfuss & Tilley, 1993). The dimensions for a 95th percentile male and a 5th percentile female will be utilized in this report. These dimensions will be used to identify required ergonomics for this product. Measurements for existing rescue tools were analyzed for how they are held, and how they interact with the user. The mechanisms for how the various support arms on the product work is sourced from "Adaptive Gravity Balancing Arm Systems" (Upadhyay, 2016). Information was also received from a 1:1 scale physical ergonomic buck that was created to see how this product would be operated in real life.

Methodology:

The ergonomic evaluation and analysis of the proposed earthquake search and rescue solution was conducted with the following considerations:

Objective: To identify the ergonomics of operating rescue breaching tools and understand the range of movement that a user has access to while operating these tools. This analysis will help to better understand the points of contact between the user and the product. It will also help to identify three areas of the body to meet the requirements of full-bodied human interaction design. (Kappen, Chong & Zaccolo, 2020).

Decisions to be made: In order to provide the best positive ergonomics for a user, the following user interactions are analyzed in this report.

1. Functionality

2. User posture/ergonomics

3. Ease of understanding/use

Description of target product audience:

The primary users for this product are earthquake rescue workers that take part in structural collapse rescue missions and breach collapsed buildings.

- Age for the user can range from 20-60 years old.
- Most of the demographic is male, making up approximately 75% of the population

Evaluation Process:

The evaluation process involved building and testing a 1:1 scale ergonomic mock up of a tool support harness to investigate how a user would interact with it. This model was primarily Constructed with cardboard, foam core, tape, and glue. This model allowed for critical observation of the following:

1. Observing how a user puts on and takes off the support harness

2. Observing the range of motion the user has while wearing the support harness

3. Observing how the harness will fit different percentile users

4. Analyzing how easy or difficult the harness is to understand and use

5. Identifying any issues the user may have with the product

Description of user observation environment used in this study:

The 1:1 scale ergonomic buck was built in Etobicoke, Ontario. A male was used as a figure in the study. Due to COVID restrictions, a 5th percentile figure was unable to be used for the ergonomic buck observations.

Location and Timeframe:

Date of Observation(s): January 11, 2021 - January 16, 2021

Location of Observation(s): Etobicoke, Ontario

Results:

The results of the ergonomic analysis are shown below. Ergonomic diagrams were created using dimensions of a 95th percentile male and a 5th percentile female. These dimensions are retrieved from The Measure of Man and Woman" (Dreyfuss & Tilley, 1993). These two human percentiles represent the largest and smallest possible user to interact and operate this product. The 1:1 scale analysis was conducted using a male figure.

Analysis:

Ergonomic Drawings:

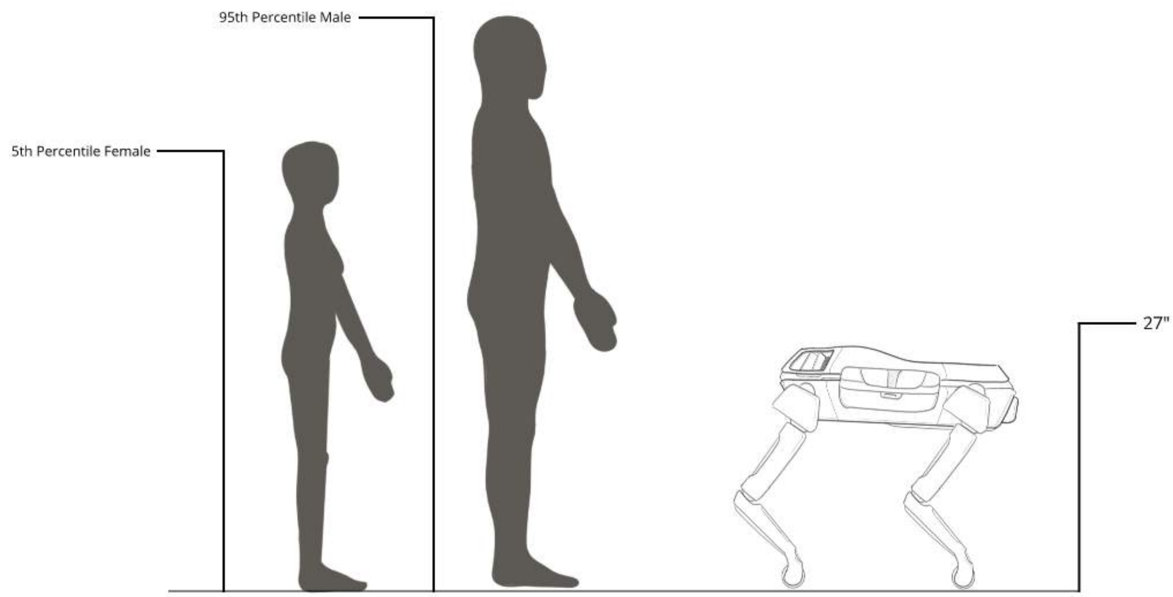


Figure 3.5 - Robotic Walker Height

The robotic walker is 27” at walking height. This height allows the user to easily access all compartments and tools located on the robot without needing to bend over or apply any unnecessary stress or strain to their bodies.

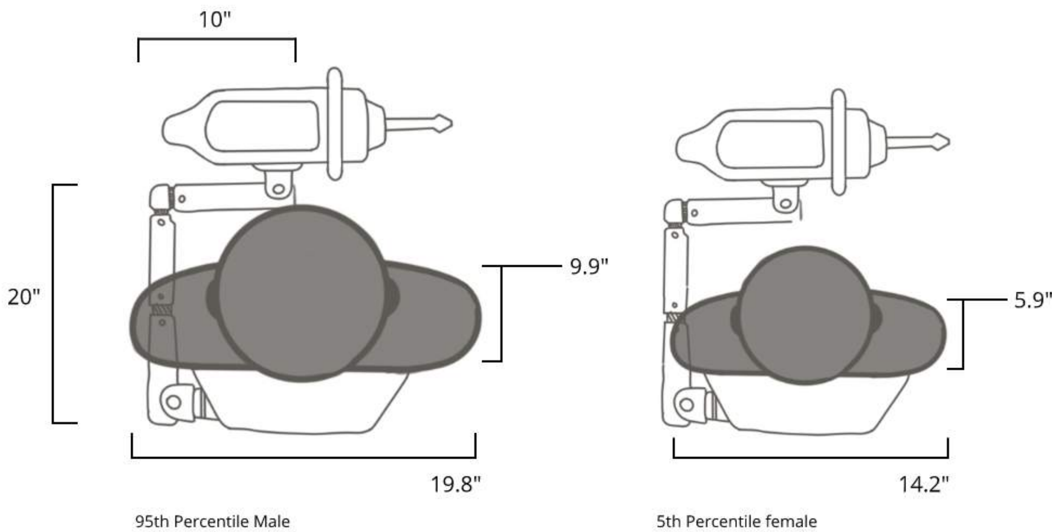


Figure 3.6 - Tool Support Arm

The tool support arm assists the user in carrying heavy equipment and removes unwanted strain from the user's arms. The arm allows the tool to remain in a static position when both in use and not in use. There are multiple joints on the arm that allow the user to position the tool in any way they need to.

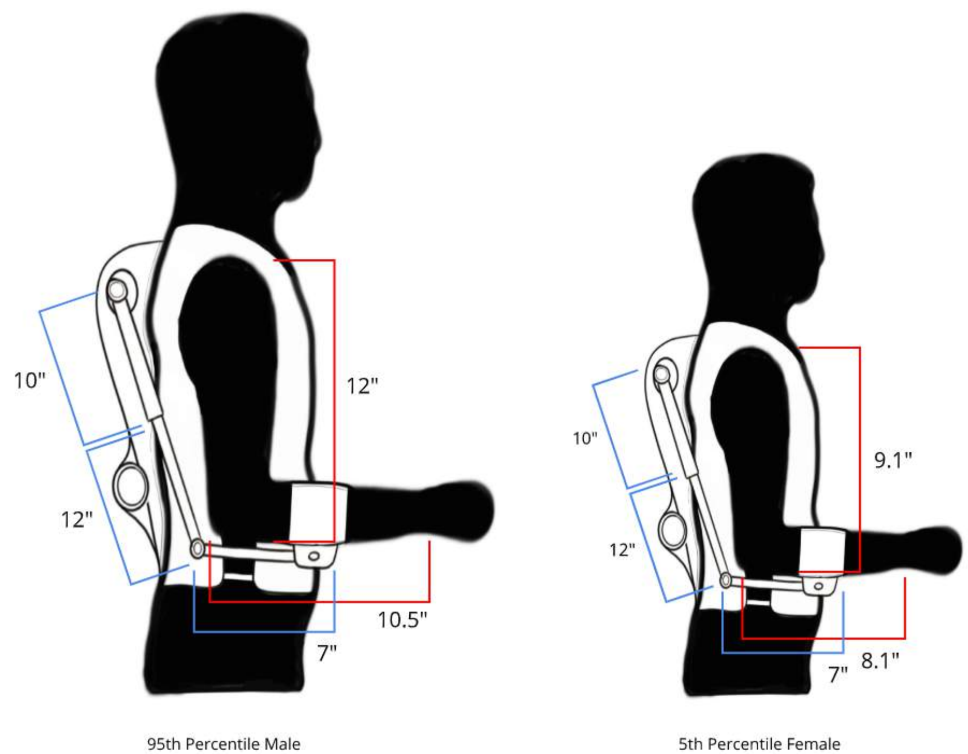


Figure 3.7 - Arm Support Bar

The arm support bar helps to relieve stress from the users arm when carrying heavy equipment. The support bar can extend and compress depending on the length of the user's arms. The bars allow the user's arm to achieve a full range of motion. The bars are articulated and can easily be manipulated depending on the needs of the user.

Ergonomic Buck Interaction:

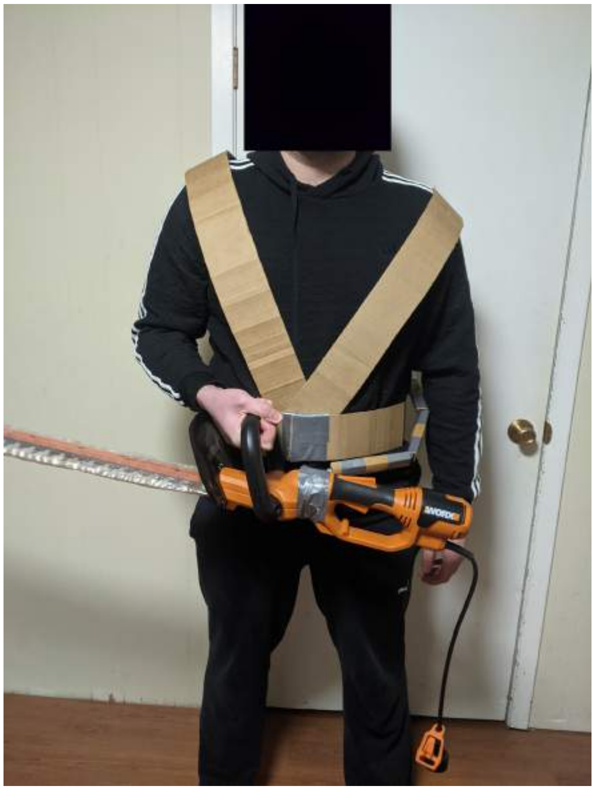
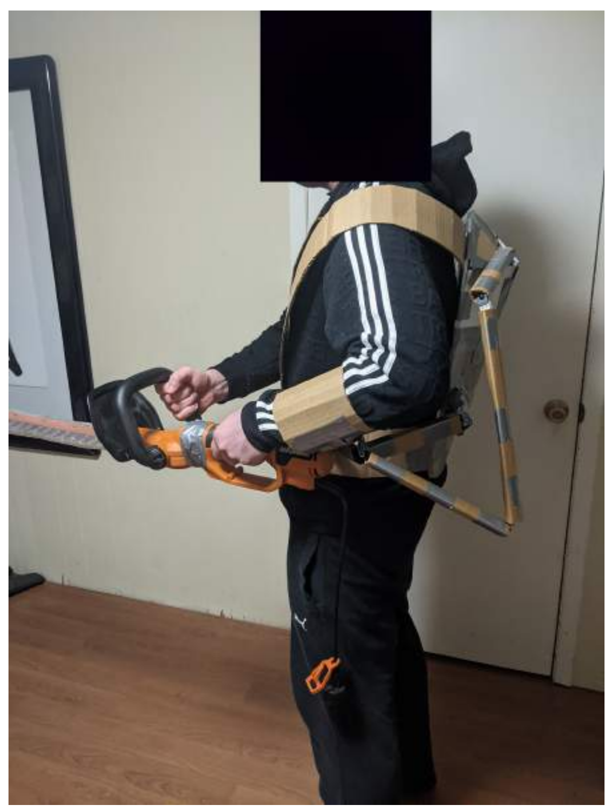


Figure 3.8 - Buck Front View

The tool support harness allows the user to comfortably carry their equipment with one hand while the rest of the tool is propped up and supported by an articulated arm

Figure 3.9 - Buck Side View



The tool support arm can swivel to the side in order to position the tool to be used for breaching. The arm can assist in reducing vibrations and strain from operating the tool

Figure 3.10 - Buck Back View

Braces are attached to the user's forearms and a support bar connects the braces to the support harness. The support bar can expand and contract to fit a wide range of percentiles.

Figure 3.11 - Tool Support Arm

The tool support arm tucks beside the user's body. The arm can be angled upwards and downwards to accommodate for the height of the user.

Ergonomic Buck Analysis:

The ergonomic buck built for this study was very helpful in identifying and getting an understanding of the ergonomics of this product and how a user would interact with it. The model helped to identify errors and problems that need to be revised in the design as well. This model assisted in discovering the correct dimensions and proportions of the product so that it can be used effectively from users between the 5th percentile female, and 95th percentile male range. The model was able to provide a rough demonstration of how the supporting armatures will move and be used in the final product.

The creation of a 1:1 scale mock up for the proposed design direction helped to pinpoint the key features of the product. The building process of the model helped to identify which areas the design needs further refinement, and potential ways that they can be improved. The support bars for the users arms is the feature that requires the most attention during the next phases of the design process. The overall shape and construction of these bars must be altered to offer the user with a greater range of mobility and freedom. These bars are connected to the bottom side of the user's forearm. This ensures that the bars do not get in the way and interfere with the surrounding environments, as they are primarily hidden behind the users arms.

The tool support and arm support bars were the most challenging components to construct during the building process of the 1:1 scale ergonomic buck. It was difficult to get these components to hold their shape. A potential solution and mechanism that can be used for these support arms for the final product are spring-based gravity balancing arms. This type of mechanism is commonly used in robotics and works similarly to desk lamp stands, using springs to maintain rigidity in a mechanical arm under load.

The back of the harness is a hard shell that can assist in keeping the users posture straight during usage. The use of heavy machinery can often cause users to slouch their backs forward. The back side of the harness ensures that the back of the user will always be straight and have correct posture while the product is being used. By reducing the level of stress on the users back, it can help prevent various musculoskeletal injuries to the user.

The final component to this product, that was not created in 1:1 scale is the robotic assistant. The height for this assistant was made to be easily accessible by various types of percentile users without having to bend over drastically, or create any unwanted strain to their bodies. This robot can raise or lower its height in order to be as convenient as possible for the user to reach the required equipment and tools that it is carrying. With the possibility of interchangeable tool heads that can be quickly swapped from the robot itself, it is important that it can be easily accessible from every direction and reduce the workload of the user as much as possible.

Overall, this 1:1 buck analysis was beneficial in the development and design process for this product and helped to reinforce the user ergonomics required for this product to work effectively. The building processes and materials used for the model were quick and affordable. This allows for rapid changes to the model to fix any potential issues. All these results will help to positively assist in the refinement of this product as the development process continues.

Limitations and Conclusion:

Overall, the study of this ergonomic buck was a success in laying the groundwork for the ergonomics and human interaction of the final product. Due to the limitations of the building materials used, the model was unable to incorporate certain aspects that will be required for the final design. The limitations identified in this study are listed below.

1. The tool support arm can include additional articulation for a greater range of mobility for the user
2. The overall dimensions of the product can be adjusted to be more compact and streamlined
3. Supports need to connect to the users arms more securely. Overall support bars need to be more sturdy

Ergonomic Issues Not Yet Resolved

The ergonomic buck provided a lot of good information in regards to the ergonomics and human interaction of the product. However, there were some issues that were unable to be resolved because of model limitations or the need for further design development. One of these issues is that the product in its current configuration does not provide the full range of articulation that can be possible. This issue is primarily reliant on the quality of the model but will also need some further design development to refine. Another issue is the overall size of the product. Depending on the materials and manufacturing methods used on the final design, it can be much smaller and be less obtrusive from the user when it is in use. This issue is also related to model build quality, and can be refined further throughout the rest of the design process.

Alternate Possibilities for the Future

Based on the ergonomic buck built for this study, alternate options that can be explored in the future are as follows:

1. Additional articulation and range of motion in the support arms of the product
2. Size reduction, minimizing the overall footprint of the product

This ergonomic study was very useful in identifying how this product will interact with a user, and any potential problems that may occur during the development of the final product design. This study was helpful in establishing the wide range of motion required from every component of this product in order for it to be effective and easy to use. The findings from this study will be greatly analyzed and developed further throughout the ongoing final design process.

3.4 Aesthetics & Semantic Profile

The aesthetic style of this solution will be similar to the style as the previously listed benchmarked products in Chapter 2. Current heavy rescue equipment on the market sports a rugged, aggressive appearance. Existing products all have similar aesthetic considerations and styling that will be implemented into the final design for this solution. These existing products are marketed through advertisements and websites as rugged, all environment equipment. These products are often very geometric in appearance. These tools are not often organically shaped. These tools also use a variety of bright colours for their exteriors. Bright colours are often chosen so that they are highly visible in the work area, and easy to identify. The colours of these tools are also often the primary colour used by manufacturers for their entire line of tools. For example, DeWalt tools are all yellow, Hilti tools are all red, Bosch tools are all blue. These colours give the manufactures an identity in the marketplace. By seeing the colour of the tool, the manufacturer is instantly recognizable.

3.5 Sustainability - Safety, Health & Environment

Sustainability is extremely important in the heavy rescue equipment industry. The safety and health of the workers is a top priority during rescue missions. The tools that these workers operate need to be safe and not put individuals in danger. The environment for structural collapse rescue is already extremely dangerous for both victims and rescue workers. The tools used must increase the safety of both parties, and avoid any potential dangers.

Safety:

The primary function of this product system is to improve efficiency and safety during earthquake search and rescue missions. That being said, the safety of the user, as well as the victim is a top priority. The various support arms on the tool harness are designed to prevent the user from supporting the weight of heavy equipment using their arms alone. The support arms allow the user to conserve their energy so that they can work for longer periods of time without running out of strength, as well as prevent potential injuries. The robotic carrier follows the user around and can efficiently carry multiple tools and equipment that are vital for the search and rescue mission. This prevents the user from having to make multiple trips to retrieve different tools. This also prevents the user from having to carry multiple tools on their person. This will decrease the amount of weight the user needs to carry around, and ultimately allow them to work safer and more efficiently.

Health:

The primary factors that affect the health of the user are the ergonomics of the tool harness and the robotic carrier. It is important that this product system can be used comfortably by any percentile user. The straps that secure the tool harness to the user are all adjustable to comfortably accommodate various heights and body shapes. The support arms of the harness are also all adjustable to accommodate for various shoulder widths and arm lengths. The robotic carrier also provides an ergonomic user experience. The robot can increase or decrease its height so that the user can comfortably access all the items on the carrier without having to bend down or produce any unwanted strain on their bodies. The dimensions that were used to determine the height adjustability were retrieved from Henry Dreyfuss' *Measure of Man and Woman.* The ergonomics of this product system are an important factor to ensure proper health for the user. If the user is able to comfortably operate the product it will result in less potential injury or over exertion. In the high stress environment of an earthquake rescue mission, every detail is important to ensure that the mission can be carried out successfully.

Environment:

With the increasing rate of climate change over the past few years, more importance and urgency is being put on companies to create their products in a sustainable, environmentally friendly manner. The material and manufacturing processes chosen for this product aim to help create a sustainable future by reducing energy consumption and reusing recyclable materials.

3.6 Feasibility & Viability

Commercial viability is another important aspect in the heavy rescue equipment industry. Understanding the market potential, as well as the cost of materials and manufacturing are both extremely important to ensure that a solution would be viable in the current market place.

Materials were chosen that are suitable for the products intended work conditions, while also being recyclable and friendly to the environment. The manufacturing processes were chosen to be sustainable and to utilize recycled plastics and metals. The design of this product allows the user to be comfortable and safe when carrying out their rescue mission. By creating an ergonomic user experience, it can help the user to remove any unwanted strain on their bodies during their stressful job.

3.7 Design Brief

The objective of this thesis is to develop a product that will improve the efficiency or earthquake search and rescue missions through the use of full body interaction design. This product will assist rescue workers breach collapsed buildings and retrieve trapped victims more efficiently. The following is a list of 10 needs that the product will encompass.

Ergonomics

- The solution can be used by all users between the 5th percentile female and 95th percentile male.

Efficiency

- The product is efficient to use, with minimal downtime during its usage.

Durability

- The product is built to be impact resistant and withstand the harsh environments where it is used.

Mobility

- The product can traverse different kinds of extreme terrain. It will reduce the strain of the user.

Functionality

- The product will perform the functions for its intended tasks, while having functionality for different tasks.

Feasibility

- The product will be realistic to manufacture.

Sustainability

- The product will incorporate sustainable materials and use environmentally friendly energy sources.

Styling

- The product will incorporate visual appealing aesthetics without compromising function.

Effectiveness

- The product will have greater effectiveness than current products on the market.

Versatility

- The product will be versatile and be able to perform various tasks.

CHAPTER 4

DESIGN DEVELOPMENT

4.1 Idea Generation

This chapter will cover the design development stages taken that led up to the final design for the earthquake search and rescue solution. Sketching and model making were used to develop the concept and arrive at the final design in accordance to the design brief.

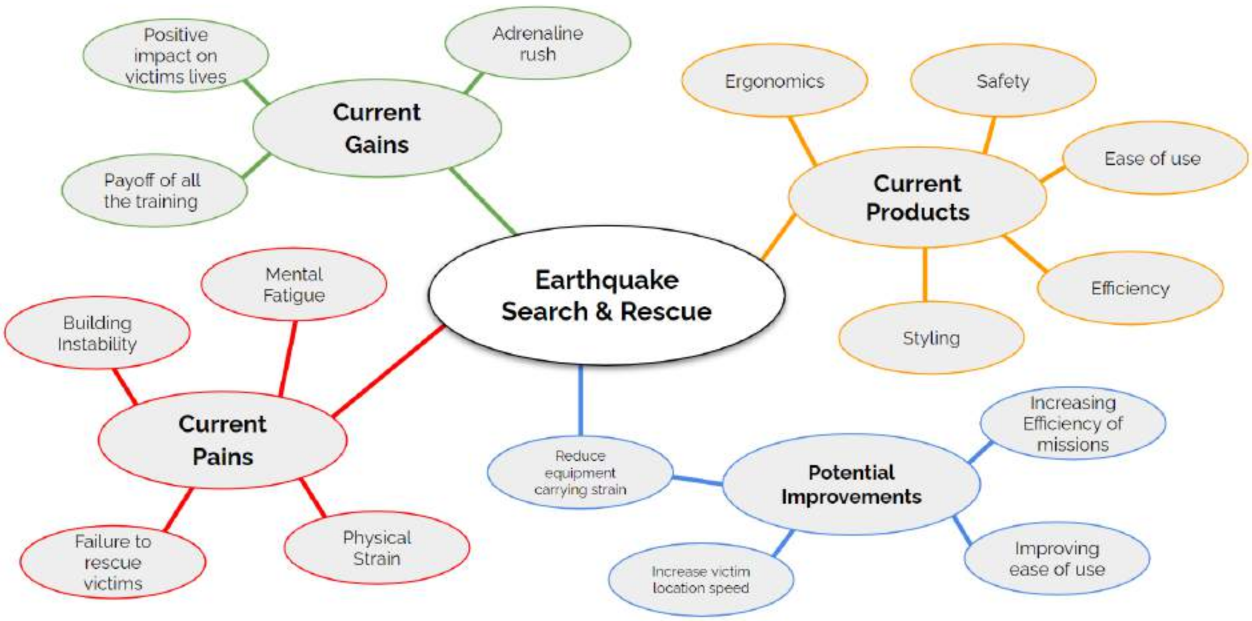


Figure 4.1 - Earthquake Search and Rescue Mind Map

Figure 4.1 describes the mind mapping and exploration taken to identify key pains and gains for existing products within the earthquake search and rescue field. This information was then used to inform the design development and give the concept a general direction to head in.

4.2 Preliminary Concept Exploration

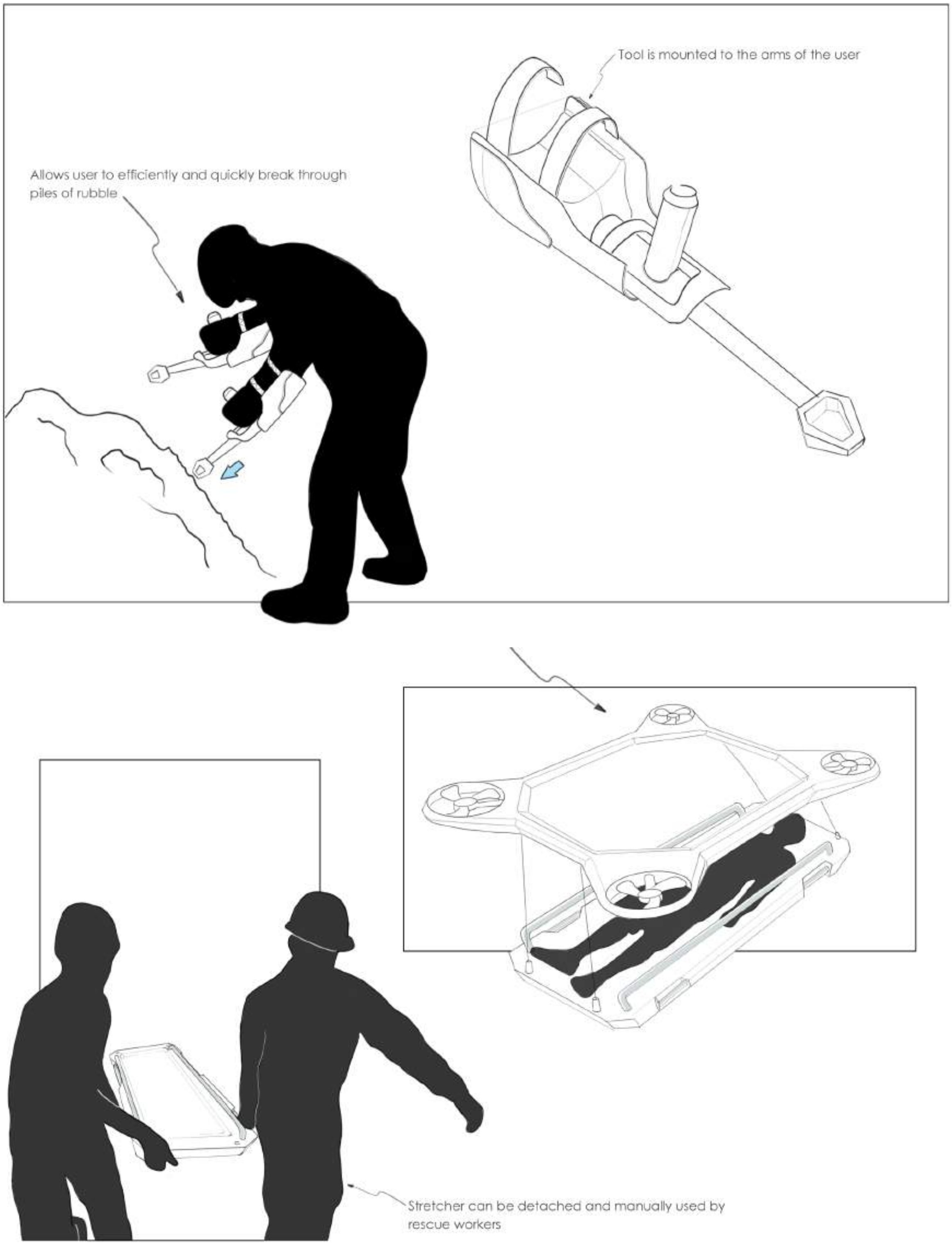


Figure 4.2 - Earthquake Search and Rescue Concept 1 & 2

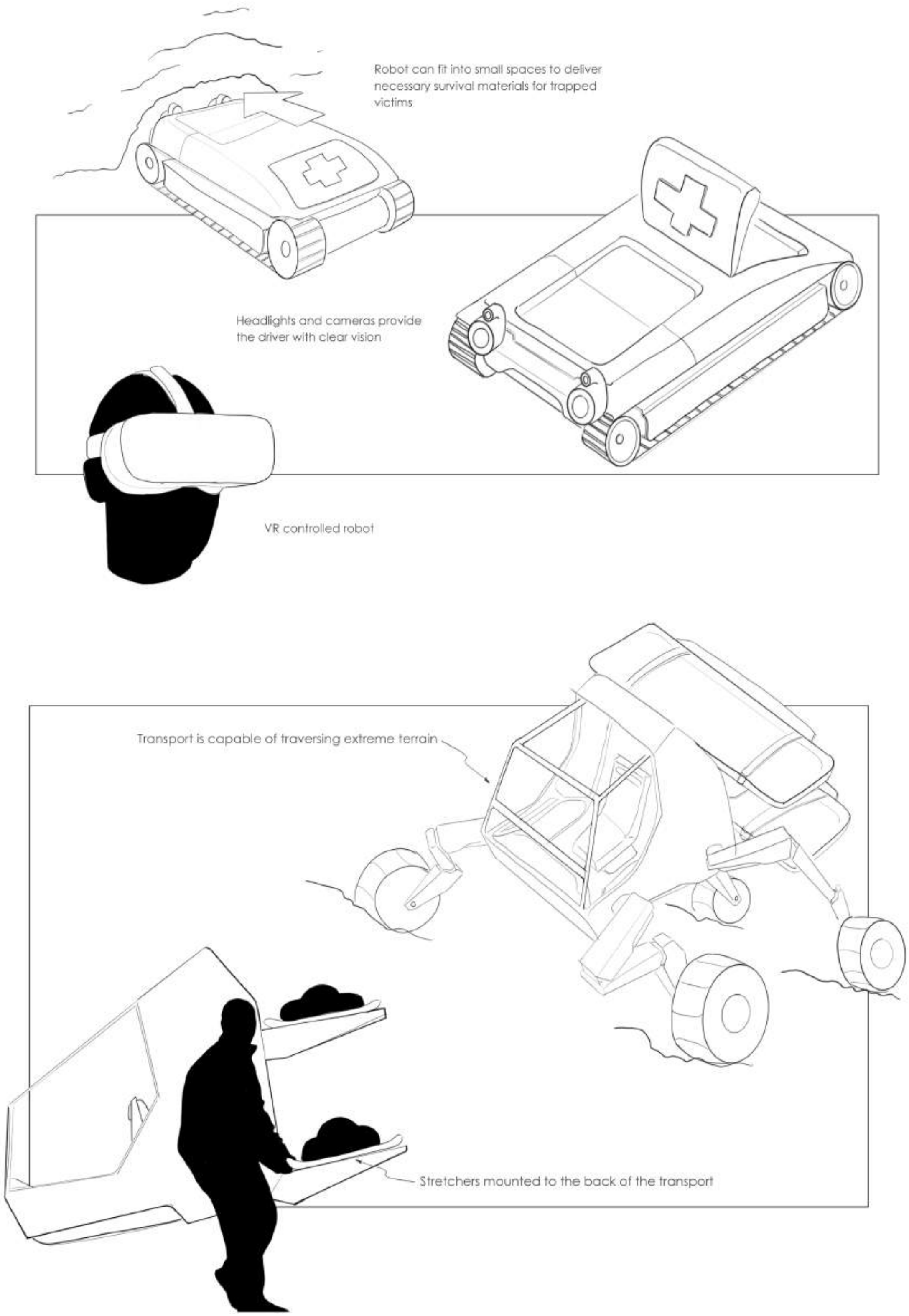
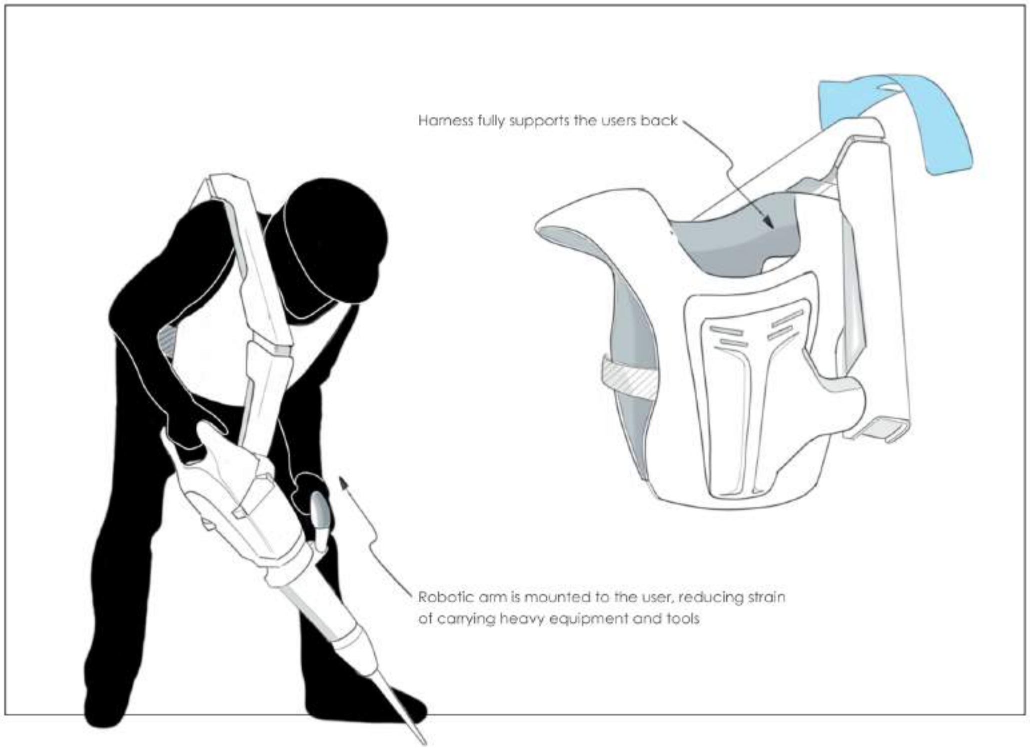


Figure 4.3 - Earthquake Search and Rescue Concept 3 & 4



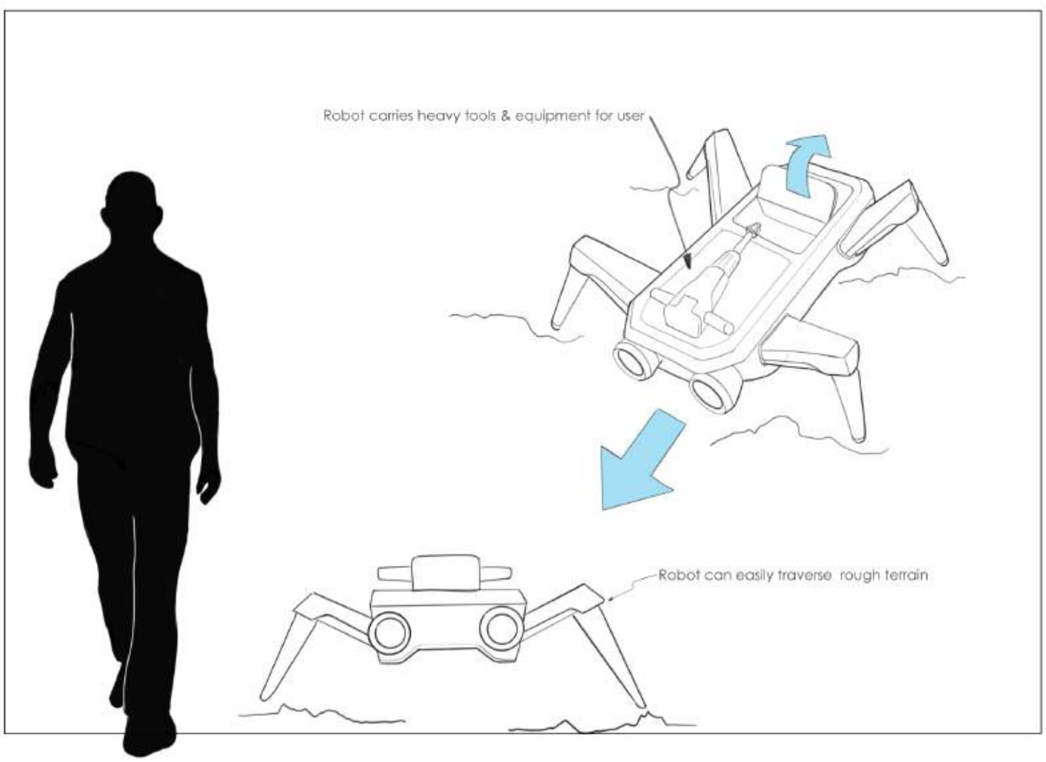


Figure 4.4 - Earthquake Search and Rescue Concept 5 & 6

The initial concept exploration helped to understand the environment and situations the final design would be associated with. Various different possibilities were explored, primarily revolving around robotics and victim retrieval during the earthquake search and rescue process. These concepts were further developed during the concept refinement phase.

4.3 Concept Strategy

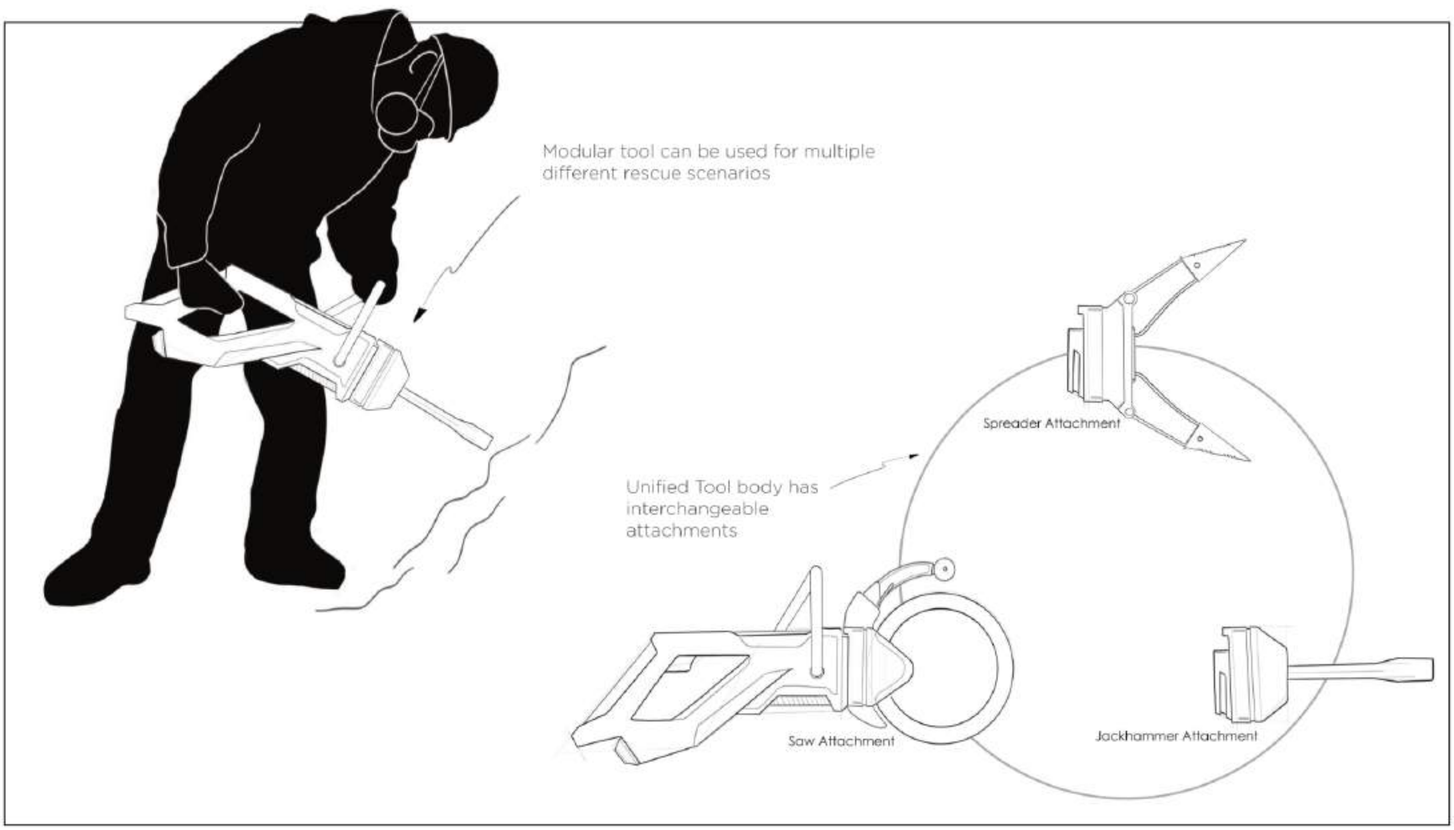
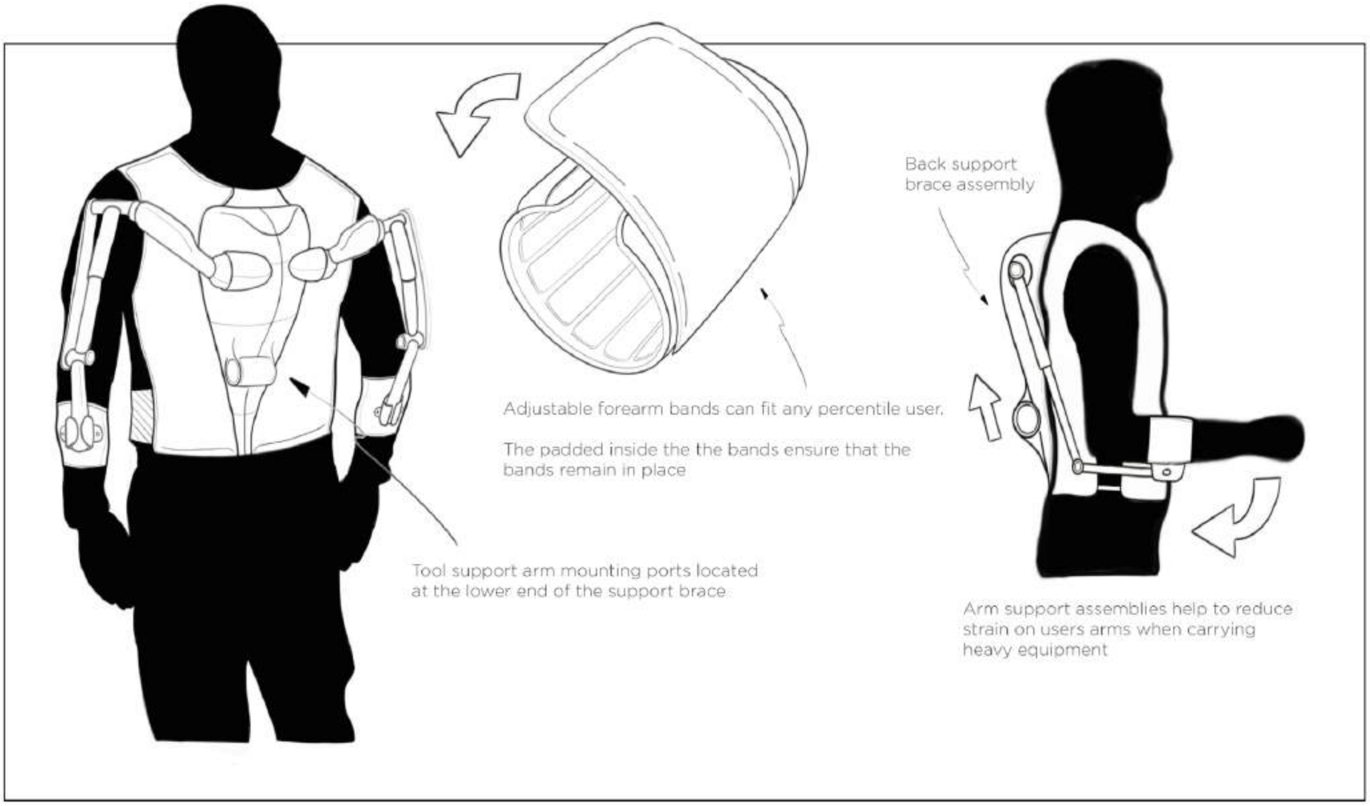


Figure 4.5 - Concept Development 1



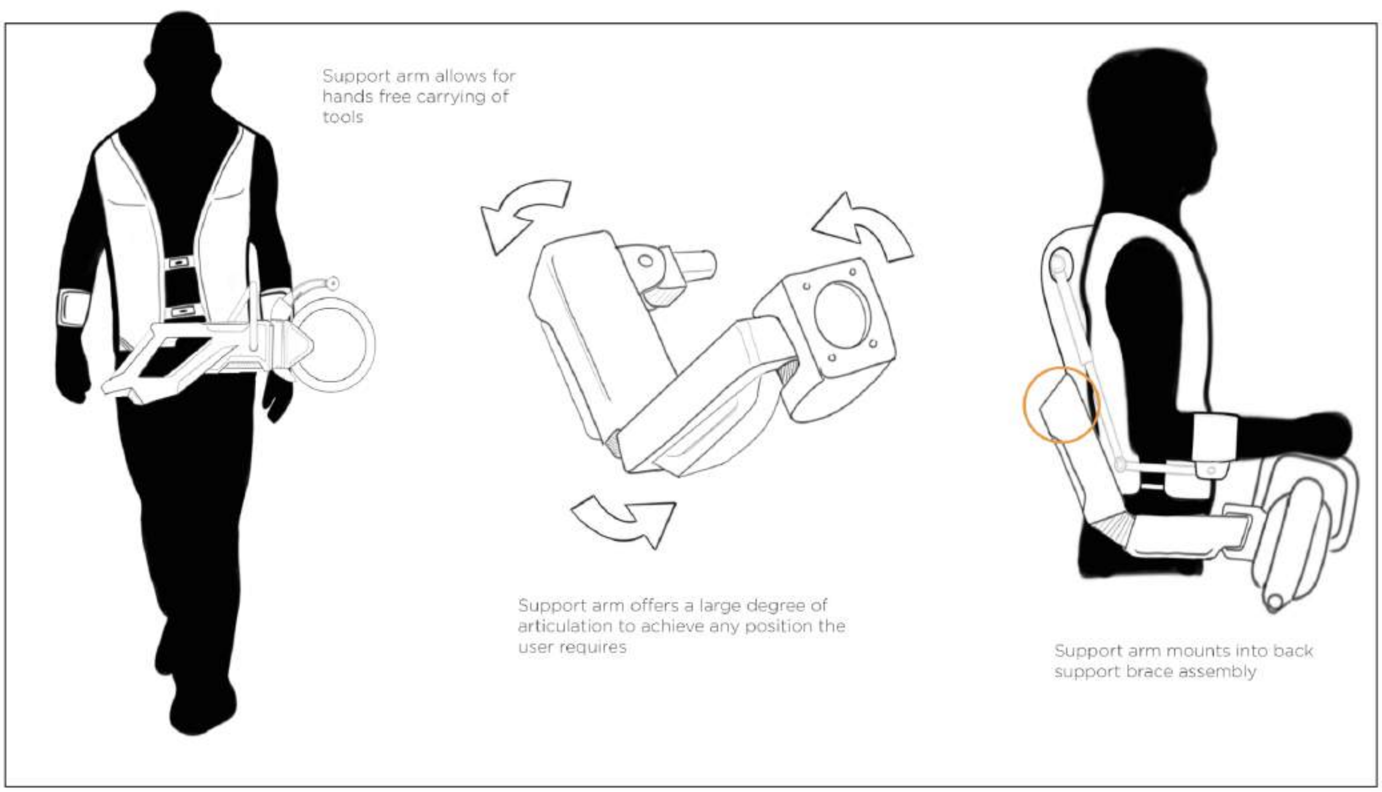


Figure 4.6 - Concept Development 2 & 3

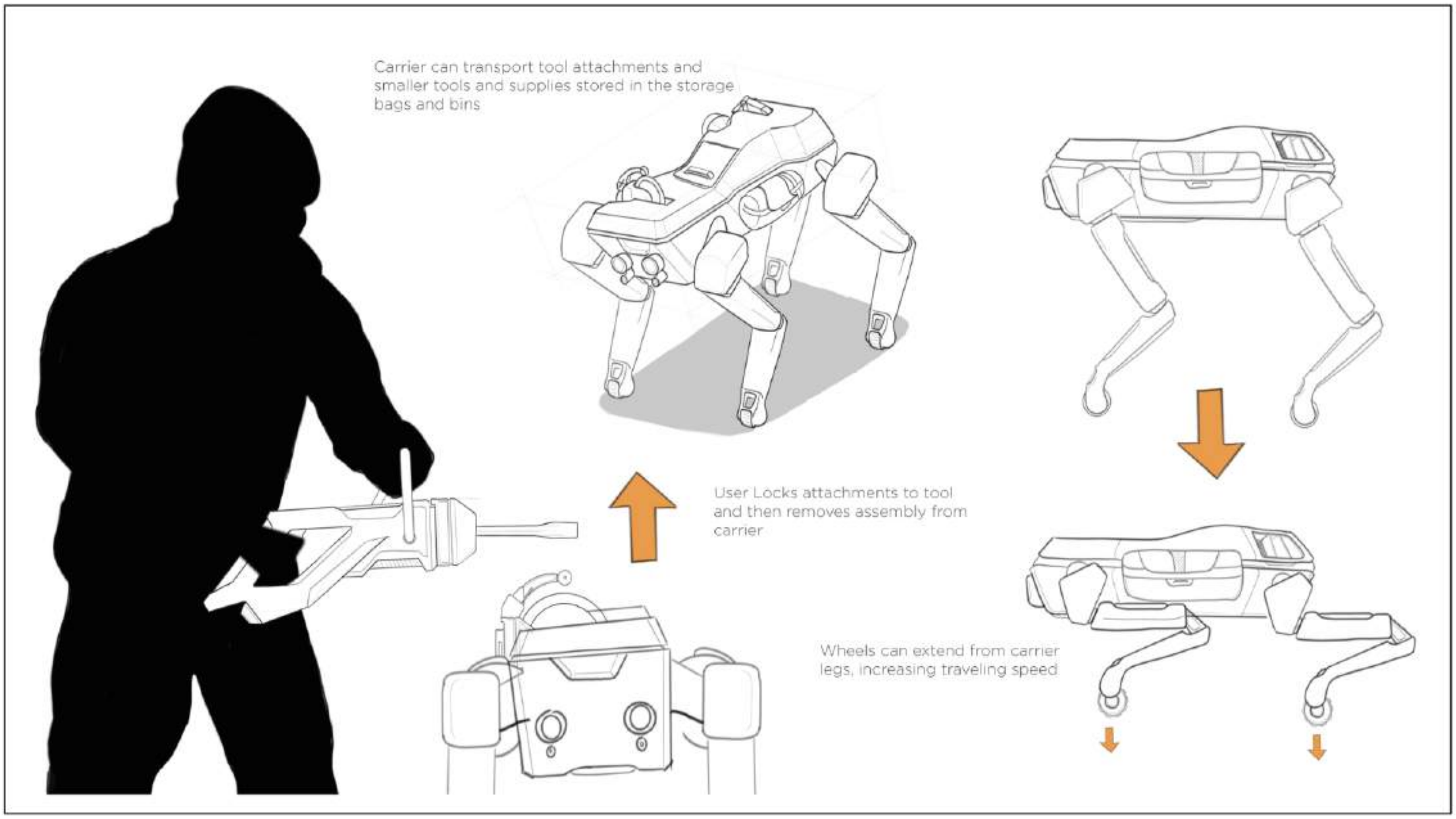
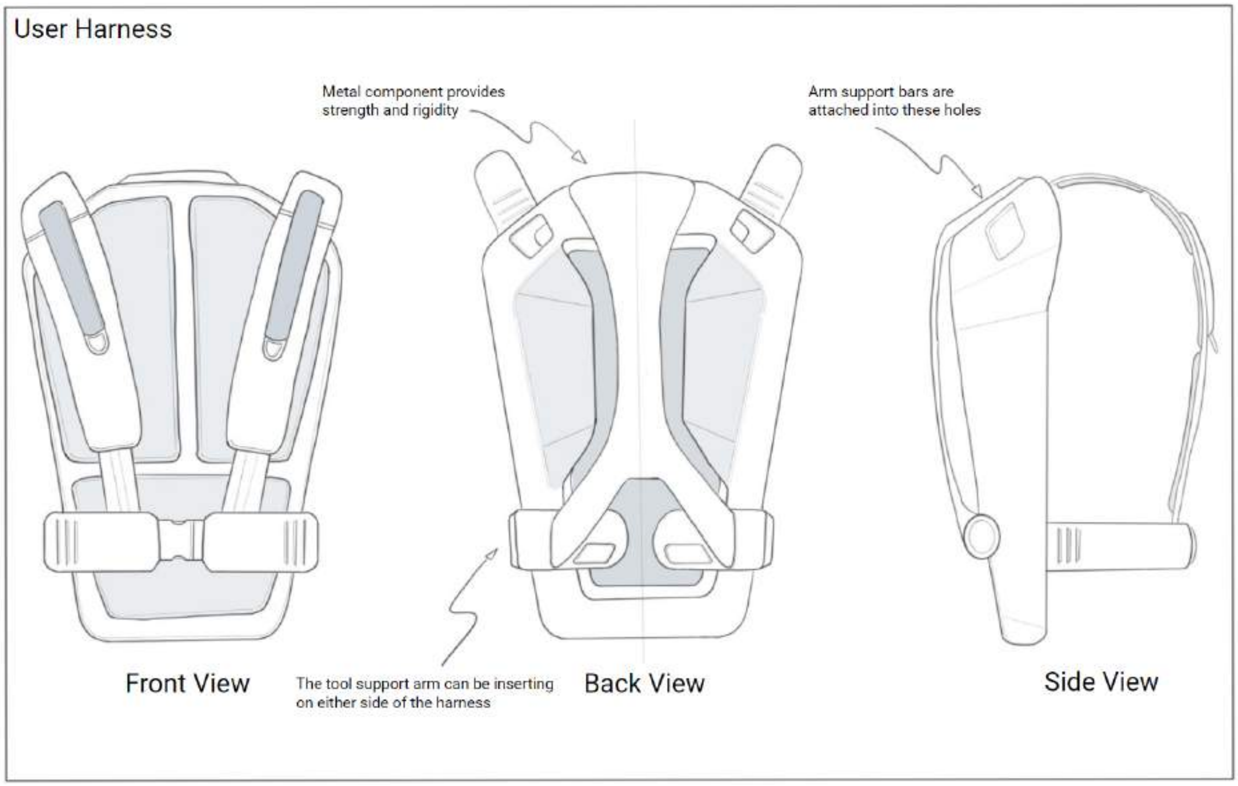


Figure 4.7 - Concept Development 4

Upon further development, the concept evolved into a wearable harness for the user that would assist them in carrying heavy equipment and objects. The harness will have a support arm that connects to a modular rescue tool. The tool has three interchangeable tips for different situations. A jackhammer, a concrete saw, and a spreader. The harness would also double as a protective armor for the users back to keep them safe from any falling debris. A robotic walker is also paired with the harness and allows for storage of the tool tips, as well as smaller equipment such as ropes, axes, flashlights, etc.

4.4 Concept Refinement



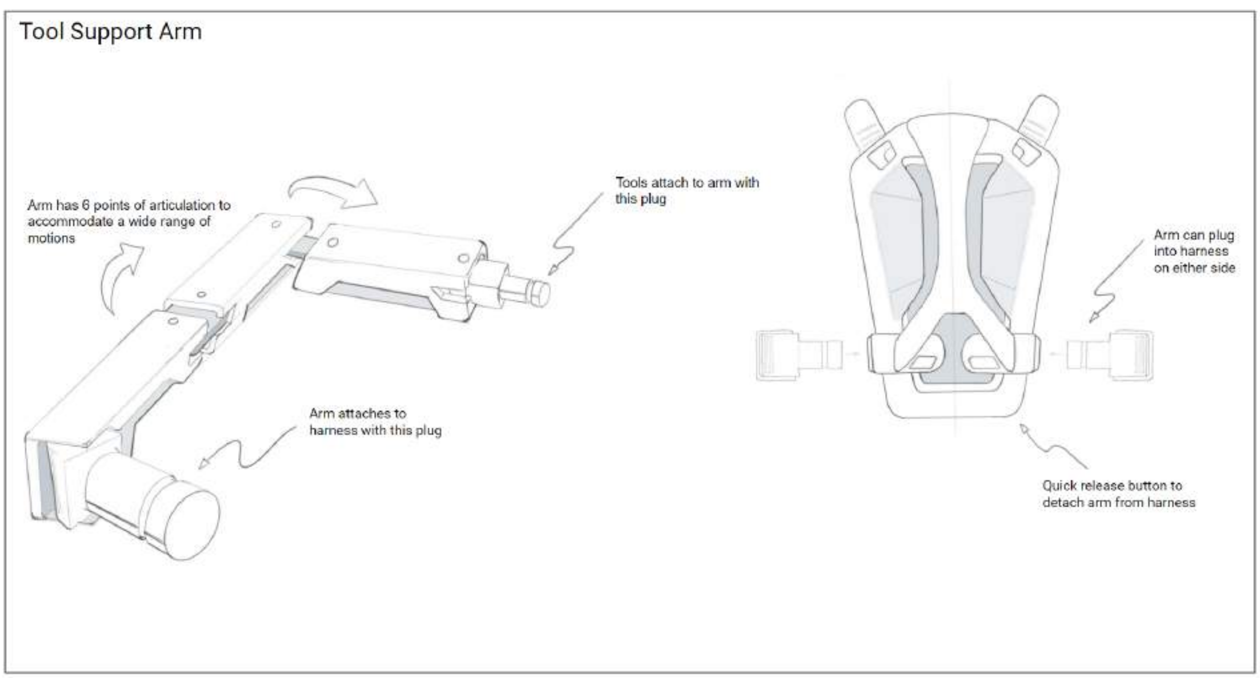
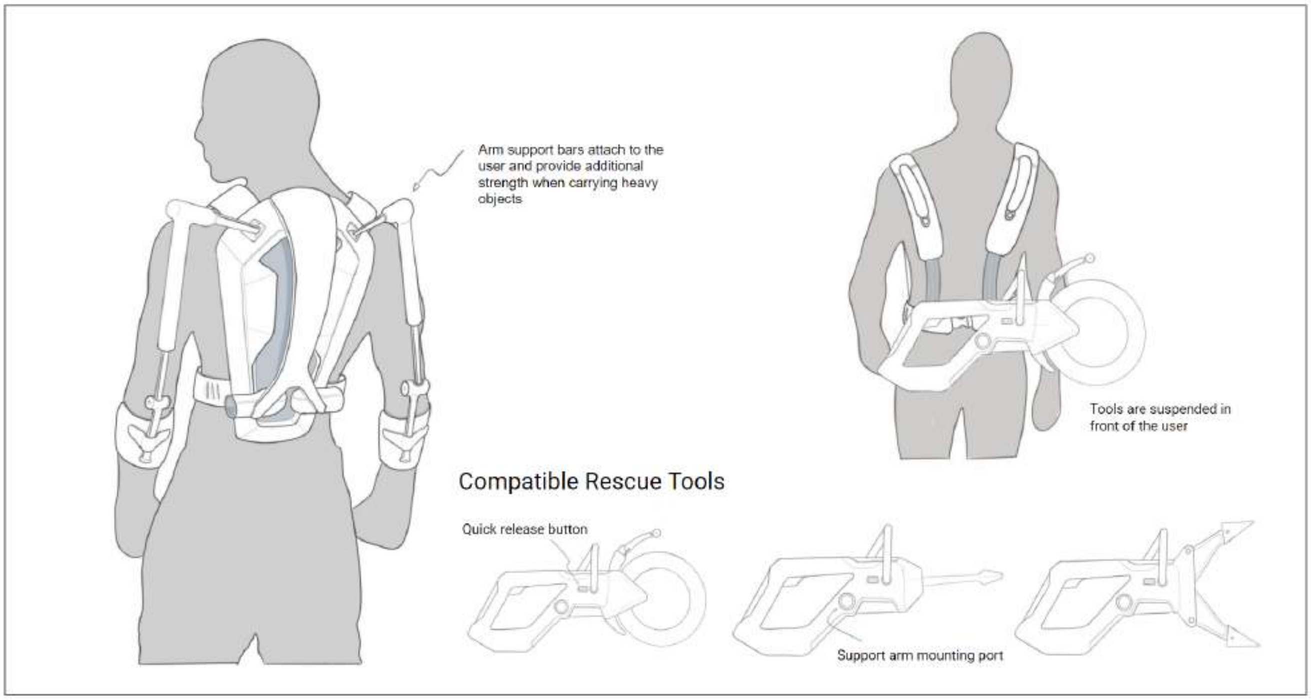


Figure 4.8 - Concept Refinement 1 & 2



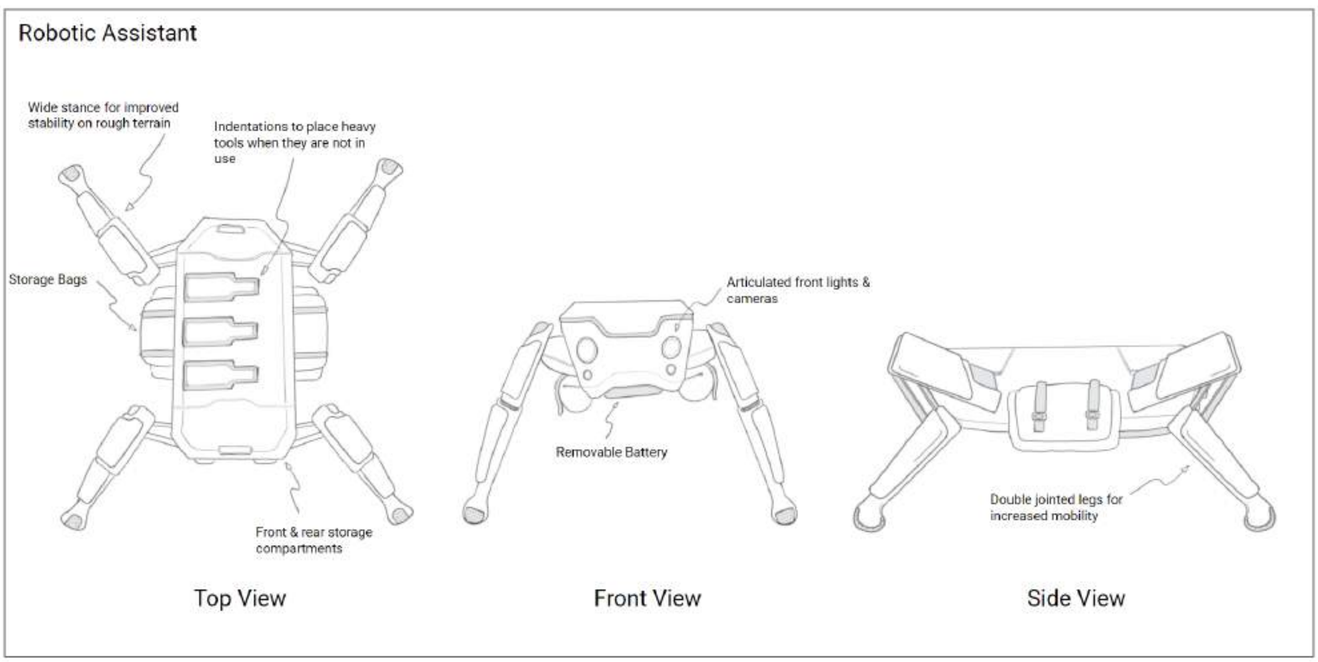


Figure 4.9 - Concept Refinement 3 & 4

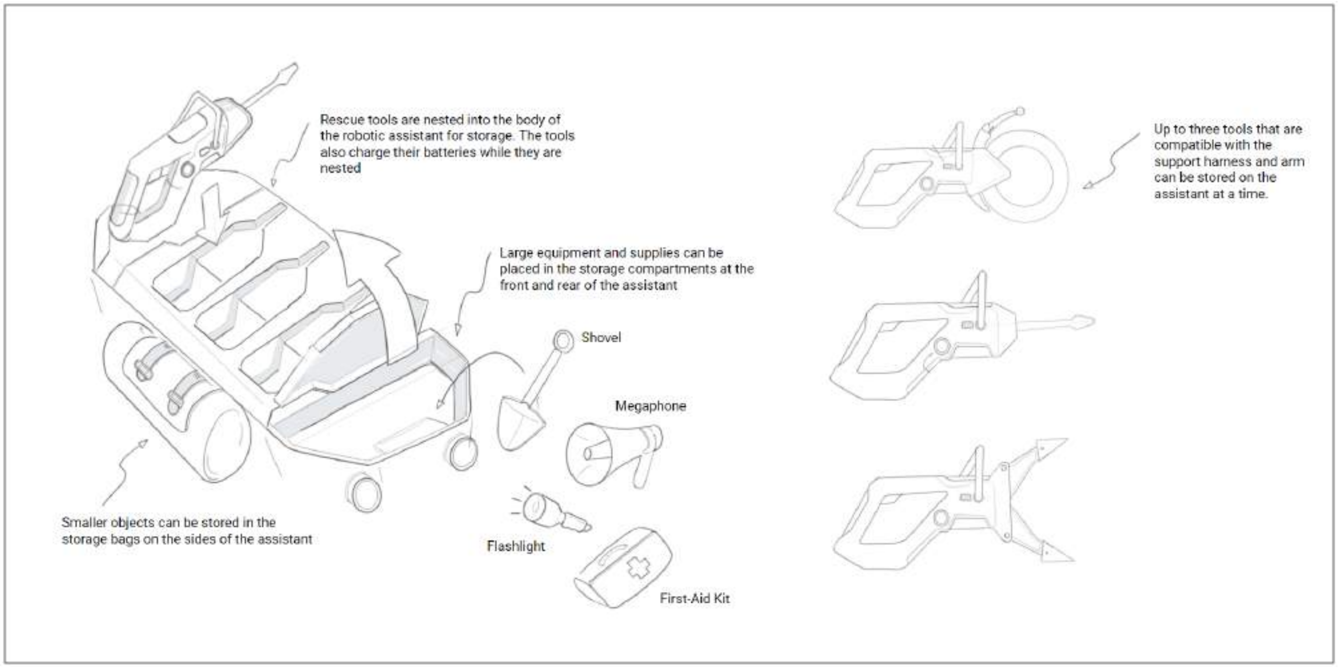


Figure 4.10 - Concept Refinement 5

During this phase of design development, the concept began to take shape and incorporated all the features that will make their way into the final design. Various details were defined and then developed further in later stages of the design process.

4.5 Design Realization

This section of the chapter will overview the physical sketch model created for the final concept design, as well as the product schematics for the design and its various components.

4.5.1 Physical Study Model

Figure 4.11 - Vest & Robot Sketch Model

Figure 4.12 - Vest Detail Views

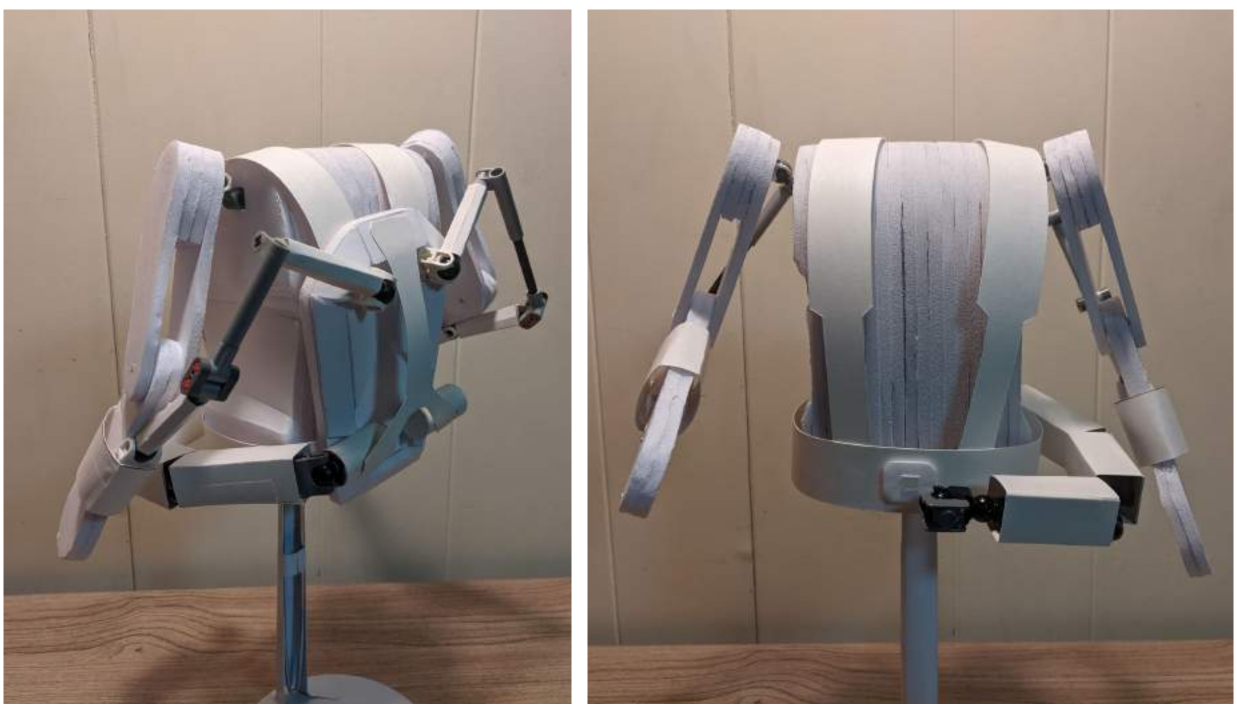


Figure 4.13 - Vest on user

Figure 4.14 Robotic Assistant

4.5.2 Product Schematic

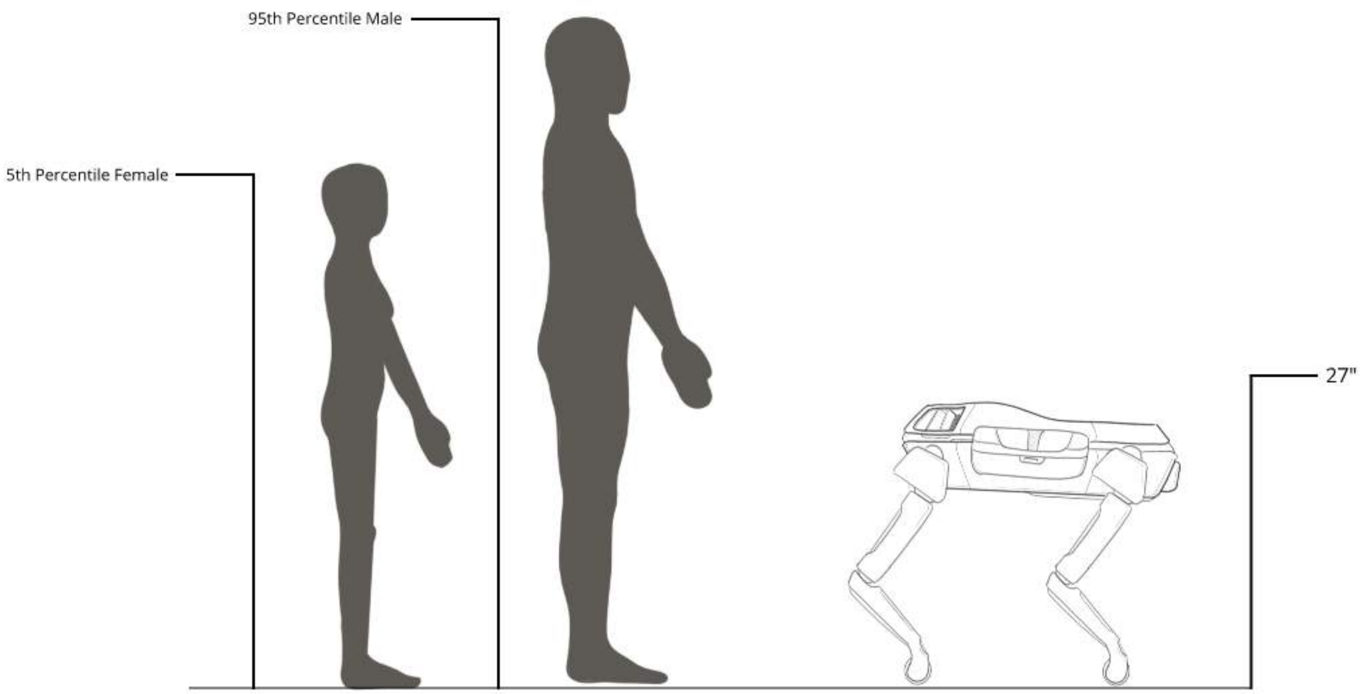


Figure 4.15 - Robotic Assistant Schematic

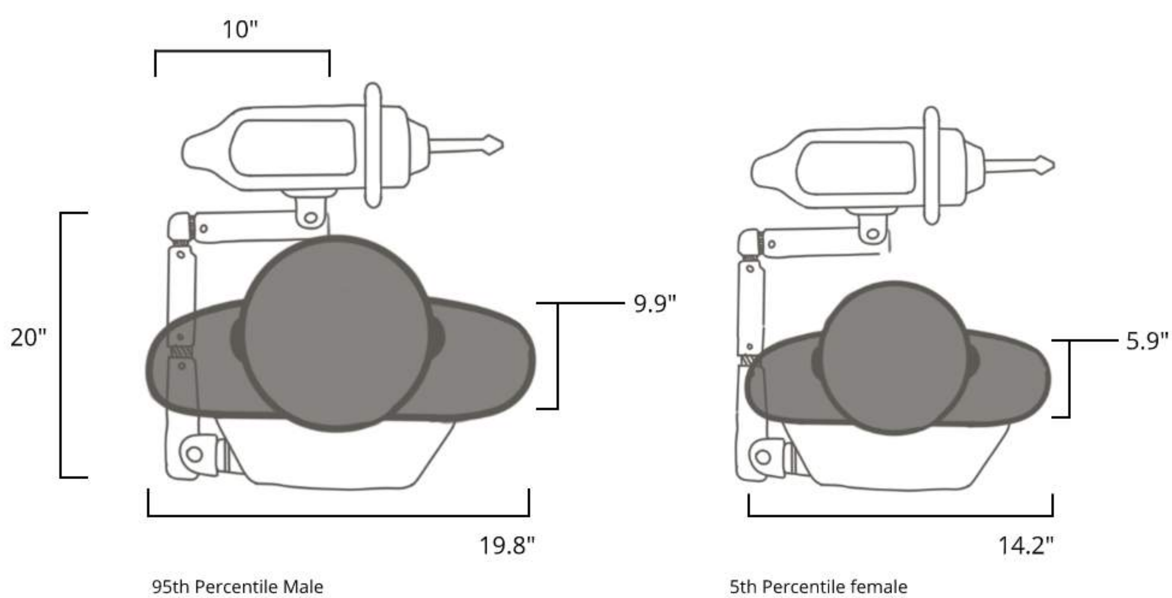


Figure 4.16 - Tool Arm Schematic

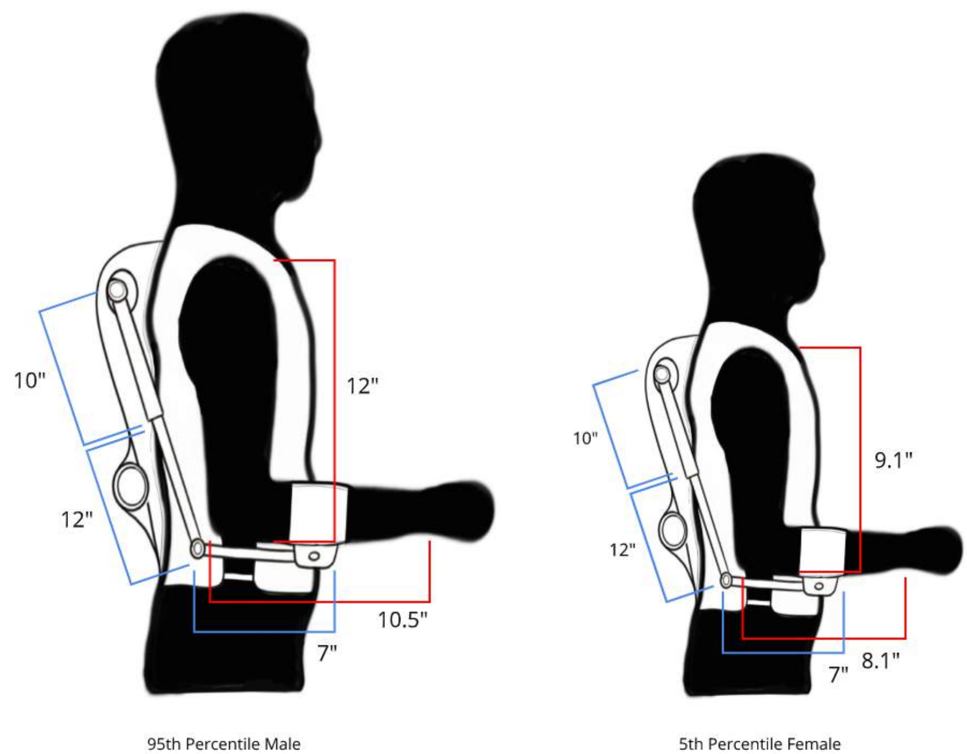


Figure 4.17 - Harness Support Arm Schematic

4.6 Design Resolution

The final stage of design development defined the final look of the concept as well as the detailing of how different components move and fit together. Examples of this include the opening and closing of the robot storage lids, the articulation of the support arm sub assemblies, and the removal of the tool tips from the tool body.

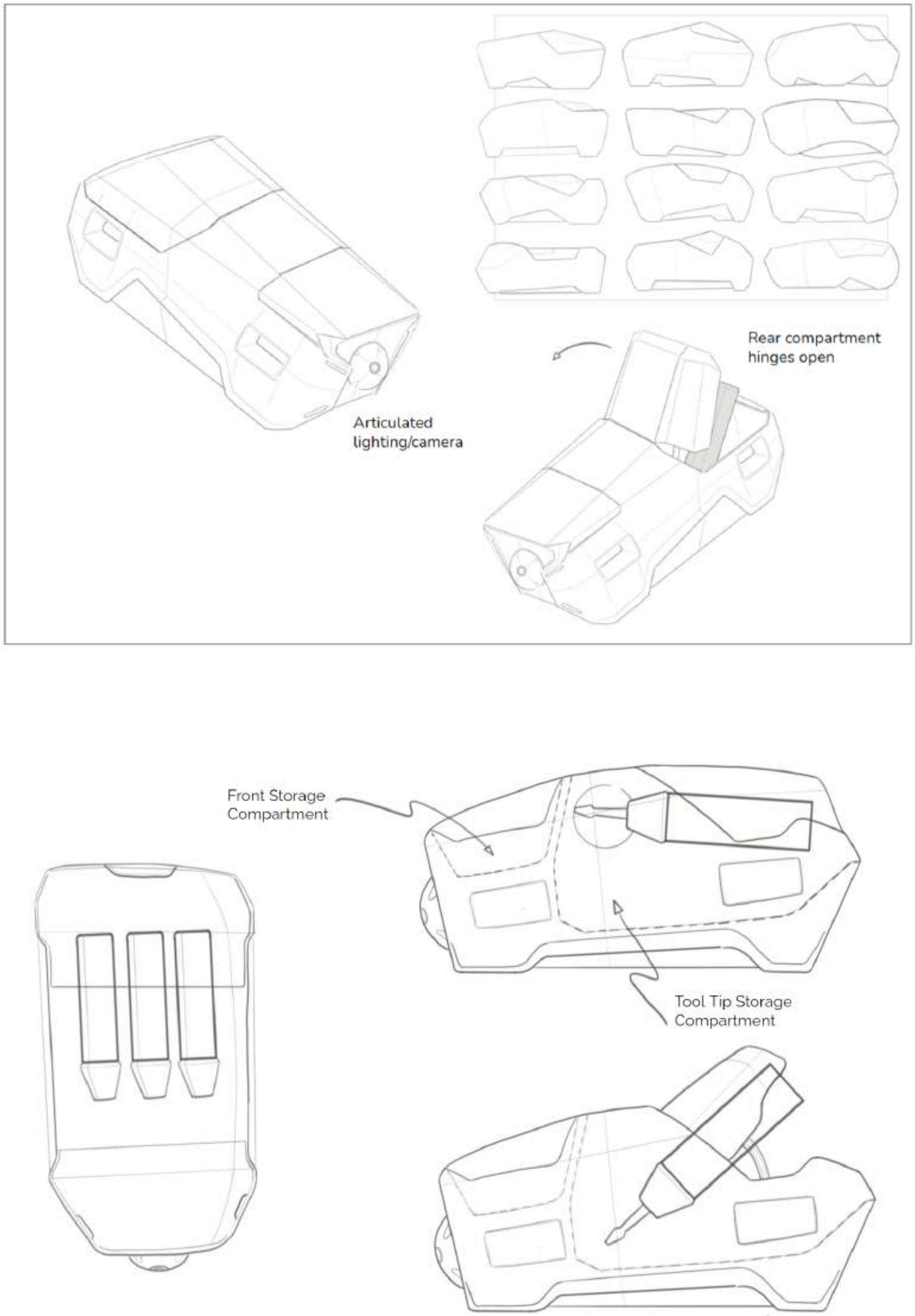
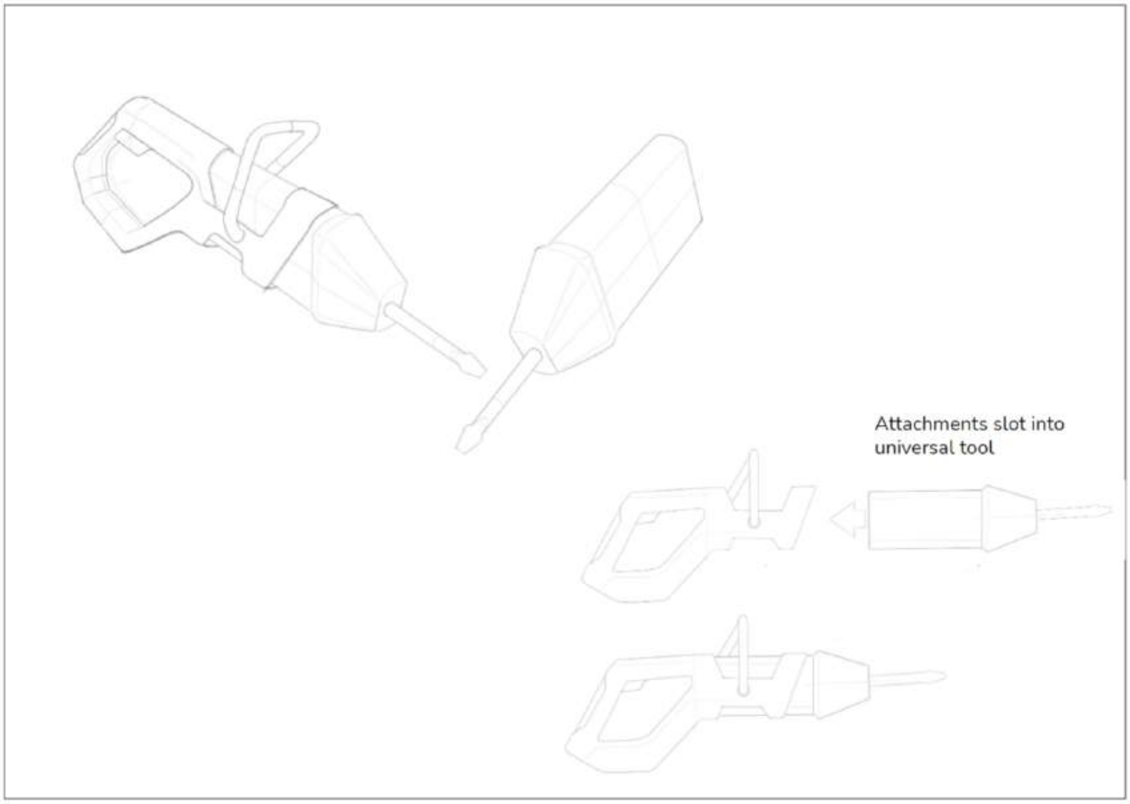


Figure 4.18 -Robot body detailing



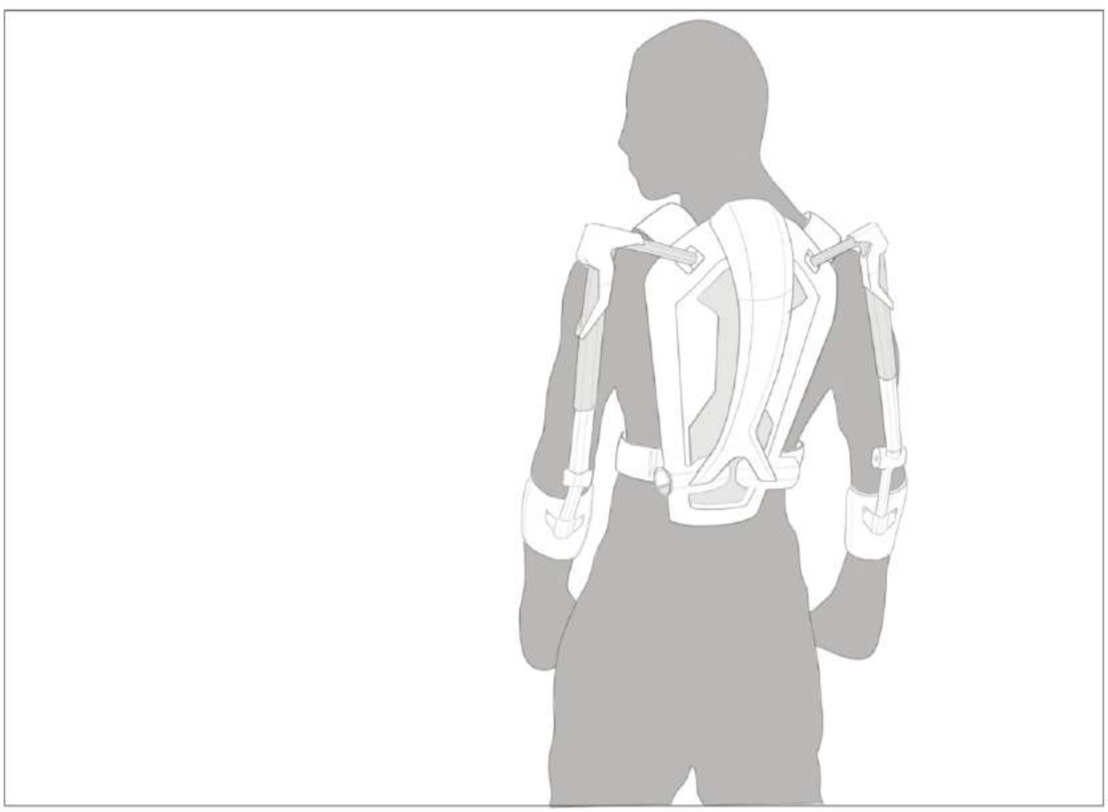


Figure 4.19 - Harness & Tool Development

4.7 CAD Development

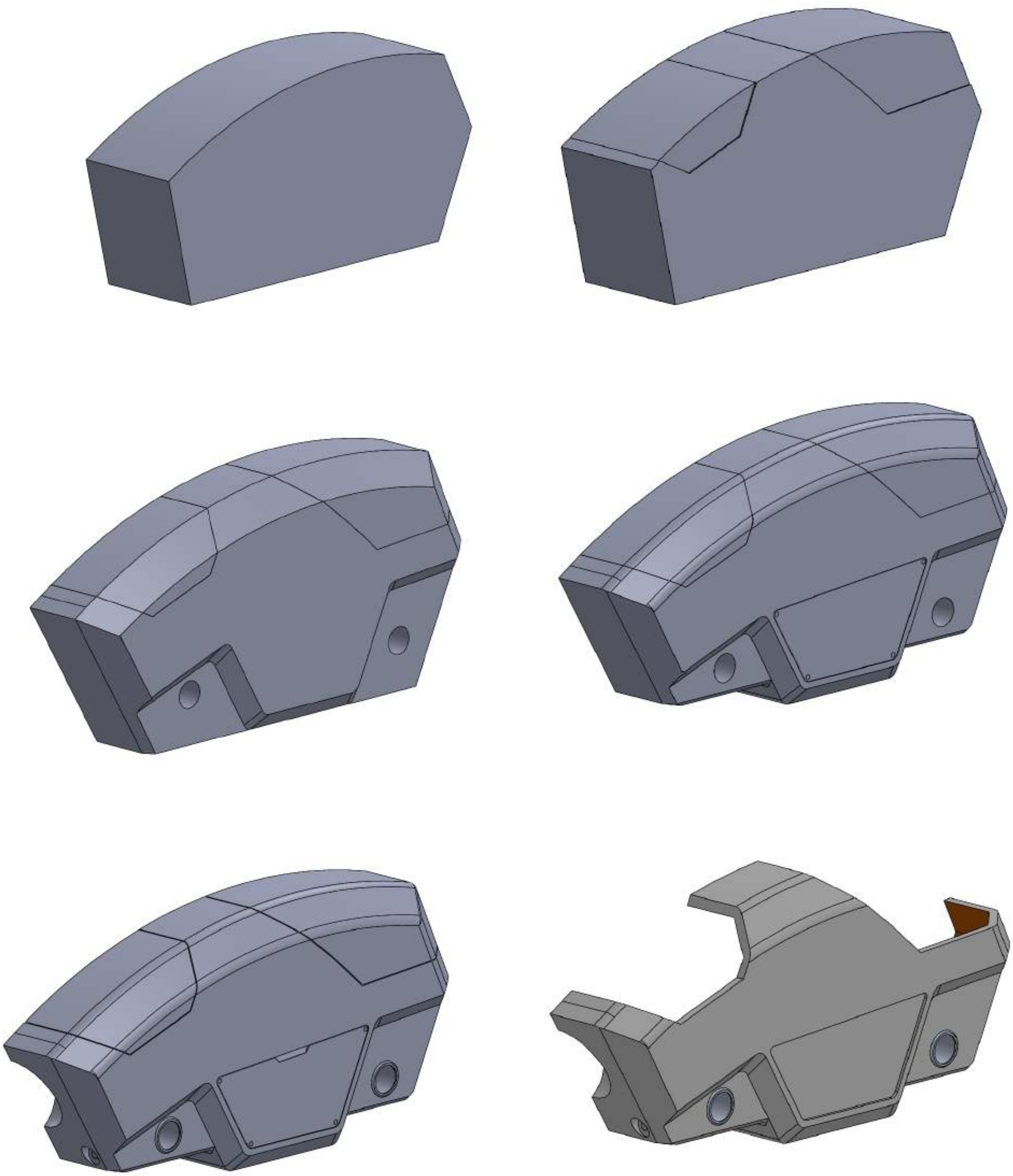
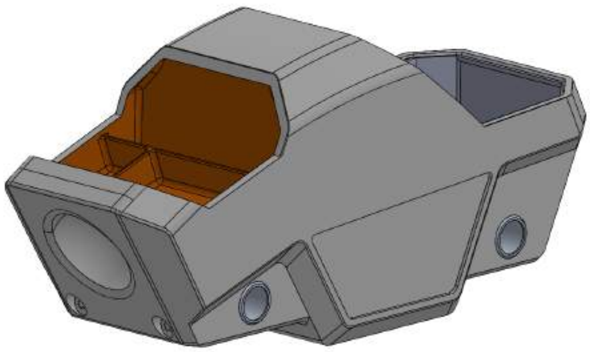


Figure 4.20 - Robot Body CAD Development 1



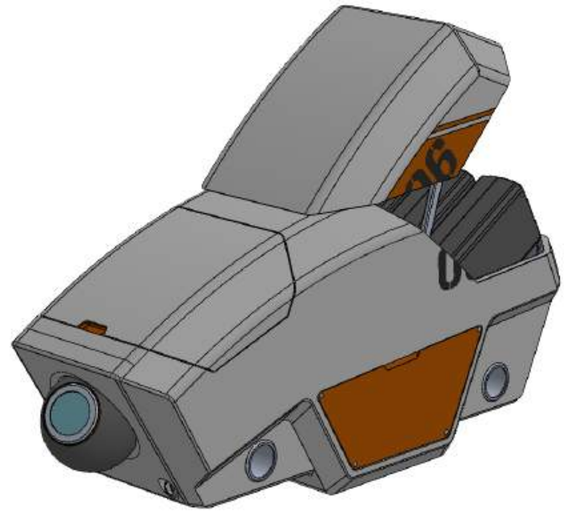


Figure 4.21 - Robot Body CAD Development 2

Figure 4.22 - Robot Leg CAD Development

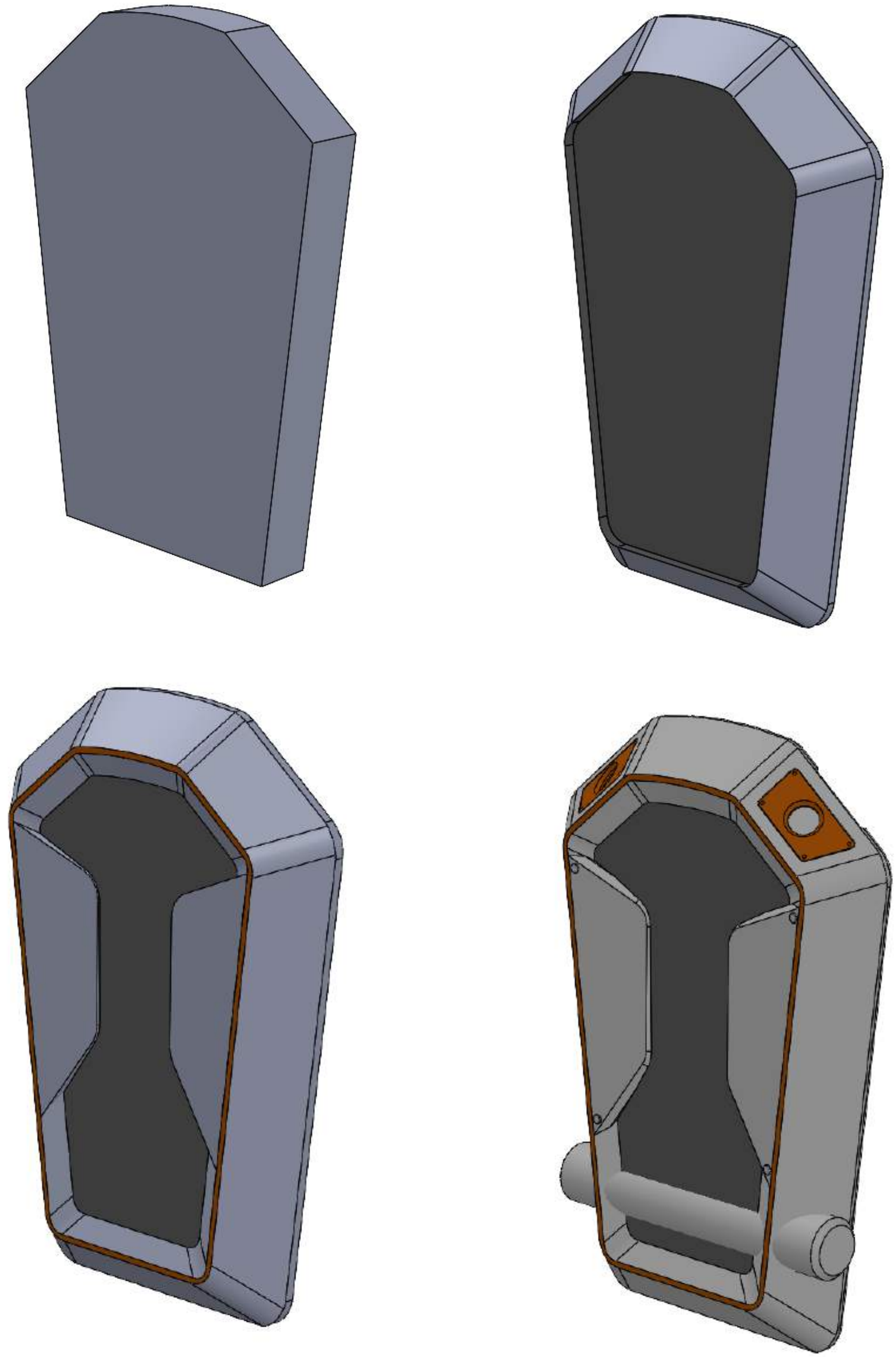


Figure 4.23 - Backpack CAD Development 1

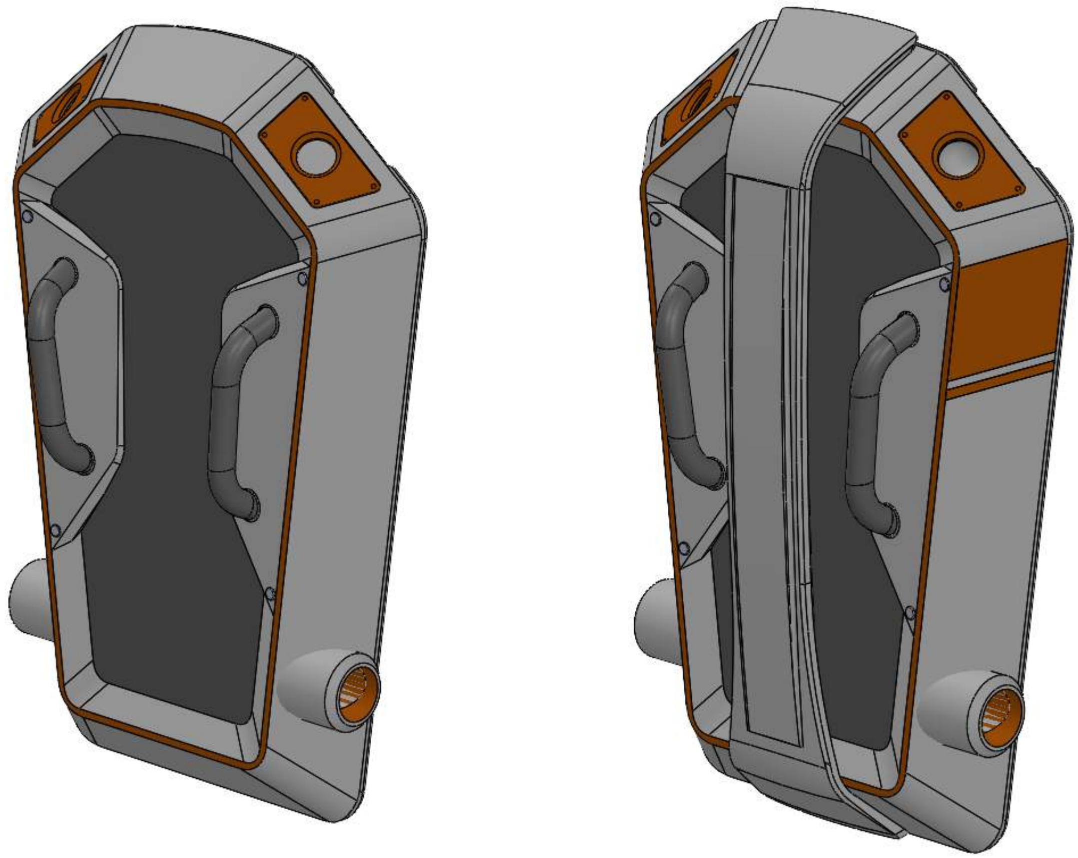


Figure 4.23 - Backpack CAD Development 2

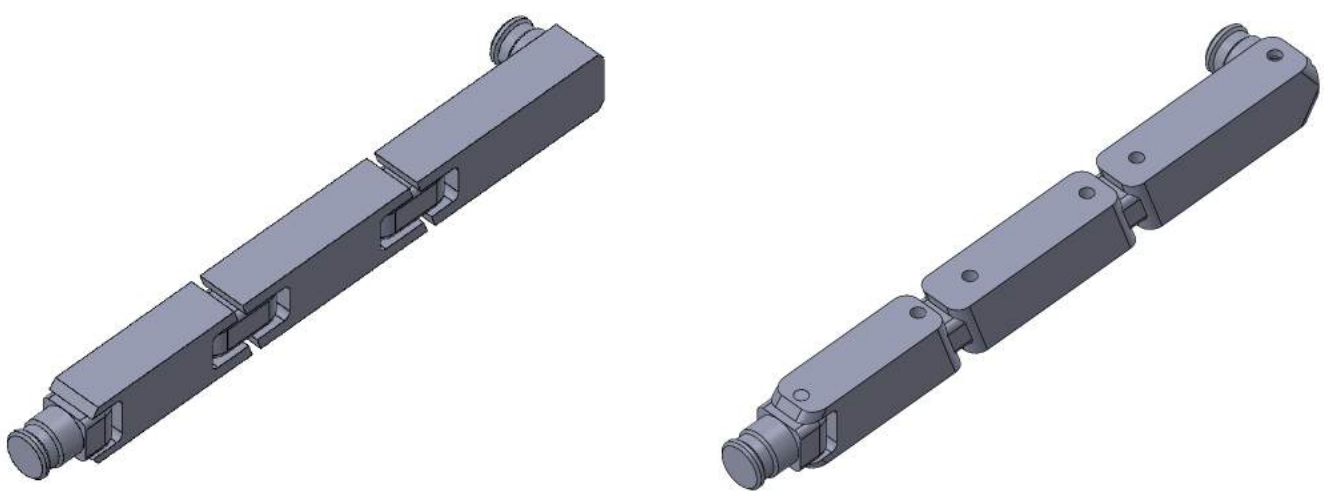


Figure 4.24 - Tool Arm CAD Development 1

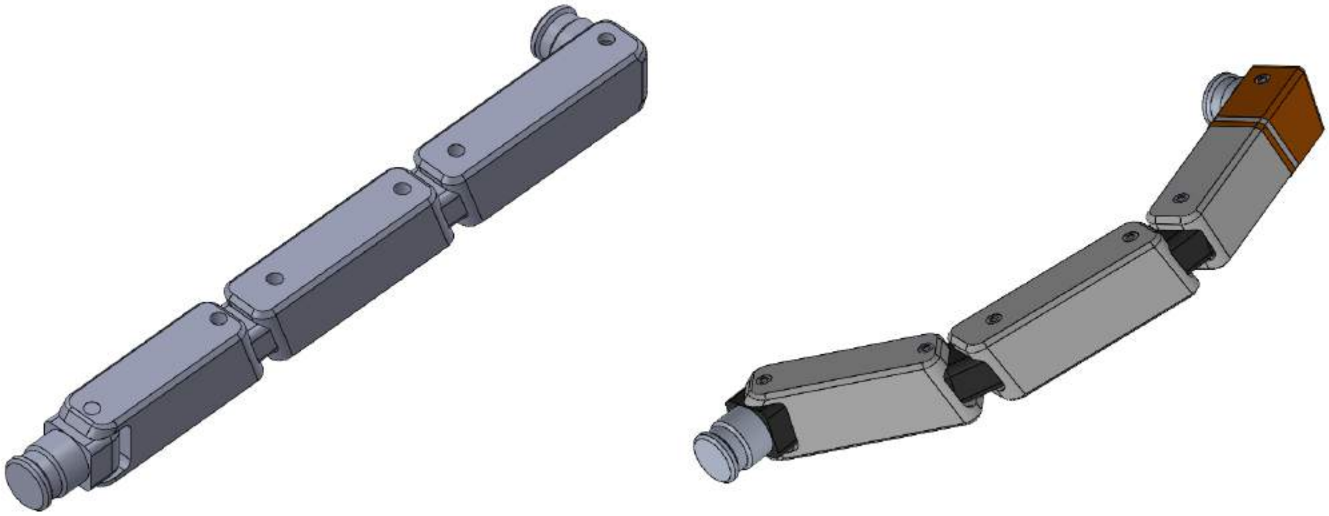


Figure 4.25 - Tool Arm CAD Development 2

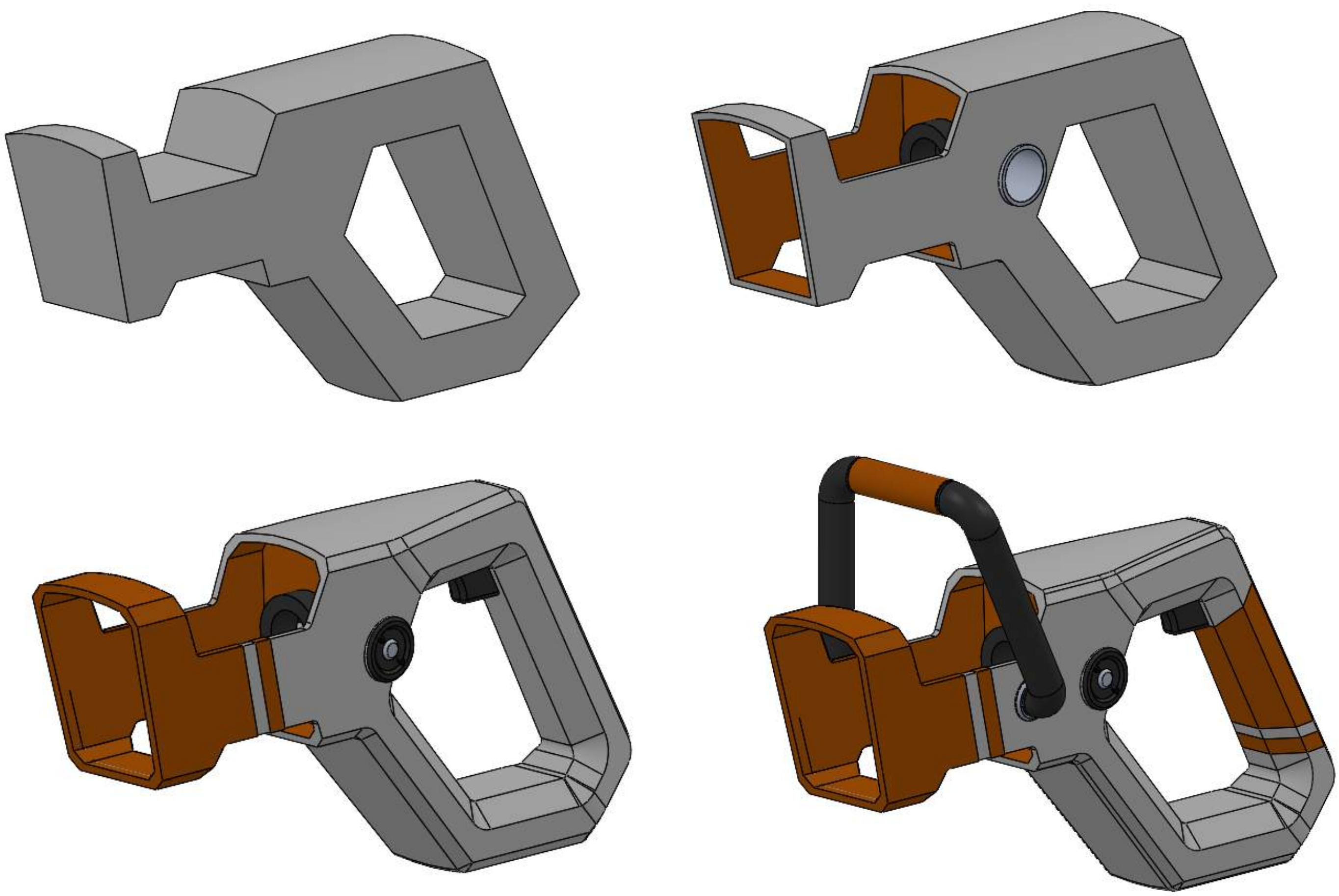


Figure 4.26 - Tool Body CAD Development

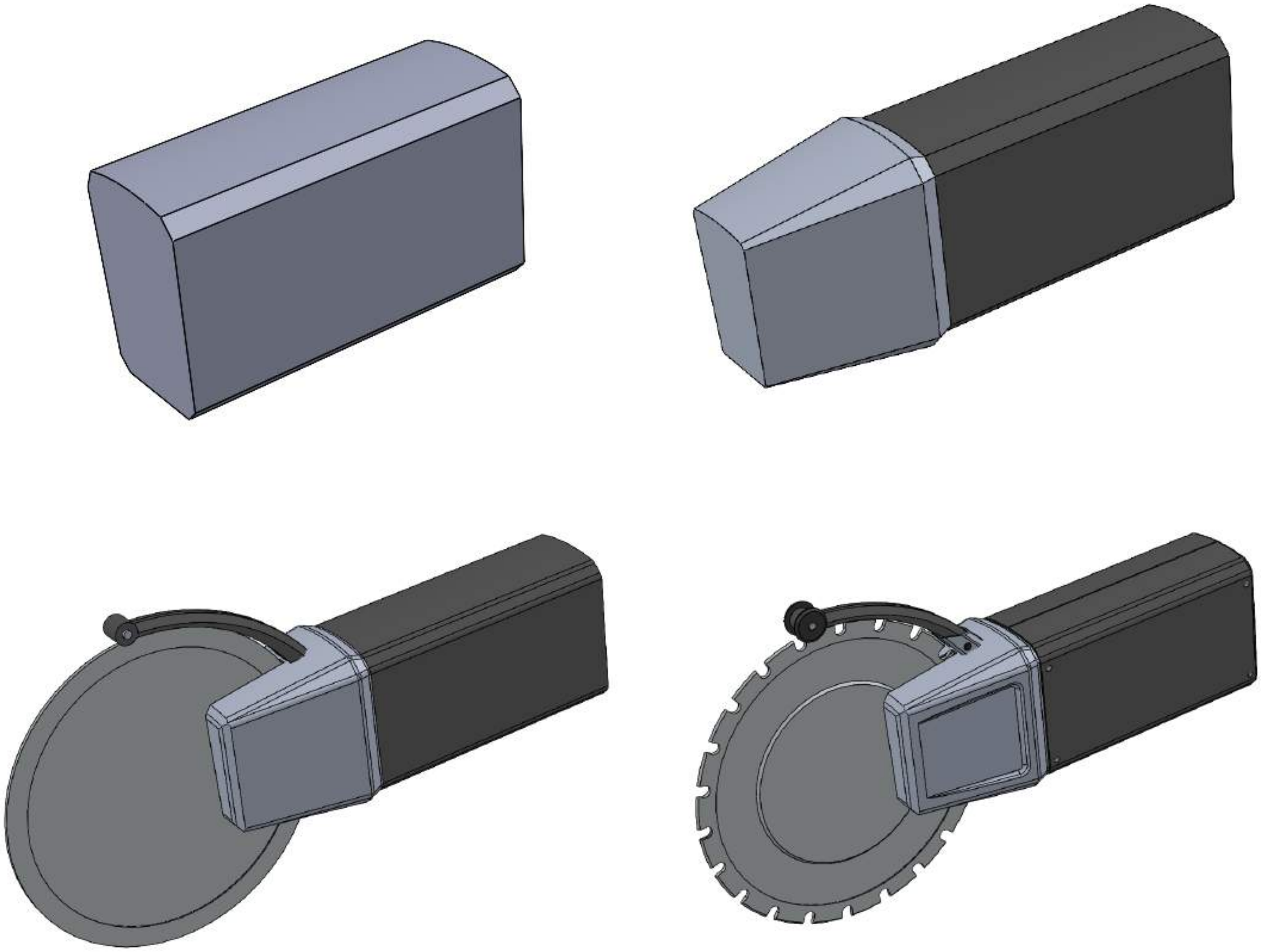


Figure 4.27 - Tool Tip CAD Development

4.8 Physical Model Fabrication

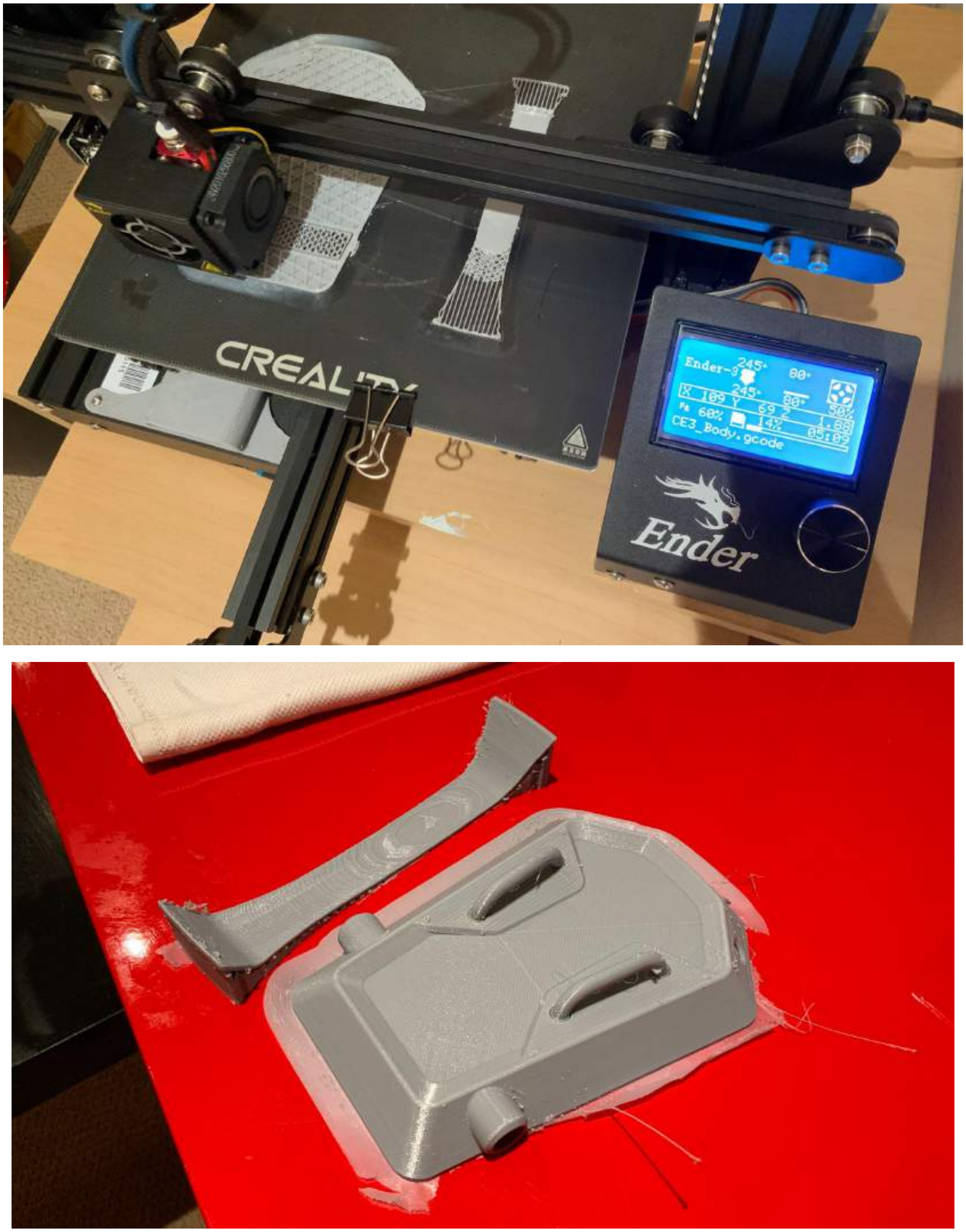


Figure 4.28 - 3D Model Fabrication 1

Figure 4.29 - 3D Model Fabrication 2

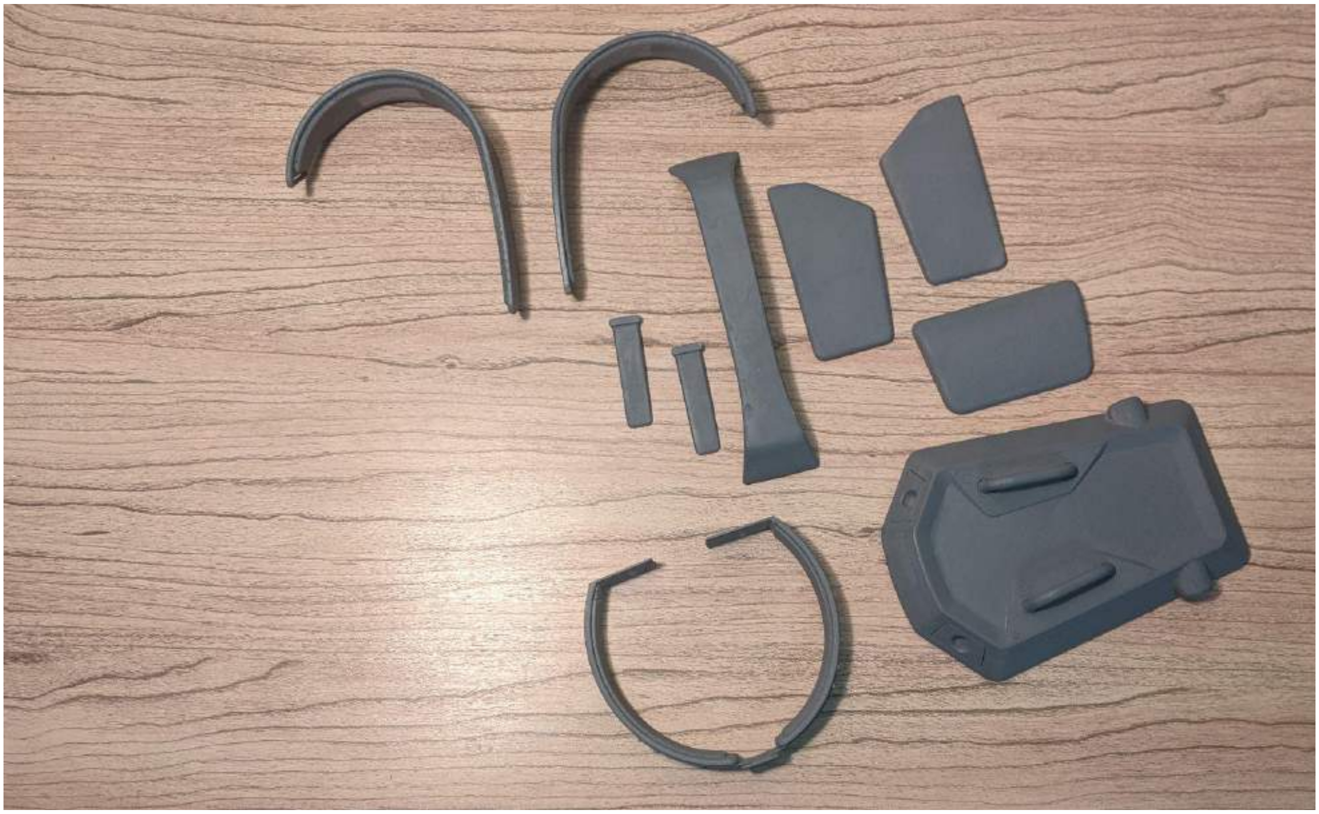


Figure 4.30 - 3D Model fabrication 3

CHAPTER 5

FINAL DESIGN

This chapter will be the culmination of all previous chapters. The final design will be displayed. Features, ergonomics, and sustainability will all be touched upon during this chapter. In addition, it will include finalized renders of the final design, and photos of the prototype.

5.1.1 Description

Rescue workers undergo tremendous amounts of stress throughout earthquake search and rescue missions. Making their jobs easier and more efficient can result in a greater amount of lives saved by them.

Lifeline is an earthquake search and rescue system designed for being used during earthquake search and rescue missions. The final design includes a wearable harness that supports the users arms and back, while still providing them with a full range of motion. A modular tool can be connected to a support arm on the user's waist. The arm allows the tool to be held upright without the user needing to exert any unnecessary energy to carry it. The tool itself has three different tips that can be interchanged and stored within a robot that walks alongside its user. The robot also has the capabilities of carrying other important rescue equipment such as flashlights, axes, and rope. This functionality allows the user to carry little to no additional equipment on their person.

5.1.2 Benefit Statement

Lifeline removes the need for earthquake rescue workers to exert unnecessary amounts of energy to carry around their heavy rescue equipment. Lifeline supports the users arms and back, providing them with increased safety and a full range of motion. A robotic walker can follow the user around and provide them with the invaluable tools and equipment that they require during their mission. Ultimately, the Lifeline earthquake search and rescue system allows its user to remove any unwanted strain and stress on their bodies, increasing the efficiency of their mission, and making it easier for them to save the lives of victims in need.

5.2 Design Criteria Met

This section will describe how Lifeline satisfies the design criteria through ergonomics, materials, processes, technologies, feasibility, and viability.

5.2.1 Ergonomics

The Lifeline earthquake rescue system is designed to adapt with its user. Every moving component in the system is adjustable to work with users ranging from a 5th percentile female, to a 95th percentile male. The user retains their regular range of motion in their arms, while also receiving additional strength from the articulated support arms connected to the harness. These support arms mitigate the load placed on the users body when carrying heavy equipment and machinery. The user can easily attach these supports to their forearms by sliding an armband over their arm, and tightly securing it in place with a pull strap.

The harness itself also provides comfort and ergonomics to the users wearing it. The backplate, belt, and shoulder straps all include padded surfaces to keep the users body comfortable, and eliminate any potential strain that can result from wearing the harness over extended periods of time. The backplate of the harness also includes lumbar support integrated into its padded surfaces. This lumbar support ensures that the user's back is kept in alignment, and that the natural curvature of their spine is maintained while wearing the harness.

A tool arm can also be connected to the harness which allows its users to easily carry heavy equipment with them, while having the arm hold up the weight of the equipment, rather than the user needing to exert additional energy to carry around the heavy equipment using their own arms. A modular tool with three different tips can be mounted to the tool arm, and is fully functional while attached to the arm. The tool arm offers a large range of articulation which allows the user to orient the tool in the way they find most comfortable while operating it.

The tool itself can be comfortably held with two hands by the handle at the back, and the bar near the front. Both touch points include a soft touch material that adds additional comfort for holding the tool during long periods of time. Both the tool and tool arm can be swapped to either side of the harness to accommodate for both left handed and right handed users.

In addition, the robotic carrier can adjust its height depending on its user to ensure all of its compartments are easily accessible. The front and rear lids on the robot can be easily lifted using handles to reveal the interior storage areas. The tool tips are stored in the rear of the robot at an angle that is comfortable for the user to insert the tip into the tool body.

5.2.2 Materials, Processes, & Technologies

Materials:

Due to the dangerous environment after an earthquake disaster, Lifeline must be durable enough to withstand abuse. The plastic components/outer housing of this product must use a durable plastic such as ABS. This plastic has outstanding impact resistance and machinability. This material would ensure that the product will be able to withstand plenty of potential damage.

In addition, ABS is also a recycled plastic compound, and itself, is entirely recyclable. The metallic components of Lifeline such as the inner frame of the robot and tool tips can be made from Magnesium. This metal is 33% lighter than Aluminum and is capable of withstanding 10x more force than Aluminum, Titanium, and Steel. This material is easy to machine, can be injection molded, and poses no toxicity hazards. This material will help to provide structural rigidity to the system while also keeping the overall weight down to help increase its efficiency and usability for the user. In addition to these benefits, Magnesium is also highly recyclable and widely available. It is a very sustainable material to manufacture.

Processes & Technologies:

The primary manufacturing process used for the plastic outer shell of the harness and robot would be injection molding. To improve the sustainability of this manufacturing process, all-electric molding machines can be used. In the past, hydraulic injection molding machines have been used for this process but they consume much more power than an all-electric machine. The use of all-electric machines are more sustainable and will have less of an environmental impact. The same process can be used for the metallic elements of the product as well. Since magnesium is able to be injection molded, it can be done using all-electric machines. Much like for the plastic components, this technology will have less of an environmental impact than traditional hydraulic machines.

The Lifeline system utilizes a variety of technologies to enhance its functionality. Some of these technologies include:

- Articulated support arms
- Artificial Intelligence
- Static Stability
- Cameras
- Interchangeable tool tips

5.2.3 Feasibility & Viability

In this section, manufacturing cost has been calculated using references from existing products. At the end of the cost breakdown, the total cost of the product system is shown.

Harness

QTY	Part Name	Part Material	Estimated Cost
1	Inner Frame	Magnesium	$90
1	Outer Shell	ABS	$50
2	Shoulder Straps	Nylon	$25
1	Belt	Various	$30
6	Padding	Foam	$5
2	Handles	Magnesium	$15
x	Mechanical Components	Various	$100
x	Fasteners	Magnesium	$10
Total Cost			**$380**

Table 5.1 - Harness Cost Analysis

Tool

QTY	Part Name	Part Material	Estimated Cost
1	Housing	ABS	$10
3	Tool Tip Housing	Magnesium	$15
x	Mechanical Components	Various	$100
1	Handle Bar	Various	$10
x	Fasteners	Magnesium	$5
Total Cost			**$165**

Table 5.2 - Tool Cost Analysis

Robot

QTY	Part Name	Part Material	Estimated Cost
1	Inner Body Frame	Magnesium	$100
1	Body Shell	ABS	$35
4	Inner Leg Frame	Magnesium	$40
12	Leg Shells	ABS	$5
1	Front Cover	ABS	$5
1	Back Cover	ABS	$5
1	Front Camera	Various	$100
2	LED Lights	Various	$10
1	Battery	Various	$1000
x	Internal Electronics	Various	$500
x	Fasteners	Magnesium	$30
Total Cost			**$1975**

Table 5.3 - Robot Cost Analysis

Support Arms

QTY	Part Name	Part Material	Estimated Cost
3	Inner Frame	Magnesium	$50
5	Outer Shell	ABS	$5
x	Internal Electronics	Various	$60
x	Mechanical Components	Various	$50
x	Fasteners	Magnesium	$10
Total Cost			**$295**

Table 5.4 - Support Arm Cost Analysis

Total Cost			**$2,815**

Table 5.5 - Total System Cost

5.3 Final CAD Renderings

Figure 5.1 - Harness Renders

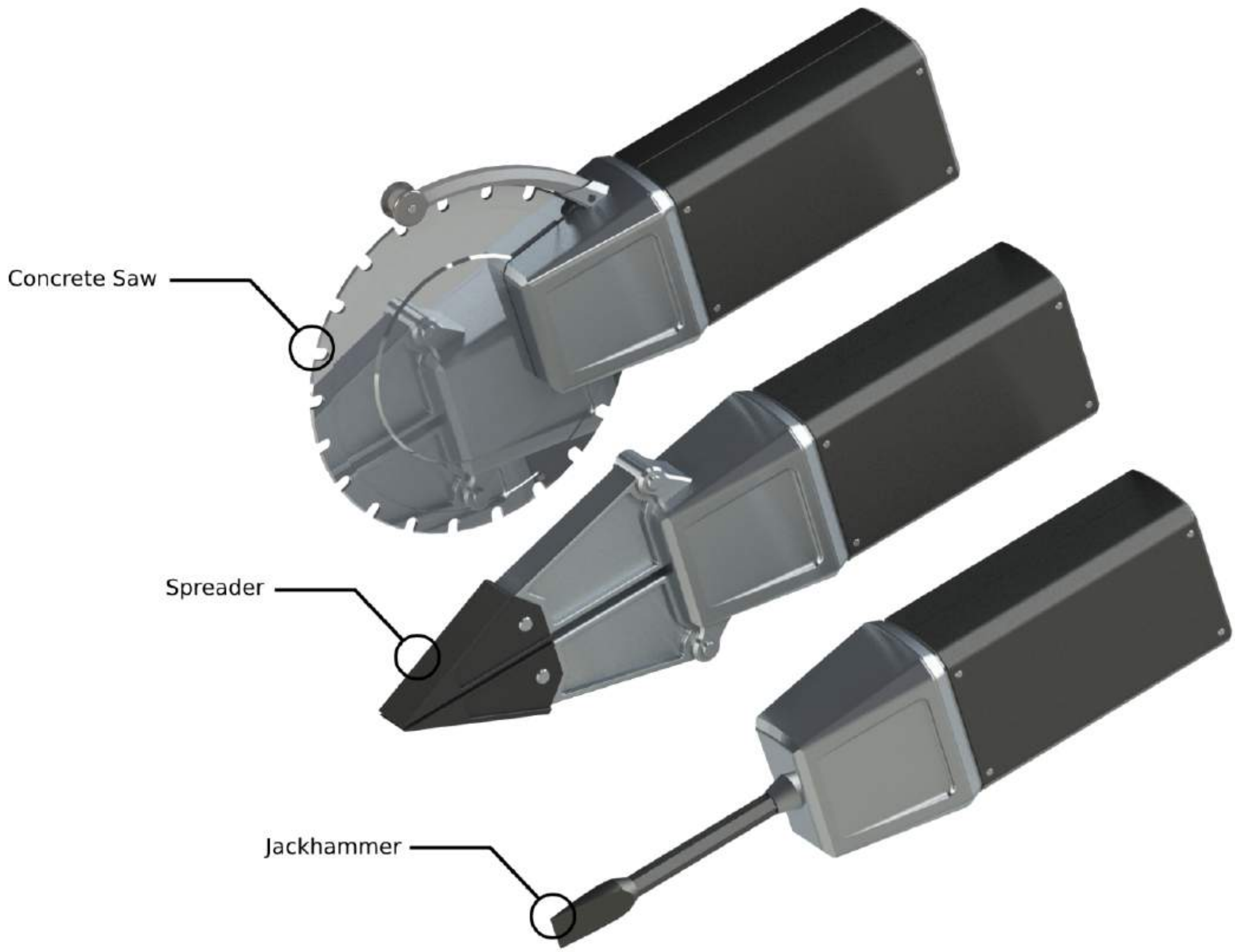
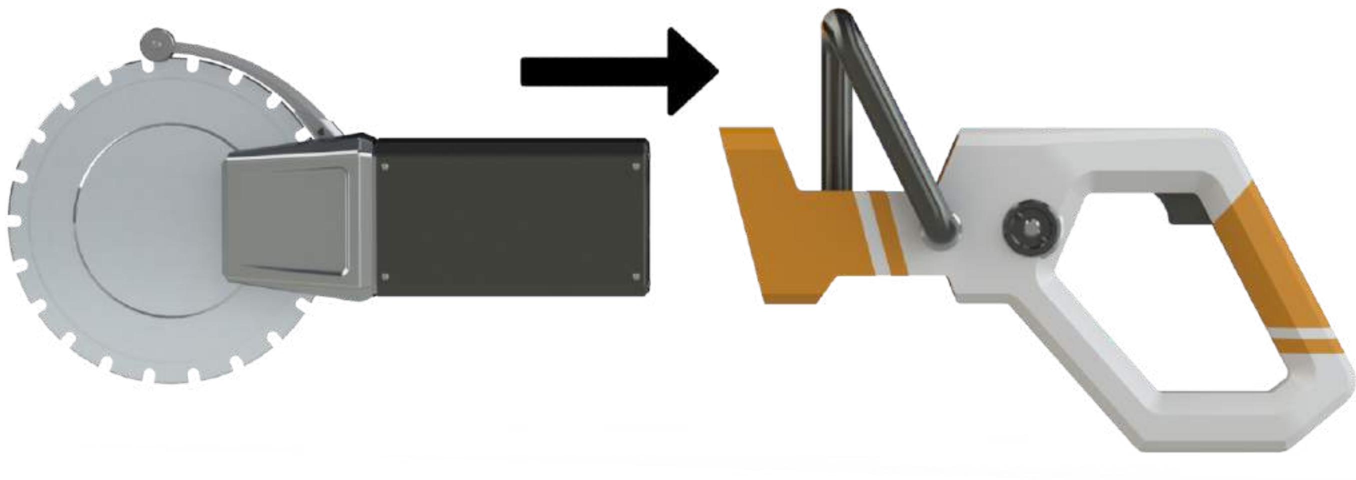


Figure 5.2 - Tool Tip Renders



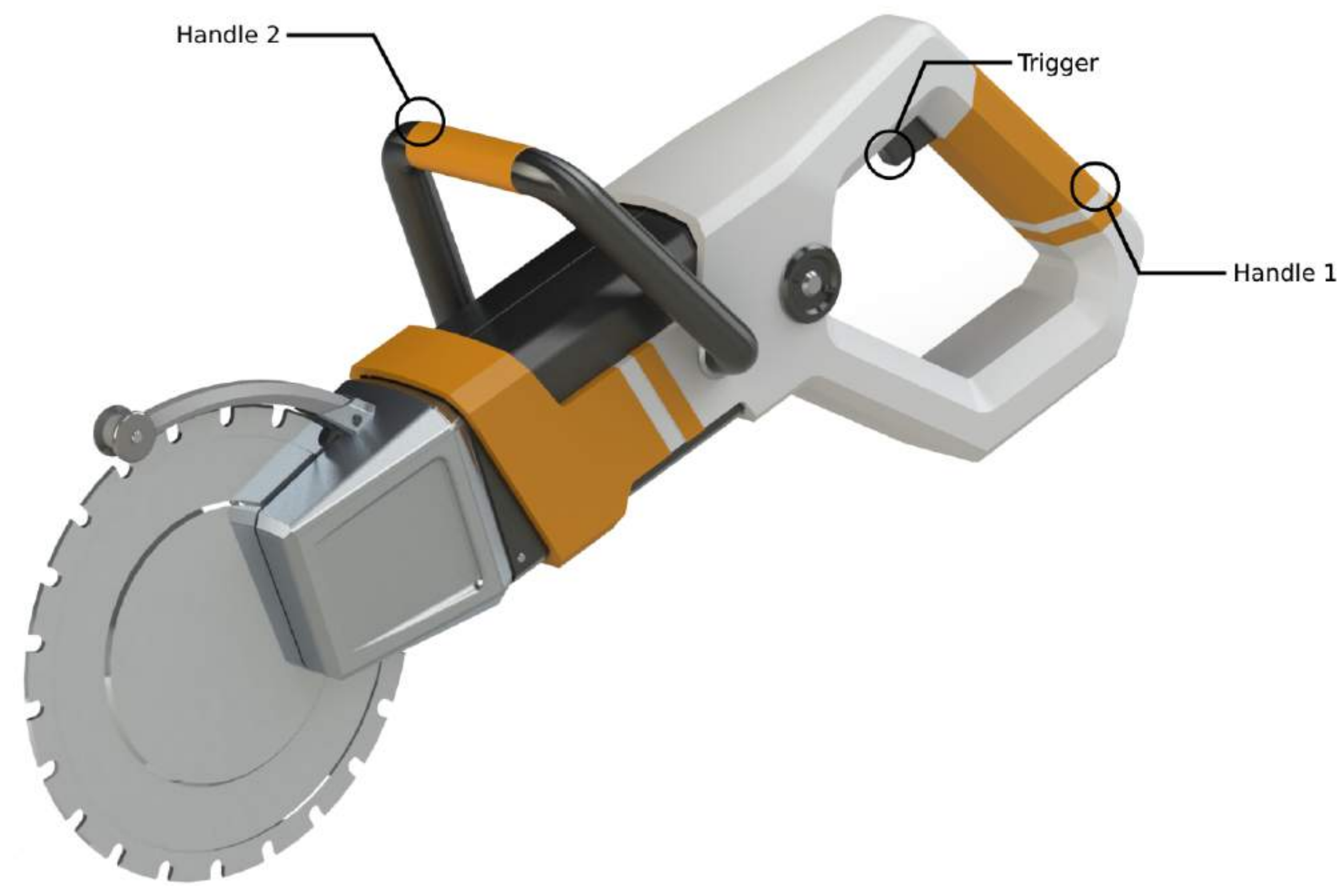


Figure 5.3 - Tool Handle Renders

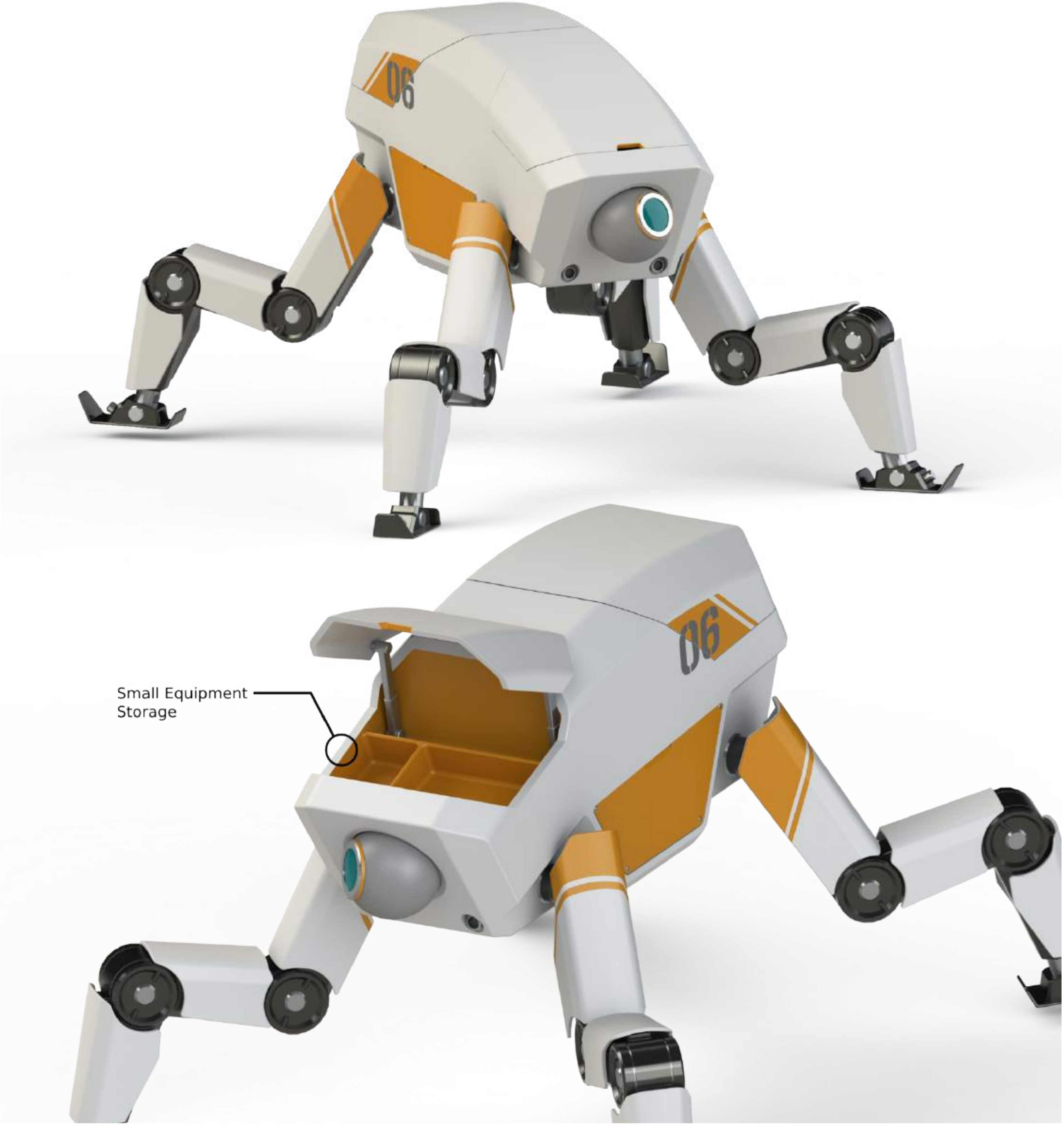


Figure 5.4 - Robot Renders 1

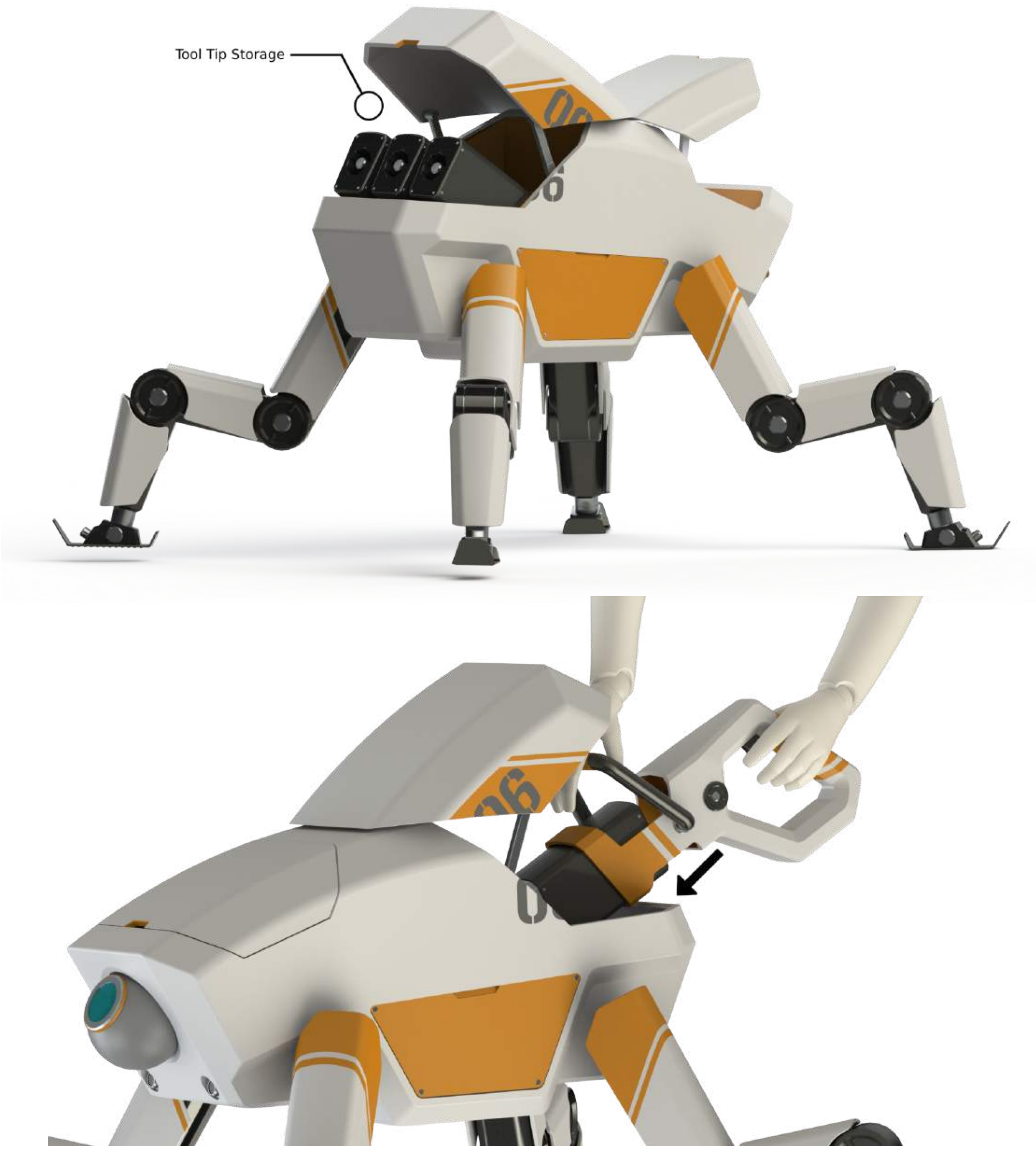


Figure 5.5 - Robot Renders 2

Figure 5.6 - System Render 1

Figure 5.7 - System Render 2

5.4 Physical Model Photographs

Figure 5.8 - 3D Model Photographs 1

Figure 5.9 - 3D Model Photographs 2

5.5 Technical Drawings

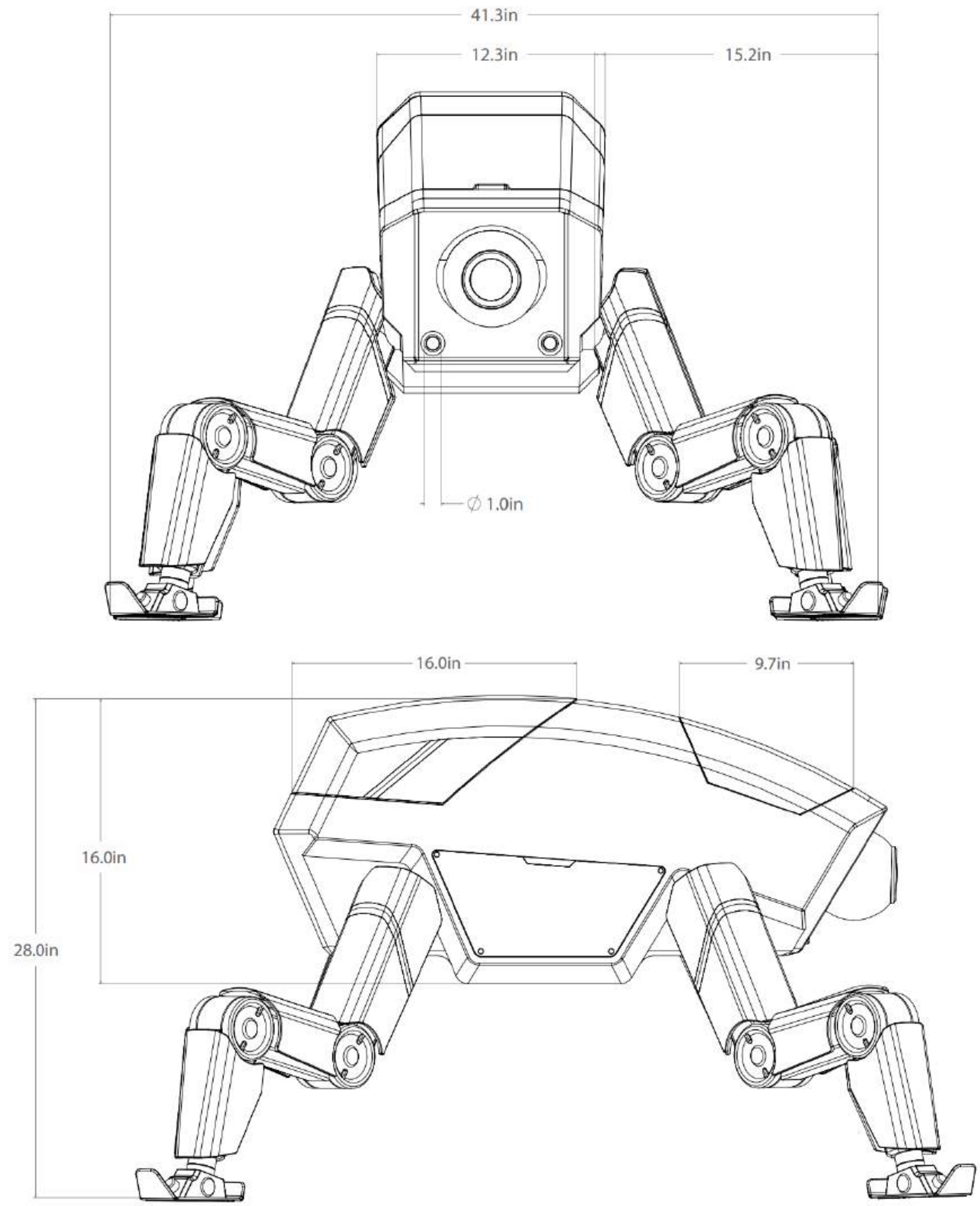


Figure 5.1 - Robot Technical Drawing

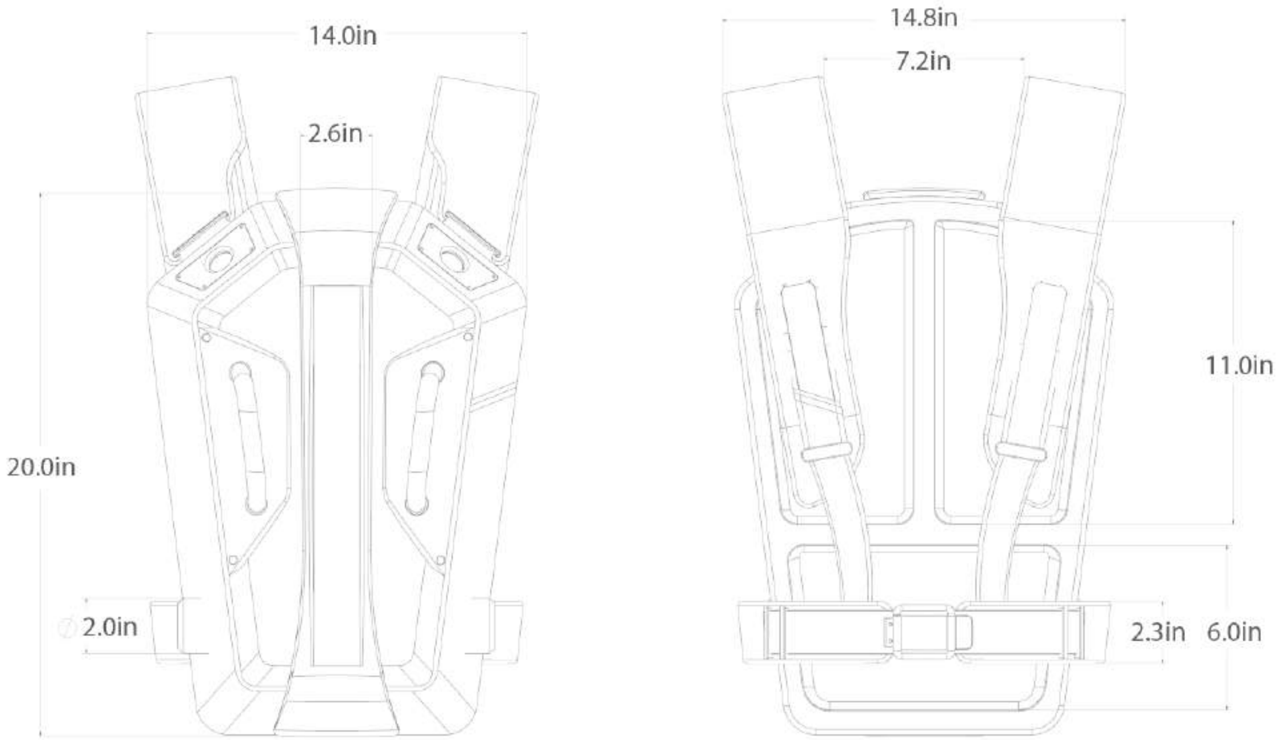


Figure 5.2 - Harness Technical Drawing

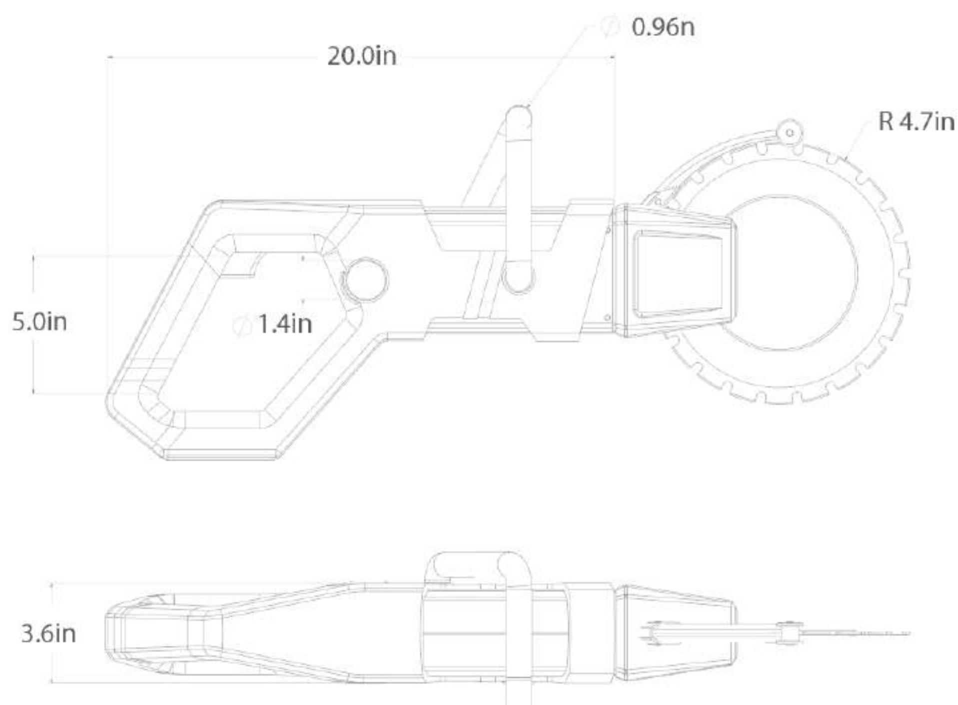


Figure 5.3 - Tool Technical Drawing

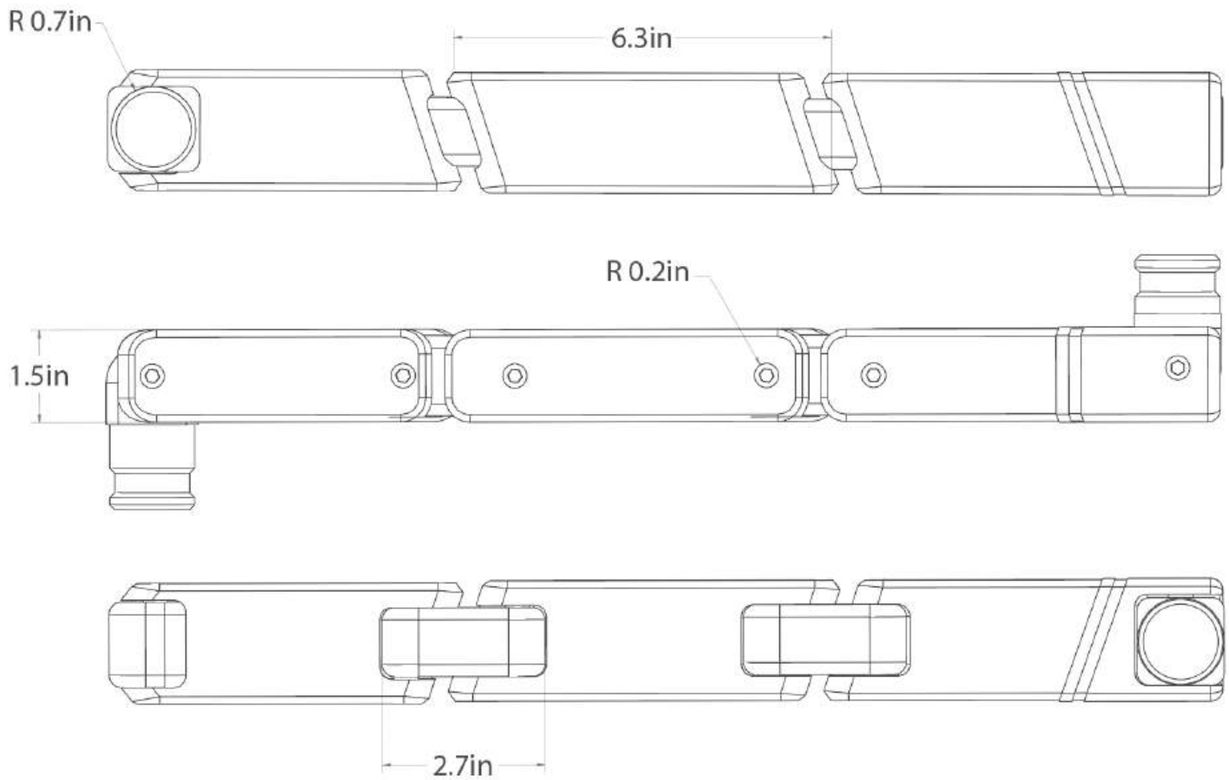


Figure 5.4 - Tool Arm Technical Drawing

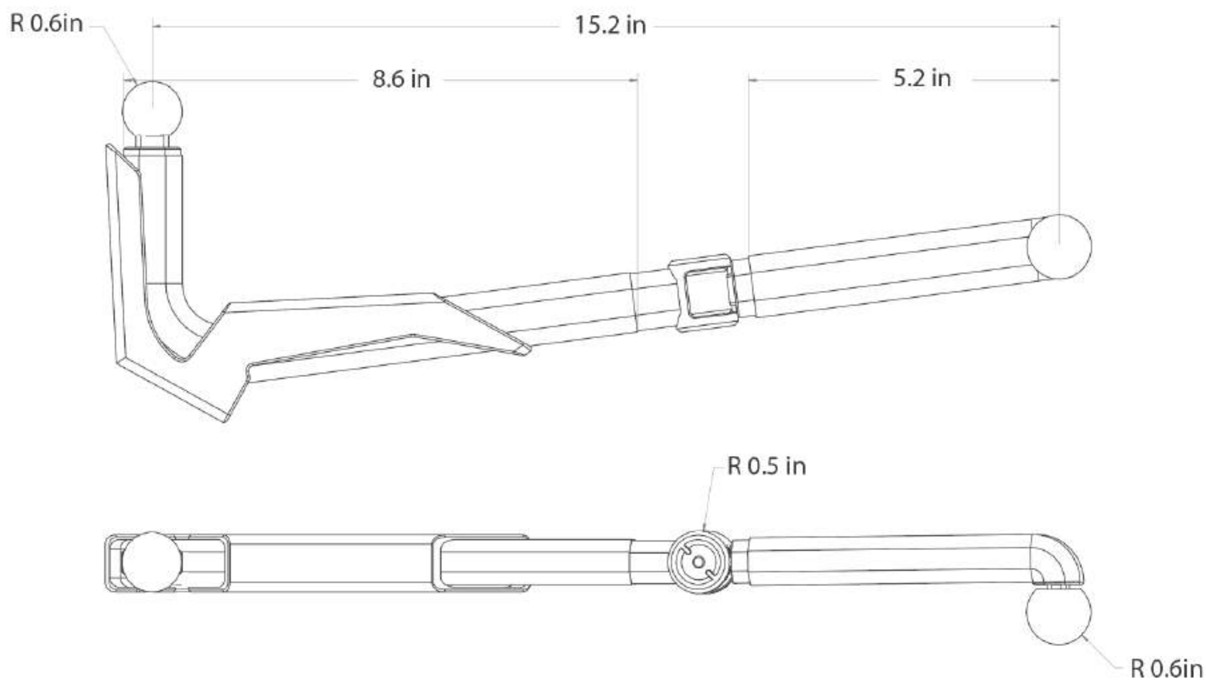


Figure 5.5 - Arm Support Technical Drawing

5.6 Sustainability

Lifeline is intended to have a long life span. Because of this, the sustainability of this product will focus on its long term reusability, rather than short term use and disposal. Applying sustainable practices to the manufacturing and safety of this product will help to both benefit the environment and the user experience.

With the increasing rate of climate change over the past few years, more importance and urgency is being put on companies to create their products in a sustainable, environmentally friendly manner. The material and manufacturing processes chosen for this product aim to help create a sustainable future by reducing energy consumption and reusing recyclable materials. Research was conducted into potentially sustainable manufacturing methods and material choices for the Lifeline system. Materials were chosen that are suitable for the products intended work conditions, while also being recyclable and friendly to the environment. The manufacturing processes were chosen to be sustainable and to utilize recycled plastics and metals. The design of Lifeline allows the user to be comfortable and safe when carrying out their rescue mission. By creating an ergonomic user experience, it can assist the user in removing any unwanted strain on their bodies in high stress environments.

CHAPTER 6

CONCLUSION

Figure 6.1 - Retrieved from https://www.shutterstock.com/image-photo/sichuan-earthquake-memorial-buildings-after-greate-1466228819

Lifeline is an innovative earthquake search and rescue system designed to help remove unwanted stress and strain on the bodies of earthquake rescue workers, ultimately helping to create a safer working environment. Removing these additional strains from their tremendously stressful jobs can result in more efficient and more successful search and rescue missions. Lifeline provides a full bodied user experience that adjusts and moves with its user. Sustainability elements were introduced through the materials and manufacturing methods, as well as its product life cycle. Lifeline provides the user with an innovative, sustainable, human centered design that helps them to make their jobs safer, more effective, and more efficient.

Figure 6.2 - System Render 3

CHAPTER 7

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CHAPTER 8

APPENDICES

A Discovery

Search Topic

Scope: How may we improve earthquake rescue missions to be more efficient in mountainous regions? Many individuals and communities around the world are negatively affected by earthquakes every year. Better equipment for rescue teams and first responders during these natural disasters will allow for a faster, and more efficient rescue and recovery process

Background: Every year, about 60,000 individuals are killed during earthquakes. The rugged terrain and poor transportation infrastructure in mountainous regions result rescue and recovery after an earthquakes being extremely challenging.

Needs Statement: First responders and rescue teams need equipment that can help make their search and rescue missions easier, and more efficient.

How is this need currently being addressed?

Currently, lots of heavy machinery and tools are used to help rescue teams move rubble out of the way, in order to locate individuals trapped within buildings. Hand tools like saws and pickaxes are also often used by rescue workers to help shift rubble when heavy machinery cannot be used. This machinery is often large and heavy. It is difficult to set up and use quickly.

Key Article 1

Method

A key article for this topic was sourced and selected. Required article content (Abstract, Introduction, and Conclusion sections) was copied and highlighted.

- Search Engine: Humber Library Discover

- Keywords Used in Search: “Earthquake rescue equipment”

Findings

Citation: You, C., Chen, X., & Yao, L. (2009). How China responded to the may 2008 earthquake during the emergency and rescue period. *Journal of Public Health Policy, 30*(4), 379-393. doi:10.1057/jphp.2009.30

Key Content: Reproduced below:

Abstract:

This article describes the overall damage caused by the May 2008 earthquake in Beichuan County of Sichuan Province in China and the response over the initial three-month ‘Emergency Response and Rescue Period’ as defined by the Chinese government. We hope to inform people by sharing observations and that lessons from the earthquake can be learned in order to make response to similar disasters more effective in future. We used questionnaires to collect data from the County government authorities, including the health bureau, civil affairs bureau, county hospital, and authorities in four townships, four township hospitals, and four village health posts. In addition, we conducted semi-structured interviews with major directors of each department. The catastrophic damage caused by the earthquake attracted rapid and widespread responses from all the departments within the County as well as many external organizations. The inputs from the central government and other provincial and municipal government authorities, external medical teams, voluntary associations, other countries, and international organizations played important roles in minimizing the risk to survivors and maintaining social order. By formulating emergency plans, departments could more effectively fulfill their functions. Additional strategies are required to enhance cooperation and coordination between different sectors, and to help social organizations and the general public actively contribute so that similar disasters can be more effectively dealt with in the future.

Introduction:

At 14:00 hours on the 12th of May, 2008, an earthquake of magnitude 8.0 points on Richter scale struck Wenchuan County in Sichuan Province, West China. It affected the whole country with the neighboring provinces of Sichuan, Gansu, and Shanxi having the most seriously damaged areas. By 6 July, the official death toll had reached 69 196, with 374 176 persons injured and a further 18 397 persons missing.1 The homes of some six million people were destroyed in the earthquake; farming and business areas also destroyed; and survivors’ lives seriously disrupted. To understand what happened in the severely affected areas and how people responded to the disaster in the initial three months, those declared by the central government to be the ‘Emergency Rescue and Treatment Period’, we investigated Beichuan County, a typically disaster-affected area, in Sichuan Province. Through our research, we wished to share experiences and lessons to inform responses to similar disasters in the future.

Conclusion:

Generally speaking, earthquakes are an unpreventable natural disaster. Nonetheless, the damage wrought by earthquakes can be limited by effective disaster planning and action. The experiences and lessons from Beichuan County show that we should emphasize the following aspects in response to similar disasters: (1) all the related departments should formulate emergency plans and their staff and the general public should be trained on how to deal with major emergencies; (2) people should be encouraged to be self-reliant in emergency situations and that emergency workers should be trained to understand the psychological impact of disasters on individuals and communities; (3) multi-sectoral cooperation and coordination is critical; (4) social organizations should be well organized to participate in assistance.

Summary Statements:

1. By formulating emergency plans, departments could more effectively fulfil their functions.
2. The earthquake that happened on May 12, 2008 in Sichuan China resulted in 69,196 deaths and 374,176 injuries and 18,397 persons missing.
3. The homes of 6 million people were destroyed. Farming and business areas were also destroyed, and the lives of the survivors were seriously disrupted.
4. The damage created by earthquakes can be limited by effective disaster planning and action
5. People should be encouraged to be self-reliant in emergency situations; Emergency workers should be trailed to understand the psychological impact of disasters on individuals and communities.

Key Article 2

Method

A key article for this topic was sourced using Google and selected. Required article content was copied and highlighted.

- **Search Engine**: Google Search
- **Key Words**: “Earthquake search and rescue teams”

Findings

Citation: BBC NEWS (2015). Nepal earthquake: How does the search and rescue operation work?

https://www.bbc.com/news/world-asia-32490242

Key Content: is reproduced below.

Information:

Strong buildings
Rescue workers need to be swift to assess where they are most likely to find survivors inside collapsed buildings. Stairwells or the spaces under large concrete beams can provide what rescue workers call 'voids', in which people may have survived.

Video cameras
Video cameras placed on the end of flexible poles can be squeezed through gaps in the rubble to help locate survivors. Using this technique means time is saved as less rubble is shifted unnecessarily. Thermal imaging equipment can also be used to locate survivors as their body heat can warm the rubble around them.

Listening for survivors
Specialist sound equipment can detect the faintest of noises to within a few metres. Silence on the site is needed

while a member of the rescue team bangs three times and hopes to hear a response. Carbon dioxide detectors can be used to find survivors rendered unconscious. They work best in confined spaces where they detect the greater CO_2 concentration in the air exhaled by those still breathing.

Weak buildings
Many of the buildings in Nepal collapsed in the initial earthquake or the aftershock. Many older neighbourhoods in the capital, Kathmandu, were made up of poorly-constructed brick buildings and these were largely destroyed in the disaster. Fewer, modern structures collapsed.

Local knowledge
Local people often know the best locations to begin the search for survivors. After speaking to them rescue workers can quickly select the most promising place to begin their work. Many local people have also joined in the search for survivors.

Search and rescue
The coordinating agency, usually the UN, and the host country, have to take the difficult decision of when to stop looking for a few remaining trapped people and concentrate resources on looking after the thousands of other survivors. The average time for this switch is between five and seven days, but individuals have been known to survive as long as 13 days, if they have access to water.

Rescue dogs
Dogs are extremely effective at using their sense of smell to pick up on signs of life that human rescuers cannot. They are also able to cover large areas quickly, speeding up the search and rescue process.

Lifting equipment
Diggers and hydraulic jacks are among the heavy machinery that rescue workers employ to shift rubble. Large concrete slabs on the outside of buildings can be pulled aside by diggers, enabling rescuers to get a view of any people still trapped inside. Rescue workers are also taking chainsaws and other power tools to cut through wreckage.

Shifting rubble
Before the heavy-lifting equipment arrives, rescuers use pickaxes and shovels to dig through the rubble. Other tools used by rescuers include chainsaws, disc-cutters and rebar cutters - which can be used to tackle the metal bars in reinforced concrete.

Summary Statements:

1. Rescue workers need to be swift to assess where they are most likely to find survivors inside collapsed buildings.
2. The average time that rescue teams need to stop looking for a few remaining trapped people and concentrate resources on looking after the thousands of survivors is between five and seven days. However, individuals have been known to survive as long as 13 days, if they have access to water.
3. Rescue machinery:

   -Diggers: help to pull aside large concrete slabs on the outside of buildings, enabling rescuers to get a view of any people trapped inside.
   -Chainsaws: Allow rescue workers to cut through wreckage.
   -Pickaxes and shovels: Before heavy-lifting equipment arrives, rescuers use pickaxes and shovels to dig through rubble.
   -Chainsaws, disc cutters, rebar cutters: Help rescue workers tackle the metal bars in the reinforced concrete

B User Research

User Profile Report

Earthquake Rescue Workers perform an extremely dangerous and strenuous job. The work they perform is essential to help save the lives of victims trapped under rubble during an earthquake. To aid them in performing their job at maximum capacity, with efficiency as a priority, we must ensure they have the proper equipment. Making these workers jobs easier and more efficient can result in a greater amount of lives saved by them. Rescue workers undergo a tremendous amount of stress throughout these search and rescue missions. To better understand how to help these workers this report builds a User Profile of an average rescue worker to understand their characteristics. Along with the three main users being identified as a rescue worker, the earthquake victim, and civilians. An image search will be used to gather primary information on the user and what they look like. Literature searches will also be performed to better understand the user demographic and behavior.

User Demographics

Targeted demographic criteria for which general characteristics and information was sought included age, gender, ethnicity, income/ purchasing power, and education.

Image search for General Demographic Characteristics.

A Google Image Search was performed to understand what typical emergency rescue workers look like. The following search terms were used:

- “Rescue Worker”
- “Earthquake Rescue”
- “Earthquake Relief Worker Team”
- “Emergency Rescue

Findings

Findings have been collected in a Table.

IMAGE	**DEMOGRAPHIC INFORMATION**
 *Figure 1 -Philippines Relief Workers. Retrieved from https://www.wsj.com/video/death-toll-rises-from-72-quake-in-the-philippines/93599DFF-1439-4887-8703-C9AE98ED6953.html*	Age: 24-49 Gender: mixed, predominantly male Culture: Philipino Income: uncertain Educational background: College Career/ Volunteer: Mixed
 *Figure 2 - Indonesia, Tsunami relief Workers. Retrieved from https://abcnews.go.com/International/death-toll-powerful-earthquake-tsunami-indonesian-island-tops/story?id=58254722*	Age: 24-49 Gender: mixed, predominantly male Culture: Indonesian Income: uncertain Educational background: College Career/ Volunteer: Mixed
 *Figure 3 - Japanese Relief Workers. Retrieved from https://www.timesofisrael.com/hopes-fade-in-mexico-city-quake-rescue-operations/*	Age: 24-49 Gender: mixed, predominantly male Culture: Japanese Income: uncertain Educational background: College Career/ Volunteer: Career

Literature Search for Demographic Data.

A literature search was also performed on the Humber Library website and Google to find statistical data relevant to rescue workers. The following search terms were used:

- "Earthquake Relief Worker Demographics"
- "Earthquake Rescue Statistics"
- "Earthquake Relief Survey"
- "Firefighter Demographics"

Findings.

Findings have been summarized below according to the relevant categories: Gender; Age; Race and Ethnicity; Income and Education.

Gender.

As inferred from the image search above most rescue workers are male, making up about ~75%. While men are very dominant in the field, women also make up a respectable percentage of workers, accounting for an average of ~25%

		Sex		
		Male (n = 159)	Female (n = 48)	Total (n = 207)
Age(year)	N(%)			
	≤19	6 (2.9)	1 (0.5)	7 (3.4)
	20–29	62(30.0)	14(6.8)	76(36.7)
	30–39	42(20.3)	15(7.2)	57(27.5)
	40–49	19(9.1)	10(4.8)	29(14.0)
	50–59	12(5.8)	6 (2.9)	18(8.7)
	60–69	12(5.8)	1 (0.5)	13(6.3)
	≥70	6 (2.9)	1 (0.5)	7 (3.4)

Figure 4 - Rescuer Demographics. [Image] (2016) Retrieved from https://www.ncbi.nlm.nih.gov/pmc/articles/PMC4960884/#

Age.

Firefighter statistics were identified for this section. Age demographics for Specifically earthquake rescue workers were not able to be identified. Age as seen in the image search was quite diverse for firefighters. Age of workers varied greatly. The ages range all the way to individuals older than 60. The average age of firefighters for both males and females is around 35-39 years old.

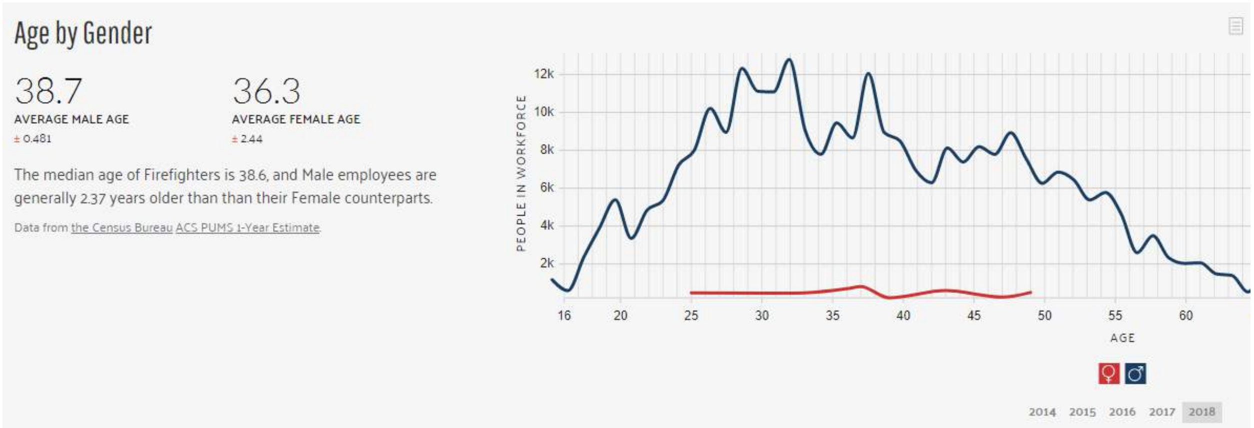


Figure 5 - Firefighter Age by Gender. [Image] (2018) Retrieved from *https://datausa.io/profile/soc/firefighters*

Race and Ethnicity.

Again, American firefighters were chosen for the statistics of this section. No data was able to be located for the ethnicity of rescue workers in Chinese regions. It is inferred that in these regions, the dominant ethnicity would be Asian. As for the data in the image, the predominant ethnicity among american firefighters is shown as being caucasian, which make up over 80% of firefighters. African Americans are the second most prominent Ethnicity. This information can still be relevant as often rescue personnel are flown in from other countries to assist with deadly earthquake emergencies.

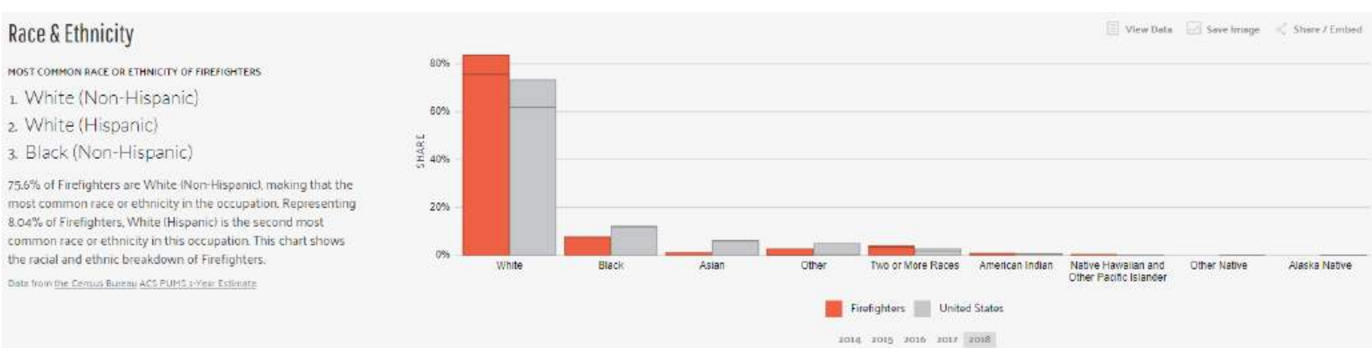


Figure 6- Firefighter Race & Ethnicity. [Image] (2018) Retrieved from *https://datausa.io/profile/soc/firefighters*

Education.

This is hard to determine by simply looking at images, so the demographic data is key to figuring out this information. The data in the image shows survey results from frontline workers during the 2011 Canterbury earthquake. The most common level of completed education was University.

Education (completed)		
Primary school	1	0.8
Secondary school	22	17.1
Technical college	18	12.9
University	88	62.9

Figure 7 -Earthquake Frontline worker education. [Image] (2017) Retrieved from https://search-proquest-com.ezproxy.humber.ca/docview/1901836237?accountid=11530&pq-origsite=summon

Income.

Firefighter wages were selected for this section, as wages of rescue workers in asian countries were unable to be identified. The statistics apply nation-wide for America. The average salary for american firefighters is $70,417/year. The average national salary for firefighters is $53,888/year. It is inferred that firefighters in Asian countries will fall into this earning range.

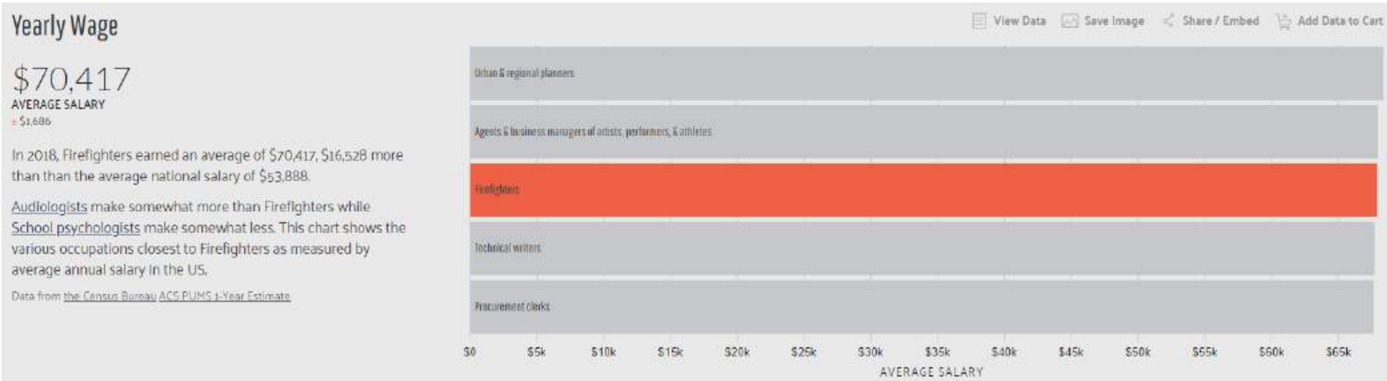


Figure 8 - Firefighter Wage Distribution. [Image] (2018) Retrieved from https://datausa.io/profile/soc/firefighters

Discussion / Conclusions.

Based on the images above, a general overview is understood of who is working as an earthquake rescue worker in an asian country, and what they look like. From the images it can be observed that the typical rescue worker appears to be between the ages of approximately 24 to 49. It is also apparent that most of these rescue workers are of Asian ethnicity. In these instances, the income is a harder statistic to infer as there is really no factor to base that on. An education level of college or a university degree was inferred. With the statistical data in front of us, it is clear to see that the images portray a realistic view of the “average” earthquake relief worker.

Demographics of Firefighters	
Age	24 - 49
Gender	Mostly Male (75%)
Ethnicity	Asian
Income	~$55,000/year
Education	Bachelor's Degree

Figure 9 - Based on data retrieved from https://datausa.io/profile/soc/firefighters, https://search-proquest-com.ezproxy.humber.ca/docview/1901836237?accountid=11530&pq-origsite=summon and https://www.ncbi.nlm.nih.gov/pmc/articles/PMC4960884/#

From this data it is evident that most rescue workers in Asian countries seem to fit into the class of being a 36-year-old male of Asian ethnicity earning around $40k to $50K with a Bachelor's degree

Primary User	Emergency Relief Worker
Secondary User	Victim of earthquake
Tertiary User	Civilian

User Behaviour

A literature search was conducted to discover a rescue workers traits relating to user behavior. For this search Google and the Humber Library website were used to extract relevant information. The following search terms were used:

- "Earthquake Emergencies"
- "Types of earthquake rescue"
- "Earthquake Rescue Deployment"
- "Rescue Worker Fitness"

Findings.

Findings have been summarized below according to the relevant categories: Activity Frequency; Group or Solitary Activity/level of focus; Motivation and lifestyle; Income Level & Purchasing Power; Location; Personality and cognitive aspects.

Activity Frequency.

Earthquake rescue workers must respond to various different types of emergencies and scenarios which require different solutions. The image below showcases the different types of operations that they carry out.

Figure 10 - Earthquake Rescue Operations. [Image] (2015) Retrieved from https://www.bbc.com/news/world-asia-32490242

The image above pinpoints the operations that rescue workers carry out during an earthquake emergency. Some of these operations include gaining knowledge from locals to help search for survivors, using specialized sound equipment to detect faint noises, using extendable, flexible video cameras to squeeze through gaps in rubble to help locate survivors, and operating heavy machinery such as diggers and hydraulic jacks to shift large amounts of rubble and concrete out of the way. (Nepal earthquakes: How does the search and rescue operation work, 2015)

Social.

Due to the cooperative nature of the job, rescue workers must be very vocal with their partners/squad. Communication is vital for rescue workers to effectively do their job. When rescuing trapped civilians, rescue workers must be able to effectively communicate the steps of what must be done. Care must also be given when communicating with civilians in danger. They must be kept calm in these high stress situations.

Lifestyle & Personality.

Rescue workers need to stay in peak physical condition in order to perform well during rescue missions. Because of this, these individuals' lifestyles should reflect what their job requires. Rescue workers are extremely active people; they spend time exercising and performing cardio to improve their stamina and strength. These individuals enjoy hobbies with physical activity when they're not on the job.

Income Level.

Earthquake rescue workers can consist of both professionals, and volunteers. It is difficult to identify an income level for volunteer workers as they may not have the same qualifications or experience that a professional would have. They also may not work as many hours as a professional. Rescue worker volunteers can come from many different countries. Volunteers are able to offer valuable physical or emotional assistance, regardless of their various backgrounds.

Location.

China in specific has its own emergency response and rescue system. These systems can be dispatched to various places in China affected by earthquakes. China has done a lot to ensure that speed, coordination, and relief resource mobilization are the three most critical aspects of response and rescue. (Lu & Xu, 2014) If an earthquake emergency is severe enough, assistance from other countries can be provided to help aid in the rescue and recovery process. The image displays the top 10 deadliest earthquakes in the world since 1900. 3 of 10 were in China, two of which were the 2nd and 3rd deadliest. The region needs effective strategies to help combat the devastation of these events.

Figure 11 -World's Deadliest Earthquakes. [Image] (2020) Retrieved from https://www.statista.com/chart/20443/deadliest-earthquakes-since-1900/

Conclusions.

The user behaviour for earthquake rescue workers relies heavily on their physical abilities and verbal skills. The workers success directly relates to their proficiency in these skills. Countries try to ensure that these skills are met by their workers so that their rescue and response systems can operate to their full potential. Both professionals, as well as volunteers can contribute to making these rescue and response systems as efficient and effective as possible.

User Profile Summary

User	**Description**
Primary	Emergency Relief Worker
Secondary	Victim of earthquake
Tertiary	Citizens

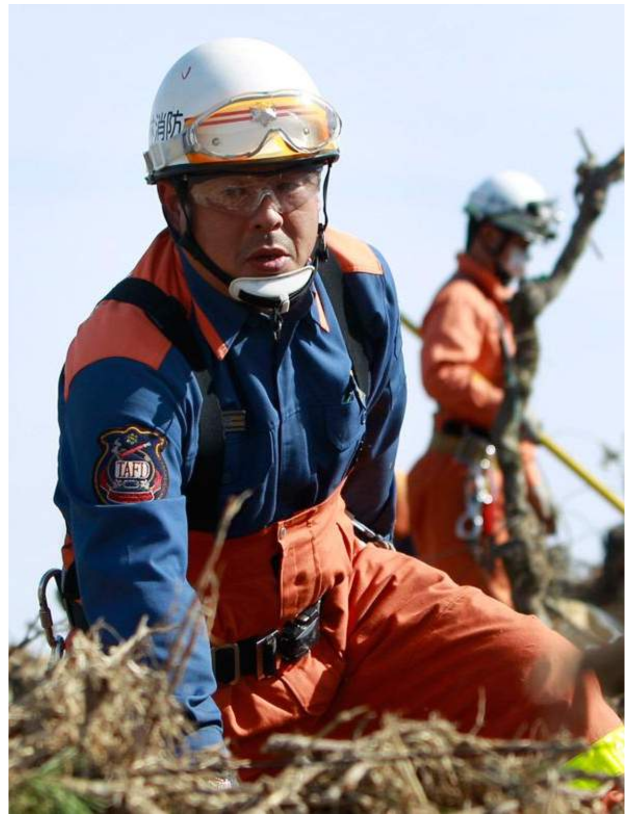
Primary User Profile

Demographics		**User Behaviour**		**Personality**		**Cognitive Aspects**	
Age	24-49	Activity Frequency	High	Locus of Control	□	Technical Skill	□
Gender	Predominantly Male (~75%)	Social	High	Self-Efficacy	□	Prerequisite Knowledge	□
Ethnicity	Asian	Lifestyle	Active	Changeability	□		
Income	Middle Class ($50,000 to $75,000)	Level of Focus	High	Uncertainty Avoidance	□		
Education	Bachelor's Degree	Location	Nation-wide				

Conclusions.

The primary user would most likely be a male between the ages of 24-49 living in China. The user is expected to have high level schooling and receives an average income. The user will on call 24/7 to respond to emergency situations. The user's job is high stress and requires a high degree of focus to accomplish effectively and efficiently. A high level of physical and social skills are required to complete his tasks.

Persona



Name: Li Feng

Age: 38

Occupation: Rescue Worker

Income: $54,000/ year

Education: Bachelor’s Degree - Medicine

Relationship Status: Married, 1 child

Location: Taiwan, China

Career/ Volunteer: Career

Years of Service: 11 Years

Social: Works with 30 other Rescue Workers

Frequency of Activity: Responds to approx. 6 emergency calls/ month

Hobbies: Cycling, Swimming, Weight Training

Profile

Li Feng is a 38 year old Asian male. He has a bachelor’s degree in marketing and earns a yearly salary of about $54,000. Being a rescue worker is his career, and has been working for 11 years. Li Began his career at the age of 27. He decided to pursue this field because he wanted to help save the lives of victims who are affected by earthquakes. He takes great pride in ensuring that he can positively impact people's lives.

User Behavior:

Li is on call at all times to respond to emergencies whenever they may happen. He responds to calls about 6 times a month. Not every call he receives is for earthquake rescue. He works with a team of 30 rescue workers, he has been a part of this team for 5 years. Li has built positive relationships with his teammates. Him and his teammates are able to communicate effectively so that when an emergency call arises, they are able to use those communication skills to efficiently complete their task.

Li's Relationship to his Rescue Equipment:

Li has been using the same rescue equipment since he began his career as a rescue worker. He has used his equipment for many rescue situations. The technology for this equipment is very specialized, and made specifically to aid in earthquake rescue. While the technology is up to date, Li thinks his manual tools are cumbersome and exhausting to use. Even with this issue, Li continues to use his equipment during rescue missions because he knows that it will assist him in saving the lives of people in danger.

User Observation - Empathy Map

Thesis Topic: Earthquake Search and Rescue

Objective of the user observation:

To determine the main pain points of the user while performing a structural collapse search and rescue mission.

User:

John Davidson - Captain, Special Operations
HUSAR Coordinator

User Background:

John Davidosn was first hired as a firefighter in 1992.

5 years ago he became the training officer for special operations, and coordinator for the Toronto Heavy Urban Search and Rescue unit (HUSAR).

Method:

Interview
- Driven by the analysis method- the Empathy Map.
- Questions

Recording Techniques Used
- Transcription app

Analysis:

The Empathy Map
The Empathy Map insights into generates insights into Pains,
and possible solutions which make the task easier, more productive, or more enjoyable?

Questions for Empathy Mapping

WHO are we empathizing with?

1. Tell me about yourself
2. What is your career background?
3. What is your current role with HUSAR?

What do they NEED TO DO?

5. What goes into preparing for a structural collapse rescue mission?
6. What motivates you to perform these missions?
7. What steps are taken during a rescue mission?

What do they SEE?

8. Do you look for anything in specific during rescue missions? Things that need to be noticed?

What do they SAY?

7. What's going on in your head when carrying out a plan or task?
8. How do you communicate with others during a mission?
9. What conversations take place during a mission?

What do they DO?

10. Where do the supplies for these missions come from?

What do they HEAR?

12. Is there anything important that you listen for during these missions?

PAINS:

13. Do you experience any difficulties during these missions?
14. What causes the most frustration during a mission?
15. Have these missions ever caused you grief, or sadness?

GAINS:

15. What is achieved from performing these missions?
16. What is enjoyable about your line of work?
17. How do you feel about the outcome?
18. Was there ever a time when you found the task itself very rewarding?

What other thoughts and feelings might motivate their behaviour?

19. Would anything make the job easier?
20. Would anything make the experience more enjoyable?
21. Would anything make the experience more productive?

Result

Transcript

WHO are we empathizing with?
Tell me about yourself.

My name is John Davidson and I am currently the team coordinator for Toronto HUSAR, Heavy Urban Search and Rescue.

Tell me about your career background

I was hired as a firefighter in 1992 and worked with the Scarborough fire department. I spent a year and a half to two years on a pumper truck. I spent the rest of that career on a squad truck. A heavy rescue, technical operations truck. The disciplines I worked with were confined space, swift water, trench rescue, etc. There were 8 disciplines total. At the age of 23 I became an acting captain. Five years ago I became the training officer for special operations at HUSAR. I look after all 10-06 disciplines for Toronto Fire. 4 years ago, I became the team coordinator for HUSAR.

What is your role with HUSAR

I am currently the team coordinator. I ensure that all teams are organized and fully stocked when going out for a deployment. I also am in charge of resupply and restock of materials when we are out on a job, if needed.

What do they NEED TO DO?
What goes into preparing for a structural collapse rescue mission?

Starting with deployment, in Ontario, because we are a provincial asset, if authority having jurisdiction (AHJ), receives an event, and they realize they need special needs for structural collapse, they contact the ontario fire coordinator, PEOC (Provincial Emergency Operations Center). PEOC Contacts HUSAR. HUSAR calls back the fire coordinator and gets a general outlook of the event. HUSAR then calls the deputy fire marshall, says AHJ requires HUSAR's services. Once we are ready for deployment, the first team we send off is a reconnaissance team. This team consists of upper management, technical operation commander or higher, team incident commander, 2 rescue specialists, 2 logistic specialists. 2 search specialists, 2 medical specialists, 2 K9 units, and a planner. This team would go to the event, size up the situation, and tell us what resources are required. If they need 60 people, we would send 60. We send only what we need. If they need initial team deployment, I notify members that they have to meet up at location X. All potential team members receive medical screenings, and are then issued clothes and equipment. The members are then transported to the event. Once at the event we start establishing emergency action plans. Everything is logged, logistics will set up sleeping quarters, eating areas, etc. Usually team members work for 6 hour shifts, to 12 hour shifts depending on the environment and weather conditions. We rotate shifts until we enter recovery mode. (Until all people are deemed as rescued).

What do they SEE?
Do you look for anything in specific during rescue missions? Things that need to be noticed?

The main thing we look for is a potential secondary collapse. We must ensure that our own safety is not compromised during the mission as well. We set up sensors to track movements in buildings to see if they are stable or not. If the buildings are deemed to be unstable we need to either evacuate the team from the area or evaluate the potential threat and see what the issue could be, and then try to resolve it. We also try to identify the specific type of collapse that occurred and then build our emergency rescue plan around the type of collapse.

What do they SAY?
What's going on in your head when carrying out a plan or task?

I feel many different emotions when we are called out for service. At first it's adrenaline. A positive vision of success is also felt. With the travel to the event, exhaustion sets in, and then you become a little discouraged when you see the disaster and all the damage that has been caused. I think about what must be done in order to carry out a successful rescue, as well as think of backup plans if the initial plans do not work out. I try to stay positive and believe that we are doing the best we can to save the people who are at risk of losing their lives.

How do you communicate with others during a mission?

The main ways we communicate to one another is by cell phone, face to face, and two way radio. Face to face is always the best option to quickly relay information between one another. We also use cell phone communication to speak with other agencies around the country if we are in need of assistance.

What do they DO?
Where do the supplies for these missions come from?

HUSAR has enough supplies to go out for 24 hours, self sufficient. And then have a restock period within three days. What this means is that we provide all of our own materials, from wood, to sleeping bags, to meals. We do not take materials from other communities. I schedule restocks, and resupplies. I see what we are missing, or short on and I create plans to replenish the stock.

What steps are taken during a rescue mission?

First we try to use either local knowledge or technology to identify the locations of potential victims. Depending on the task at hand, we figure out what needs to be removed (concrete, wood, etc). This is done with various different methods. Alternate breach, dirty breach, clean breach. We use saws to cut wood, and use shoring when we breach.

What do they HEAR?
Is there anything important that you listen for during these missions?

The primary thing we listen for is secondary collapse. We use wood to create support structures because it gives us auditory feedback. You can hear the wood cracking and breaking if things are starting to collapse again. We also set alarms with sensors. If buildings begin to move, alarms sound to warn the team members. We either evacuate or stop and understand the reason as to why it's happening. We also use DELSAR, a set of triangulation sensors that are interconnected. These help us to triangulate the sound of victims in order to pinpoint their exact location.

PAINS:
Do you experience any difficulties during these missions?

I do not think there are any pains from an operation planning point of view. It all depends on preparation of materials and team members. Always have back up plans ready so that you are not blind sided and things usually go as smoothly as possible. From a workers perspective, carrying around heavy tools all day can result in strain in the body, and increase fatigue overtime. There are high levels of stress between workers because of the uncertainty of saving lives. Things can always go wrong, and there is stress associated with that. Work hours are also long and strenuous. These work hours result in lack of sleep as well, which can be another pain for workers.

What causes the most frustration during a mission?

Nothing is really frustrating, it's as frustrating as you make it. You have to ensure that everything is planned accordingly and that everything that needs to be done will get done. If you follow the plans, nothing should be frustrating. Every worker has a protocol, and training. We have to use what we have learned to carry out these rescues. If things go wrong, they go wrong. At the end of the day you have to tell yourself that you did the best you could.
Have these missions ever caused you grief, or sadness?

Yes, there have been times when we tried our best to save individuals but they unfortunately died before we were able to get to them, either from dehydration, or bodily harm. When these things happen they are extremely discouraging, but we just have to say to ourselves that we did what we could and tried our best.

GAINS:
What is achieved from performing these missions?

Obviously Rescuing of a person, and providing a unique service to Ontario. Being able to save lives is rewarding and gives you a great sense of accomplishment.

What is enjoyable about your line of work?

The thing that is most enjoyable is the feeling of accomplishment. I'll give you an example. When we went to Mississauga for a house explosion, the whole plan worked out and fell into place. Everything that was planned was carried out perfectly. It was very rewarding to be a part of it.

What other thoughts and feelings might motivate their behaviour?
Would anything make the experience easier or more enjoyable?

I don't think that anything would make my job easier. The way that it is set up, at most, we could use more designated staffing to make things run a bit quicker. But with the way it is working now, I have no complaints. It is a very positive experience. But I think that anything that can solve any of the pains we spoke about would make the job easier as well.

Would anything make the experience more productive?

I believe that currently, our rescue missions are very efficient and carried out well. I think that right now there is no need to improve efficiency.

Analysis

Empathy Map Canvas

1 WHO are we empathizing with?

Emergency rescue worker who is performing search and rescue during a structural collapse disaster

2 What do they need to DO?

Effectively locate victims in danger
Perform various tasks to rescue victims from danger

PERSONA

3 What do they SEE ?

Different types of collapsed buildings (V, Pancake, etc)

Large amounts of damage and rubble from buildings

Secondary Collapse

4 What do they DO ?

Break rubble and create paths into collapsed buildings

Locate trapped victims

Extract victims to safety

PAINS

Fears, frustrations, anxieties

Carrying around heavy equipment

High levels of stress

Long work hours

Little amounts of sleep

Grief, Sadness

GAINS

Goals achieved

Saving the lives of people in need

Helping to make others lives better

Providing a unique service

5 What do they SAY ?

Communicate with team members/squad leaders to create a course of action

Communicate to trapped victims to keep them calm

6 What do they HEAR ?

Communication with other team members

Radio Communication

Listen for secondary collapse (wood cracking, alarms)

What might make this easier, more productive, more enjoyable?

Improving efficiency of carrying around heavy tools

Increase sleep hours, decrease work shift duration

Reduce stress levels during rescue missions

Summary

Major Take-aways from the Empathy Map

In summary, the major takeaways for this empathy map are that the primary pains and gains of structural collapse rescue have been identified. With this information, the process of developing a feasible solution can begin. The primary pains for the user involve carrying around heavy equipment/tools, high levels of stress, long work hours, little amounts of sleep, and grief/sadness. Improving any of these pain points would result in a more positive experience for the rescue worker. Learning the process of what a rescue worker sees, does, says, and hears has also helped with identifying possible solutions. By putting oneself in their shoes, areas can be identified that can be improved to better the quality of life for the user. This empathy map has provided a lot of useful and relevant information regarding what a user does and thinks during a rescue mission.

User Observation - Journey Map

Thesis Topic: Earthquake Search and Rescue

Objective of the user observation:

To determine the main pain points of the user while performing a structural collapse search and rescue mission

User:

John Davidson - Captain, Special Operations
HUSAR Coordinator

User Background:

John Davidosn was first hired as a firefighter in 1992.

5 years ago he became the training officer for special operations, and coordinator for the Toronto Heavy Urban Search and Rescue unit (HUSAR).

Method:

Type of User Observation: Video observation with an expert

Recording Techniques Used: transcription app

Analysis:
User Journey Map
User Experience Map

Method
Brief description of set-up with the expert

Video #1
URL: https://www.youtube.com/watch?v=c5XZWoIURkc&ab_channel=IllinoisFireServiceInstitute

Title: Structural Collapse Rescue Technician

Brief Description: Highlights from the structural collapse rescue technician class. This course offers an intense and physical training opportunity in a simulated collapse environment

Relevance to Thesis Topic: This video demonstrates the tasks that rescue workers need to do in order to rescue victims from collapse environments. My thesis topic aims at improving the efficiency of these tasks.

Results

Transcript

Video Explanation

The first thing we see here is a crane moving a large concrete slab. This is a technique used by rigging specialists, but it is also required to be a rescue specialist. We do this training here in Toronto as well.

Next we see four people using 4x4s and steel rollers to push along an even larger concrete cube. This cube would probably weigh around 4050 pounds. If something large like this was in your way, you would use this technique to move it. A lever can be used to move things like this as well. It's all about mechanical advantage.

At 29 seconds we see people stitch drilling. They're drilling holes into a 3’ triangle, every 2 inches apart. They put the holes to create the breach shape.

At 36 seconds we see a person using a hammer drill to gain access through a slab of concrete.

At 49 seconds, we can see that after the slab is broken through with a dirty breach, they're cutting the rebar out of the way. This can either be done with torches or a rebar cutter.

At 52 seconds shows a vertical overhead breach. This technique is used if rescuers can't gain access to a location from the top, they would need to gain access from the bottom. This is a very messy technique as all the dust and particles goes directly in your face when you're doing it.

At 57 seconds you see a gold paratech wall shoring raker. Steel rods are put into the ground and act as an anchor point to lock the system to the wall. The black pads you see are nailing pads. These allow the raker to be secured together by nailing 2x6 planks in between them. The planks help to stiffen the raker for lateral and horizontal stabilization. There is also a specific nailing pattern that we do to ensure maximum strength of the wood to the nailing pad.

At 1:02 we see a dirty breach to break through the wall. At 1:09 we see rigging again being used to lift a concrete slab.

At 1:21 a ring saw is used to make a clean breach into the floor.

At 1:25 shows the end result of saw cutting for floor breaching. The cuts into the floor are made at an angle. This is to stop the concrete from falling down into the hole once it's been completely cut out. After that, a hole is drilled in the center of the concrete so that it can be anchored and removed from the floor with rigging, pulleys, and cranes. Engineering components are taught to the rescue team. There is a method to the madness. Everything is done for a reason.

At 1:33 we see a saw being used to breach concrete. Concrete is terrible for your lungs so heavy duty respiratory production is a must.

Finally, at 2:11 we can see that the victim is extracted, first aid is provided, and paramedics are able to assess the victim.

Order of Tasks

In terms of how all of these processes are usually ordered, we begin with Preparation and deployment. Once we arrive at the event we try to identify victims through the last known location. We do audible listening and call out to victims to see if anybody responds. We drill holes and use camera systems and K9 units to locate victims. Once a victim is located, we create a rescue plan and perform the best operation for the situation. We determine what we need to get into the building, assess survivability rate. If no victims are located, we move on to the next area.

User Experience

For emotions, once we get the initial call, emotions are positive, we have success in vision and our adrenaline is rushing.

After we begin the long travel to the event, depending on the length of the drive, exhaustion sets in a bit.

Once you arrive at the event you can be discouraged from looking at all the destruction that has been caused.

We conduct a plan, and our emotions are positive. We are anticipated to put the plan in motion.

Once victims are located, it becomes an emotional rollercoaster. It can either be very positive, if victims are found to be alive, emotions are positive. If unfortunately the victims are found to be deceased, emotions are negative. You begin to think that you could have done something more. That something else could have been done so that the victim could have survived.

Once the operation is over and clean up begins, we just need to reassure ourselves that we did our best and did all we were able to do. Sometimes not everyone can be saved, and you have to accept that.

Images

Shown below are samples of the photographs taken from the user observation.
The photographs were generated from the chosen youtube video and camera images taken from HUSAR hq



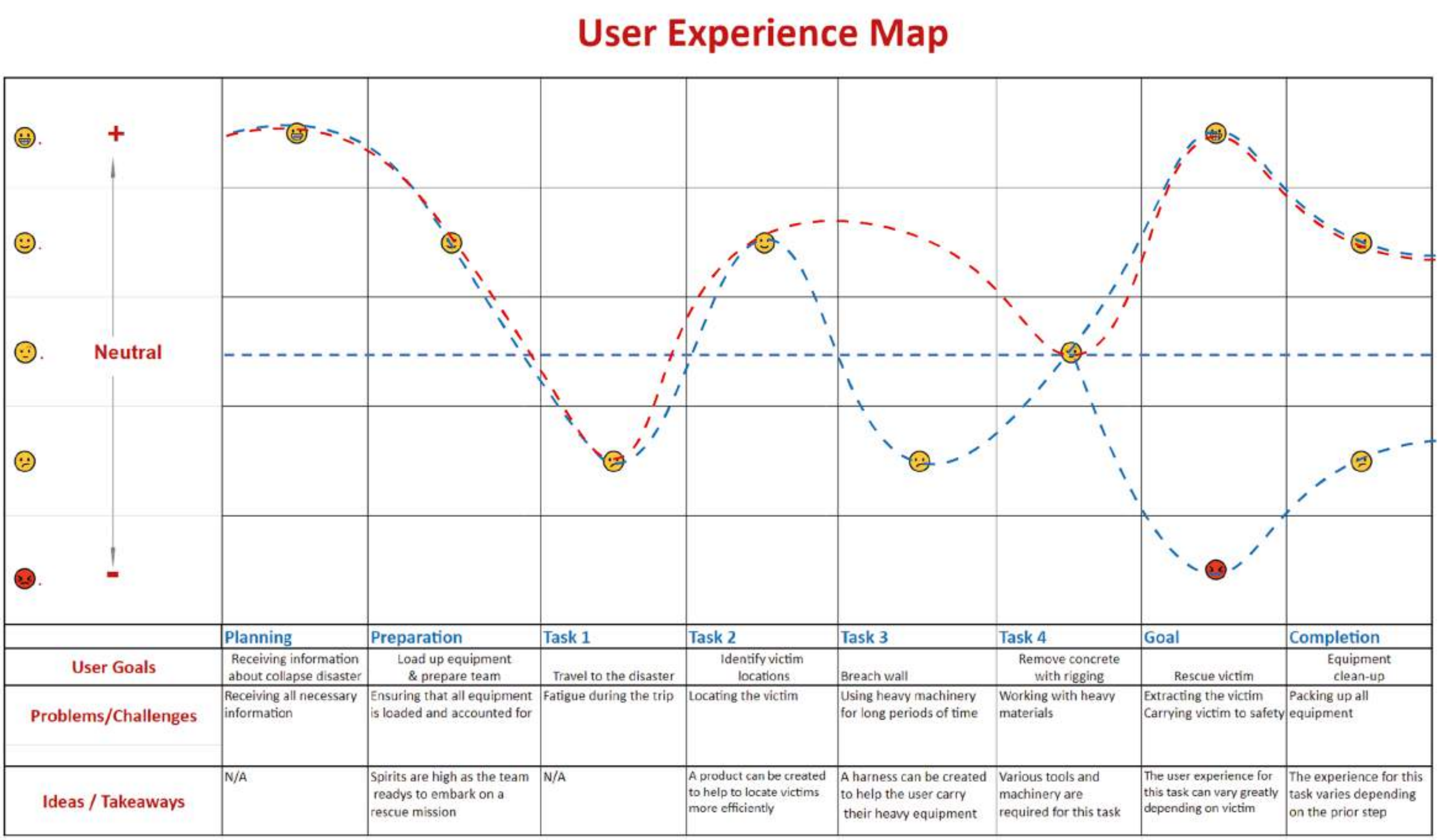








Analysis


User Experience Map
+
Neutral
-
Planning
Preparation
Task 1
Task 2
Task 3
Task 4
Goal
Completion
User Goals
Receiving information about collapse disaster
Load up equipment & prepare team
Travel to the disaster
Identify victim locations
Breach wall
Remove concrete with rigging
Rescue victim
Equipment clean-up
Problems/Challenges
Receiving all necessary information
Ensuring that all equipment is loaded and accounted for
Fatigue during the trip
Locating the victim
Using heavy machinery for long periods of time
Working with heavy materials
Extracting the victim
Carrying victim to safety
Packing up all equipment
Ideas / Takeaways
N/A
Spirits are high as the team readys to embark on a rescue mission
N/A
A product can be created to help to locate victims more efficiently
A harness can be created to help the user carry their heavy equipment
Various tools and machinery are required for this task
The user experience for this task can vary greatly depending on victim
The experience for this task varies depending on the prior step

USER JOURNEY MAP

	Planning	Preparation	Task 1	Task 2	Task 3	Task 4	Goal	Completion
User Goals	Receiving information about collapse disaster	Load up equipment & prepare team	Travel to the disaster	Identify victim locations	Breach wall	Remove concrete with rigging	Rescue victim	Equipment clean-up
User Actions	Receive initial disaster call. Understand the situation and begin preparations to dispatch rescue team	Trucks are loaded with all necessary equipment All team members receive a medical screening and their equipment	Team members are transported to disaster location by plane or truck	Use last known location, audible listening, K9 Unit & cameras to locate victims	Use Jackhammers and concrete saws to breach walls using a triangular cutout shape	Anchor the cut out slabs and remove them with rigging, pully's, or cranes	Extract the victim from the collapsed structure & provide first aid	Pack up all equipment and return back to location of origin
User Thoughts	"Where is the disaster?" "How many team members are required?" "How many days will we be gone?"	"Do I feel 100%?" "Do I have any current Illnesses?" "Do I have all the equipment I need?"	"How long until we get there?"	"Where was this person last seen?" "Which areas have the highest chance for survivability?"	"This is very tiring" "This equipment is very heavy"	"What is the easiest way to do this?" "What is the most efficient way of doing this?"	"Does the victim have any injuries?" "Is the victim going to survive?" "Is the victim alive?"	"We did the best we could" "We saved as many people as possible" "I can finally go home and rest"
Storyboard / Photos								
User Experience								
+ / Neutral / -								
Problems/Challenges	Receiving all necessary information	Ensuring that all equipment is loaded and accounted for	Fatigue during the trip	Locating the victim	Using heavy machinery for long periods of time	Working with heavy materials	Extracting the victim Carrying victim to safety	Packing up all equipment
Ideas / Takeaways	N/A	Spirits are high as the team readys to embark on a rescue mission	N/A	A product can be created to help to locate victims more efficiently	A harness can be created to help the user carry their heavy equipment	Various tools and machinery are required for this task	The user experience for this task can vary greatly depending on victim	The experience for this task varies depending on the prior step

Summary

Major Take-aways from the User Journey Map and User Experience Map

In Summary, the major takeaways from creating this user journey and experience map are that the user experience has been fully analyzed. The research shows that the user has a negative outlook on the wall breaching process. The task is very labour intensive and physically demanding. This is a feasible task that can be improved by an industrial design solution. Attempting to improve this task can result in an overall more positive user experience, as well as reduce the stress and strain put onto rescue workers during these search and rescue missions. Creating this user journey and experience map has provided very valuable information regarding how a user feels, and what could be improved during a structural collapse rescue mission.

C Product Research

Benefits & Features of Comparable Products

Product #1

Husqvarna K970-14" Gas Ring Saw

https://desertdiamondindustries.com/products/husqvarna-k970-14-gas-ring-saw

Promotional Piece

The **Husqvarna K970-14" Gas Ring Saw** lets you cut 10" deep, **twice as deep as standard 14" handheld saws,** which can **reduce excavation** needed to reach pipes and **increase safety**.

New pipe clamp **reduces complexity of job,** adding more **precision, safety** and **ergonomics** to the sawing operator. Thanks to the peripheral drive you can **cut far deeper** than with a traditional power cutter.

Features

1. **Deeper Cuts:** The Husqvarna K970-14" Gas Ring Saw cuts up to 10" deep, **twice as deep as standard 14" handheld saws,** and may reduce excavation needed to get at pipes.
2. **More Power With Less Fumes and Fuel:**The Husqvarna K970-14" Gas Ring Saw's X-torq® engine increases power while reducing emissions and fuel use, and its Smartcarb™ carburetor maintains **high power with less fuel.**
3. **Less Downtime:** With the Husqvarna K970-14" Gas Ring Saw's Active Air Filtration™ and dust-sealed Durastarter™.
4. **Easy to Start:** With the Husqvarna K970-14" Gas Ring Saw's Easystart™ decompression valve.

Product #2

Spreader GSP 5240 EVO 3

https://www.holmatro.com/en/rescue/spreader-gsp-5240-evo-3

Promotional Piece

Spreader - 5000 series, battery-operated model. **Suitable for spreading, squeezing and (with accessories) pulling.** Part of our latest EVO 3 range, **offering a higher speed when it counts (under load)** at a **lower weight and noise level.**

Features

1. **Optimized ergonomic carrying handle design** increases operator **comfort** in various working positions.
2. **Improved LED lighting** in the carrying handle: no less than six lights with a higher light output. **Rescuers can start right away, night and day, without being hindered by their own shadow.**
3. Can also be used in the case of extreme precipitation
4. **Emission-Free:** Healthier for rescuers and victims. **Ideal for use in confined and/or underground spaces**
5. Battery location on top of tool. **Easy access,** even in tight spaces. Replacement without shifting weight
6. **Control handle in central position:** Always within reach on back of tool.
7. Effective profile on the spreading tips: Perfect grip for every situation.
8. New and improved drive unit: **Increased tool speed, decreased weight, lower noise level.**

Product #3

Bosch Breaker Hammer BH2760VC

https://www.rona.ca/en/bosch-breaker-hammer-bh2760vc-330009248

Promotional Piece

The Bosh®Brute Breaker Hammer delivers the best concrete removal rate in its class, impressive for a tool that **weighs just 63 Lbs.** Providing 1,000 BPM and 35 Ft.-Lbs. of impact energy, this tool can **handle heavy-duty applications** such as asphalt work or foundation removal. The Vibration Control system includes a longer air cushion in the hammer mechanism and **shock-mounted handles.** For **longer tool life and better return on investment,** it delivers a grease-packed gearbox and hammer mechanism, **a heat-dissipating hammer tube and rubberized non slip housing cover that helps to prevent accidental fall-over.**

Features

1. Impact-to-Weight Ratio – 35 Ft.-Lbs. impact energy at **only 63 lbs.**
2. **Total portability** – operates on 115/120 V AC/DC, 15 Amp outlet or 2,500-watt portable generator
3. **Ergonomic shock absorbing handles** – also reduces vibration for greater user comfort
4. **Rubberized non slip housing cover** – reduces accidental fall-over
5. **Vibration Control system** – elongated air cushion in the hammer mechanism for **all-day use**

Product #4

Spreader GSP 5240 EVO 3

https://www.holmatro.com/en/rescue/spreader-gsp-5240-evo-3

Promotional Piece

The new Bosch 1191VSRK hammer drill has a powerful 7 A reversing motor which provides the highest performance to weight ratio in its class. It also has an **ergonomic design**. All this means the 119VSRK is engineered to provide the **highest performance to weight ratio in its class**. Use the selector lever to **choose the hammer drill for tough concrete.** Smooth power transmission and **extended tool life**. Variable speed reversing switch to complete control for drilling, driving and removing bits or screws. Select drill only for steel, wood, or aluminum. Kit **includes a 360-degree handle**, depth gauge, and carrying case.

Features

1. **360 degree locking auxiliary handle** to allow for control and comfort in difficult drilling operations.The handle has a **built-in depth gauge for drilling accuracy.**
2. Features a **heavy-duty, three-jaw ½-in. Keyed chuck** that prevents drill bits from slipping during high torque applications.
3. The tool's **pistol grip handle** has a **compact ergonomic design** and is made with a **soft-grip housing,** for additional operator comfort for long-term drilling applications.
4. The **variable-speed trigger** with reversing allows accurate bit stars as well as removing fasteners.

BENEFITS

From Promotional Material

Safety
Reduced excavation
Reduces Complexity
Less Downtime
Reduced Weight
Reduced Noise
Ergonomic
Efficiency
Lower Noise Level
Decreased weight
Accident Prevention
Shock Absorbing
Ergonomic Handles
All Day Use
Ergonomic Design
Extended Tool Life
Drilling Accuracy
Soft Grip Housing
Longer Tool Life
Better Return on Investment
Handle Heavy Duty Applications
Time Efficiency

Sort #1

DATA [On Menu Bar] →

Accident Prevention
All Day Use
Better Return on Investment
Decreased weight
Drilling Accuracy
Efficiency
Ergonomic
Ergonomic Design
Ergonomic Handles
Extended Tool Life
Handle Heavy Duty Applications
Less Downtime
Longer Tool Life
Lower Noise Level
Reduced excavation
Reduced Noise
Reduced Weight
Reduces Complexity
Safety
Shock Absorbing
Soft Grip Housing
Time Efficiency

Sort #2

Groups like categories

comfort	***6***
All Day Use	
Ergonomic	
Ergonomic Design	
Ergonomic Handles	
Shock Absorbing	
Soft Grip Housing	
Safety	***3***
Accident Prevention	
Handle Heavy Duty Applications	
Safety	
efficiency	***13***
Better Return on Investment	
Decreased Weight	
Drilling Accuracy	
Efficiency	
Extended Tool Life	
Less Downtime	
Longer Tool Life	
Lower Noise Level	
Reduced excavation	
Reduced Noise	
Reduced Weight	
Reduces Complexity	
Time Efficiency	

FEATURES		Sort #1	Sort #2
From Promotional Material	Re-order: NOUN first	DATA [On Menu Bar] →	Group like categories
Cut Far Deeper	Advantage: Cut Far Deeper	Advantage: Choose the hammer drill for tough concrete	Advantage 13
Cut Twice as Deep	Advantage: Cut Twice as Deep	Advantage: Cut Far Deeper	Advantage: Cut Far Deeper
Deeper Cuts	Advantage: Deeper Cuts	Advantage: Cut Twice as Deep	Advantag: Total Portability
More power with less fumes	Sustainability: More power with less fumes	Advantage: Deeper Cuts	Advantage: Higher speed when it counts
High power with less fuel	Sustainability: High power with less fuel	Advantage: Easy Access	Advantage: Cheese the hammer drill for tough concrete
Easy to start	Advantage: Easy to start	Advantage: Easy to start	Advantage: Cut Twice as Deep
Suitable for spreading, squeezing	Advantage: Suitable for spreading, squeezing	Advantage: Highter speed when it counts	Advantage: Deeper Cuts
Higher Speed when it counts	Advantage: Highter speed when it counts	Advantage: Ideal for use in confined and/or underground spaces	Advantage: Easy Access
Improved LED Lighting	Advantage: Improved LED Lighting	Advantage: Improved LED Lighting	Advantage: Easy to start
Emission Free	Sustainability: Emission Free	Advantage: Increased Tool Speed	Advantage: Ideal for use in confined and/or underground spaces
Ideal for use in confined and/or underground spaces	Advantage: Ideal for use in confined and/or underground spaces	Advantage: Suitable for spreading, squeezing	Advantage: Improved LED Lighting
Easy Access	Advantage: Easy Access	Advantage: Total Portability	Advantage: Increased Tool Speed
Control handle in central position	Handle: Control handle in central position	Advantage: Vibration control system	Advantage: Suitable for spreading, squeezing
Increased Tool Speed	Advantage: Increased Tool Speed	Body: Built in depth guage	Advantage: Vibration control system
Weight just 63 lbs.	Body: Weight just 63 lbs.	Body: Heat dissipating hammer tube	
Shock-Mounted Handles	Handle: Shock-Mounted Handles	Body: Heavy-duty, three-jaw keyed chuck	Body 8
Heat dissipating hammer tube	Body: Heat dissipating hammer tube	Body: Highest performance to weight ratio in its class	Body: Weight just 63 lbs.
Rubberized non slip housing	Body: Rubberized non slip housing	Body: Only 63lbs.	Body: Built in depth guage
Only 63lbs.	Body: Only 63lbs.	Body: Rubberized non slip housing	Body: Heat dissipating hammer tube
Total portability	Advantage: Total Portability	Body: Rubberized non slip housing cover	Body: Heavy-duty, three-jaw keyed chuck
Rubberized non slip housing cover	Body: Rubberized non slip housing cover	Body: Weight just 63 lbs.	Body: Highest performance to weight ratio in its class
Vibration control system	Advantage: Vibration control system	Handle: 360 Degree locking auxiliary handle	Body: Only 63lbs.
Highest performance to weight ratio in its class	Body: Highest performance to weight ratio in its class	Handle: Control handle in central position	Body: Rubberized non slip housing
Choose the hammer drill for tough concrete	Advantage: Choose the hammer drill for tough concrete	Handle: Includes a 360 degree handle	Body: Rubberized non slip housing cover
Includes a 360 degree handle	Handle: Includes a 360 degree handle	Handle: Pistol grip handel	
360 Degree locking auxiliary handle	Handle: 360 Degree locking auxiliary handle	Handle: Shock-Mounted Handles	Handle 6
Built-in depth gauge	Body: Built in depth guage	Handle: Variable-speed trigger	Handle: Control handle in central position
Heavy-duty, three-jaw keyed chuck	Body: Heavy-duty, three-jaw keyed chuck	Sustainability: Emission Free	Handle: 360 Degree locking auxiliary handle
Pistol grip handle	Handle: Pistol grip handel	Sustainability: High power with less fuel	Handle: Includes a 360 degree handle
Variable-speed trigger	Handle: Variable-speed trigger	Sustainability: More power with less fumes	Handle: Pistol grip handle
			Handle: Shock-Mounted handles
			Handle: Variable-speed trigger
			Sustainability 3
			Sustainability: More power with less fumes
			Sustainability: Emission Free
			Sustainability: High power with less fuel

Benefits Table

Key Benefits of Comparable Products	
Keyword	***Frequency***
Comfort	6
Safety	3
Efficiency	13

Features Table

Key Features of Comparable Products	
Keyword	***Frequency***
Advantage	13
Body	8
Handle	6
Sustainability	3

D Analysis

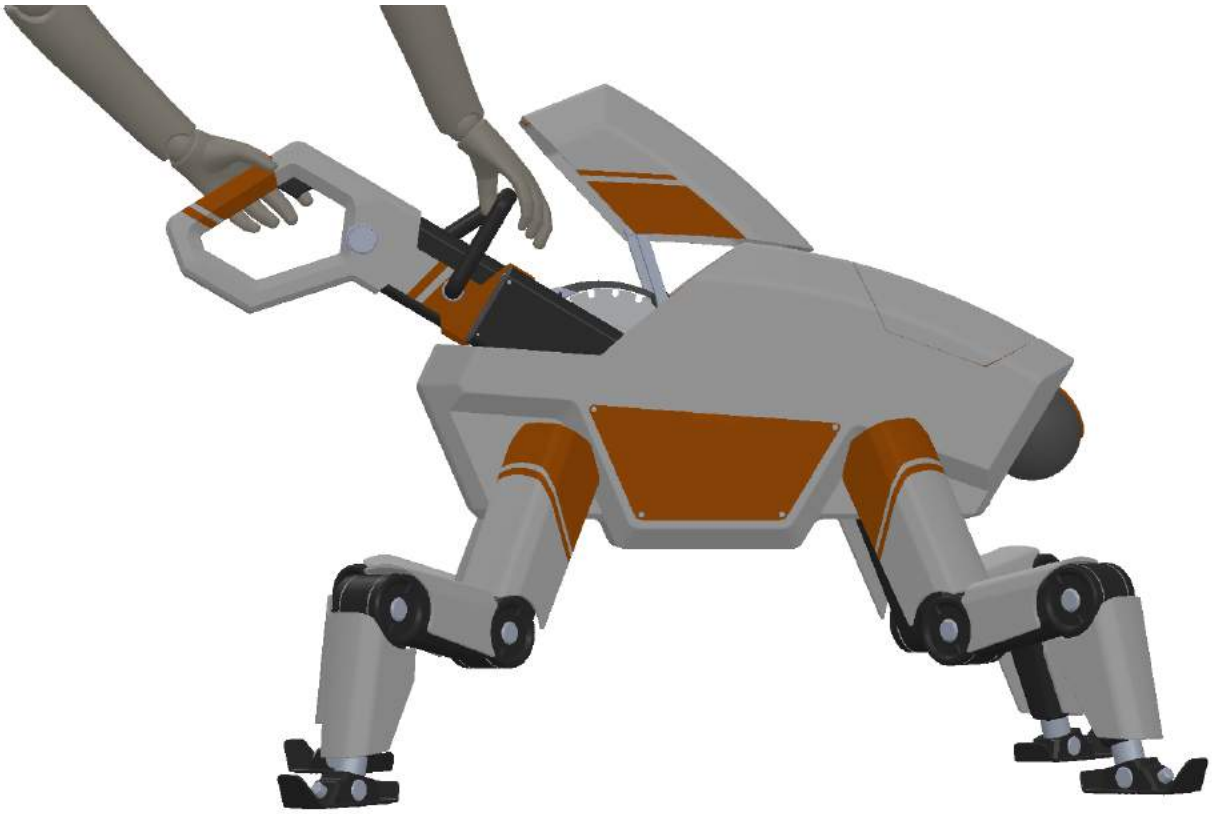
Why Should We?

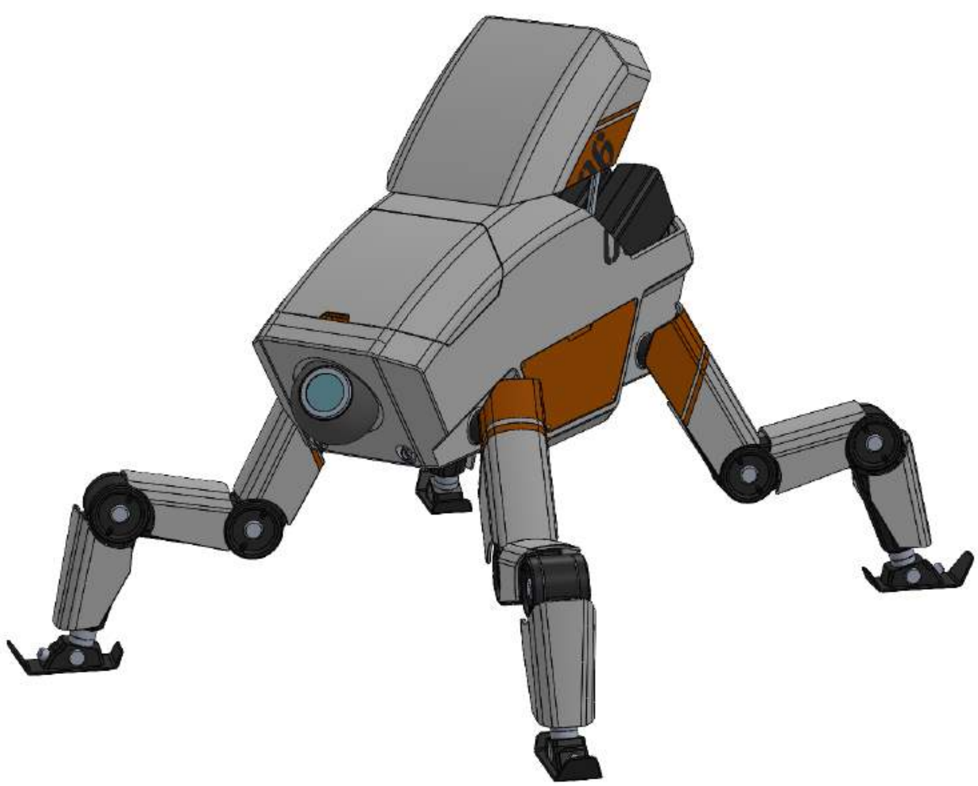
What Fundamental Human Needs [FHN] does this topic or 'problem space' address?						
NEEDS		**DESCRIPTION**	**COMMENTS BASED ON EVIDENCE & EMPATHY**			
Category of Fundamental Human Needs **(Max-Neef)**	Category of Psychological Needs **(Maslow)**	Interpretation of possible relevance to design problem space	Comments about Needs discovered in topic/problem space (include source from discovery search, if possible)	Level of Importance		
				Slight	Moderate	High
Basic Needs						
Subsistence			A solution to my problem would rely more on supporting others, rather than supporting oneself, but it could potentially be an option as well		Moderate	
Protection			The protection of both rescue workers and earthquake victims is of highest importance			High
Affection			A minimal level of affection should be given to victims who are being rescued during these natural disasters		Moderate	
	Physical (the need for air, water, food, rest, health)		Earthquake victims require many physical needs to remain healthy and survive			High
	Security (the need for safety, shelter, stability)	-control over one's environment -value, in terms of fulfilling a need at lower price and enhancing access, reliability	A solution to my problem must provide safety and security. It must give victims hope that they will be ok			High
Social Belonging (Effort/ resources to belong to a 'tribe')						
Understanding			A moderate degree of understanding should be required by rescue personnel to operate this effectively		Moderate	

Participation	-convenience, in terms of speed (fast, uses less time) -optimization of limited resources	It is very important for a solution to speed up the rescue process and make the most of what is given during a earthquake scenario			High
Leisure		Leisure is very unimportant as this solution would not be used in anything else but a medical emergency	Slight		
Social (the need for being loved, belonging, inclusion)	-fear of abandonment -fear of the enemy -Tribal identity (belonging to the winning team) -Peer Pressure (direct and indirect 'Everybody else has it') -could also consider ease of use that permits participation where participation had been limited	There is potential that rescue staff can deal with uncontrollable loss of life while on the job. This can give rescue workers the fear of failing to do their job		Moderate	
Ego (the need for self-esteem, power, recognition, prestige)	-social expectation -social status (the elite has it.. I want to be like them) -social recognition -convenience and ease of use that enhances social recognition -gift giving: reciprocal social covenant	Ego would not be very important as a solution to my problem would not be used in an everyday social setting. Social status and social recognition would not provide anything a solution	Slight		
Personal Accomplishment					
Creation	-could consider the convenience aspect of a product (tool) that amplifies human abilities -ease of use	The solution must be extremely easy to use and convenient. Workers must be able to operate it under extremely high stress scenarios and environments			High
Identity	-could relate to the next generation and be longer term / less immediate. Examples: sexual attractiveness; the health/care/education of children -environmental sustainability	Sustainability should be of moderate importance. A solution should be meant to last many years and the manufacturing processes and materials used should be environmentally		Moderate	

		sustainable			
Freedom	-convenience in terms of availability (is it easy to buy)	The solution would primarily be operated by rescue and medical personnel. Because of this, it will not be easy to purchase or available to everyone	Slight		
Self-Actualization (the need for development, creativity)	-includes sensual pleasure, such as: visual, acoustic, tactile, haptic, taste, olfactory -includes aspects of emotional response, such as: empathy, excitement, fun, nostalgia, memory, etc. -could also include compulsive behaviours, such as: buying, gaming, smoking, drinking, sex, adrenaline rush, etc. -aesthetically pleasing -intrinsic pleasure -the ability to prepare for the future in terms of insurance (house, car, medical), pension, investments	A solution should be tactile, aesthetically pleasing, and include aspects of emotional response. These aspects would help to greatly increase the user experience		Moderate	

E CAD Development





F Approval Forms

Thesis Topic Approval (Topic Descriptive Summary)

Student Name: Luca Domenis

Topic Title: How may we improve earthquake rescue missions to be more efficient in mountainous regions.

Abstract:

Earthquakes are unpredictable and unpreventable natural disasters that can cause catastrophic damage to cities, and their inhabitants around the world. Mountainous regions are affected greatly by these earthquakes because of their geographical location. Severe damage is caused to communities, and the lives of the people living there are greatly endangered. How can we make rescue missions in these mountainous regions more efficient? Rescue workers undergo tremendous amounts of stress throughout these search and rescue missions. Making their jobs easier and more efficient can result in a greater amount of lives saved by them. An in-depth study on the challenges that these rescue workers face will be conducted. Data will be collected through observational studies, interviews, and surveys. Analysis of this data will focus on improving the efficiency of rescue workers, and eliminating any problems that they currently face. A one to one model will be developed to better understand proper human factors and full-bodied human interaction design. This study will result in a design solution that will enhance the efficiency of rescue workers, and increase the odds of saving individuals lives who are negatively impacted by earthquakes in mountainous regions.

Student Signature:

Date: 05/10/2020

Instructor Signature(s):

Date: 07/10/2020 Catherine Chong

CRITICAL MILESTONES: APPROVAL FOR CAD DEVELOPMENT & MODEL FABRICATION

Student Name:	**Luca Domenis**
Topic / Thesis Title:	**Earthquake Search & Rescue Solution**

THESIS DESIGN APPROVAL FORM

Thesis design is approved to proceed for the following: X	**CAD Design and Development Phase**
Comment: Initial CAD progress well as of week #7/March 1st, continue with detailing and refinement.	

Thesis design is approved to proceed for the following: X	**Model Fabrication Including Rapid Prototyping and Model Building Phase**
Comment: Design development progress well as of week #7/March 1st, once CAD is completed, can move forward to model fabrication from week #9 onward.	

Instructor Signature(s): Catherine Chong Sandro Zaccolo	
Date:	10th March 2021

PANEL ON RESEARCH ETHICS

Navigating the ethics of human research

TCPS 2: CORE

Certificate of Completion

This document certifies that

Luca Domenis

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

Date of Issue: **4 October, 2020**

G Advisor Agreement Forms

IDSN 4002 /4502
SENIOR LEVEL THESIS ONE & THESIS TWO

HUMBER
Faculty of Applied Sciences & Technology
Bachelor of Industrial Design / FALL 2020 & WINTER 2021

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.

understand that the data from this study may be published.

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

John Davidson		October 26, 2020
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: (416) 276-8607
Email: luca.domenis

My supervisors are:

Prof. Catherine Chong, **catherine.chong@humber.ca**
Prof. Sandro Zaccolo, **sandro.zaccolo@humber.ca**

1

HUMBER
Faculty of Applied Sciences & Technology
Bachelor of Industrial Design / FALL 2020 & WINTER 2021

IDSN 4002 /4502

SENIOR LEVEL THESIS ONE & THESIS TWO

PARTICIPANT INFORMED CONSENT FORM

Research Study Topic: How may we improve earthquake rescue missions to be more efficient in mountainous regions?

Investigator: Luca Domenis, (416) 276-8607, luca.domenis@gmail.com

Courses: IDSN 4002 & IDSN 4502

I, John Davidson have carefully read the Information Letter for the earthquake search and rescue project, led by Luca Domenis. A member of the research team has explained the project to me and has answered all of my questions about it. I understand that if I have additional questions about the project, I can contact Luca Domenis at any time during the project.

I understand that my participation is voluntary and give my consent freely in voice recording, photography and/or videotaping; with the proviso that my identity will be blurred in reports and publications.

Consent for Publication: Add a (X) mark in one of the columns for each activity

ACTIVITY		YES	NO
Publication	I give consent for publication in the Humber Library Digital Repository which is an open access portal available to the public	☒	☐
Review	I give consent for review by the Professor	☒	☐

Privacy

All data gathered is stored anonymously and kept confidential. Only the principal investigator /researcher Luca Domenis and Prof. Catherine Chong or Prof. Sandro Zaccolo may access and analyze the data. All published data will be coded, so that visual data is not identifiable. Pseudonyms will be used to quote a participant (subject) and data would be aggregated.

I also understand that I may decline or withdraw from participation at any time, without negative consequences.

I understand that I can verify the ethical approval of this study, or raise any concerns I may have by contacting the Humber Research Ethics Board, Dr. Lydia Boyko, REB Chair, 416-675-6622 ext. 79322, **Lydia.Boyko@humber.ca** or Luca Domenis, (416) 276-8607, luca.domenis@gmail.com

Verification of having read the Informed Consent Form:

☑ I have read the Informed Consent Form.

My signature below verifies that I have read this document and give consent to the use of the data from questionnaires and interviews in research report, publications (if any) and presentations with the proviso that my identity will not be disclosed. I have received a copy of the Information Letter, and that I agree to participate in the research project as it has been described in the Information Letter.

John Davidson		October 26, 2020
Participant's Name	Participant's Signature	Date

2