Thesis Design Dossier

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Vigilo – Police Communication and Safety Gear

by

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Abstract

Law enforcement officers (LEO) face many dangerous scenarios in their line of work, leading to hundreds of officer fatalities per year in the United States alone. According to FBI statistics, many casualties and injuries are firearms- and traffic-related, with many more as the result of accidents. Some trends indicate a rise in gun violence as a cause, with other research pointing towards militarization of the police as a precursor to the rise in gun violence. From a sociological standpoint, negative sentiment towards law enforcement has also been growing due to cases of abuse of authority and civilian casualty. A literature review was completed to gain a background on police safety and public perception, while one-on-one interviews and external sources for user observation will be used for further analysis of LEO behaviours and actions. Including a benchmarking of existing solutions and user activity mapping, the goal is to guide the design process to a solution for improving officer safety. Law enforcement officers perform a crucial role in helping to keep communities safe and responding to criminal activity, likewise, it is also crucial to ensure their safety as well.

Acknowledgements

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A thank you for my friend who became my advisor on this project for providing me with the necessary knowledge and resources on law enforcement to help better understand my chosen topic and develop a solution to the challenge at hand.

Special thanks are owed to my family for supporting me throughout my design education, and to my brother, Eric, for being the reason I ever pursued industrial design and giving me the boost that I needed to get to where I am now.

A final thank you is for my close friends who kept me grounded and supported me when I thought I couldn’t keep going forward anymore.

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Chapter 1 – Introduction

This chapter will introduce the topic of this thesis report and the problems and challenges that law enforcement officers have to handle in their line of work. It will explain the rationale and methods planned for research, as well as any impacting background trends.

Figure 1 - Toronto Police, Jeremy Gilbert - Retrieved from https://www.flickr.com/photos/jer1961/44561216351/

1.1 Problem Definition

Law enforcement can be a very dangerous occupation with the various scenarios that officers may find themselves in. It frequently involves officers responding to criminal activity, calls for help, traffic incidents, and other disturbance calls. FBI statistics (2020) report up to hundreds of officer fatalities in the United States alone, with primary causes being felonious, via

firearm, or traffic-related and accidental. Meanwhile, Toronto Police Service (2021) reports tens of thousands of assault cases per year, accounting for 50% of all major crime indicators. This thesis report will follow the process of understanding the challenges that law enforcement officers encounter in their line of work while seeking to reach a design solution that can assist them in dangerous encounters.

1.2 Rationale and Significance

1.2.1 Key Information to be Determined

The most important information that needs to be understood is who the primary user is, as well as any potential secondary or tertiary users. Additionally, the user's needs, pain points, and any regulations will be key to guiding any solution. The types of products that LEOs use and the current solutions for officer safety will also be compared and evaluated to determine what current standards have been set.

1.2.2 Key Questions to be Answered

Before progressing with the design phase, there are key questions that will need to be answered. For example, asking what kind of equipment is common or required, the kinds of activities that officers are involved in, mistakes that can result in injury or fatality, and user experience on the job. Questions such as these can reveal more key information that is not as readily available and provide valuable insights to common pain points.

1.2.3 Investigative Approach Planned

In order to acquire the aforementioned key information and decide on a direction, a plan is needed. The planned methods that will be used are listed below:

- Literature reviews
- Information searches
- Product benchmarking
- Expert advisor interviews
- User observations
- Activity mapping
- Needs analysis

The intent behind these activities is to gain a better understanding of what information is available and what current solutions are on the market. They can then be compared and contrasted with information gained from an expert in the field of law enforcement to gain insights of possible opportunities or gaps in the market for a new solution.

1.3 Background / History / Social Context

1.3.1 Demographic and Lifestyle Trends

The vast majority of law enforcement officers are male, with 78% of Canadian law enforcement officers in 2019 being male (Jeudy, 2021). The number of female officers, however, are steadily increasing, and 30% of Canadian officers is a significant enough population for both genders to be accounted for.

The life of a law enforcement officer while on-duty can be quite stressful, with a lot of stress due to long work hours and dealing with paperwork or interacting with people. Situational awareness and training to be ready to react and respond is important. However, for most officers, it is a dream job and something that they want to do.

1.3.2 Media Trends

Law enforcement is being observed under a microscope by media and the general public. Due to widely publicized cases of improper use of force, abuse of authority, or racially-motivated actions, the police are often portrayed in a negative light. According to Masera (2021), there is also a growing negative sentiment on the militarization of the police as well. On the opposite side, there are many who openly support the police as a whole and promote an understanding of their actions. One thing that remains constant is the reporting of assault cases, shootings, and other violent crimes.

1.3.3 Product Trends

Common trends in some North American law enforcement agencies are the acquisition of military surplus equipment, such as body armour, rifles, and armoured vehicles. Increasing use of less-than-lethal weapons and equipment have also seen increased use, as well as utility such as body cameras. Some police forces have even begun to use robots for specialized tasks or increased coverage, although their effectiveness and public reception remain a point of contention.

Chapter 2 – Research

Research is a key component to understanding a problem and discovering where to focus design efforts. This chapter will outline potential users, map their activities, and benchmark existing market solutions and ergonomic factors.

Figure 2 - Toronto Bike Police at CN Tower - Christopher Katsarov – The Canadian Press – Retrieved from https://www.rcinet.ca/en/2018/07/12/toronto-police-ramp-up-patrols-over-potential-risk-to-public-safety/

2.1 User Research

2.1.1 User Profile – Persona

A fictional persona was created based on common user profiles and descriptions of law enforcement officers and serves as the basis for a primary user (see Table 1). The persona description is applicable to both male and female users.

Name	Tony / Tanya Jackson
Age	35 years old
Occupation	Police Officer Rank - Sergeant
Education	High school diploma Police college graduate
Relationship	Married w/ children
Location	Toronto, Ontario
Work Hours	Up to 12 hours per shift+ overtime, day or night varies
Other Notes	• Law enforcement is a big part of personal and family history • Being a police officer is essentially a “dream job.” • Worked in law enforcement for over a decade • Experienced military training in the past; disciplined

Figure 3 - Officer Persona Male - Retrieved from https://www.pexels.com/photo/man-people-woman-street-7714757/

Figure 4 - Officer Persona Female - Retrieved from https://www.pexels.com/photo/man-people-woman-street-7714757/

Table 1 - User Persona

Primary User

The primary users can be described as the first responders and backup responders.

These are the officers that are most often involved in responding to calls.

Secondary User

Secondary users, as they relate to law enforcement, can include more backup responders, investigative and forensics personnel, emergency medical services (EMS), fire services, victims, and any civilians or bystanders at a scene.

Tertiary User

Tertiary users may involve mechanics, engineers, computer technicians, or software engineers that handle the maintenance certain equipment, as well as police dispatch.

2.1.2 Current User Practice

Expert Interviews / Surveys / Discussion Boards

The chosen method for learning about the involved users was through one-on-one interview-style correspondences with a Police Foundation graduate knowledgeable in Canadian law enforcement, Ontario in particular. (See Appendix B and Appendix C).

Following the first interview with the advisor, an initial understanding was gained regarding the kinds of situations officers may find themselves in, their thoughts and feelings, and what they do. This led to the forming of an empathy map. The empathy map poses questions that, when answered, can help gain insights on a potential user's experience.

Over a series of different interviews with the advisor, the questions asked included:

- What are some of the most common calls that police take?
- What are some of the most dangerous calls, or ones that have the most potential to get violent?

- What is the experience like while on-duty?
- Are there any crucial mistakes that can cost someone their lives?
- Can you list some common equipment that most officers have at any given moment? (e.g., weapons, protective equipment, utility, etc.)

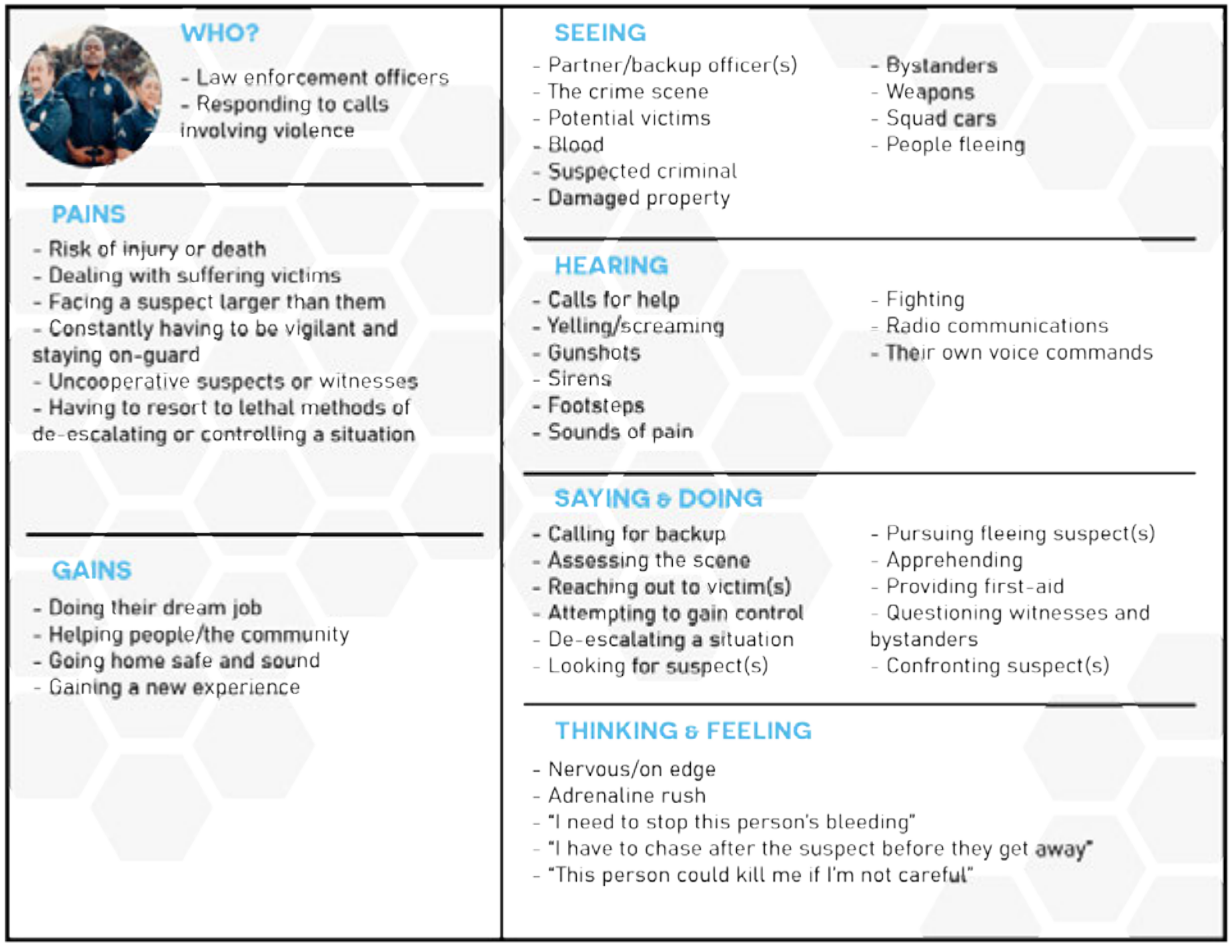


Table 2 - Empathy Map

During the first interview, the advisor stated that the amount or type of crime can vary per season. Some common offenses included driving under the influence and minor theft (under $5000). The most common calls are public disturbances, and during summer and winter holiday season assault cases tend to be higher. A source was provided with publicly available

statistics on major crime indicators in Toronto, Ontario, that showed assault cases making up for 51.35% of all crime in 2021 as of December. Among the more dangerous calls for an officer to respond to, assault cases can be at the top due to the potential for weapons to be involved, such as blunt objects, knives, or firearms. Gang-related crimes are dangerous for the same reason, as there are very often weapons involved. Domestic violence calls can also be very volatile, with a high risk of a calm situation turning violent. In addition, officers will often be in a tight, unfamiliar space, such as a house or apartment, where there can be a potential for weapons, the suspect has the advantage, and may even be intoxicated. Other factors that can make a situation dangerous is weather impacting mobility or visibility, and elevation changes.

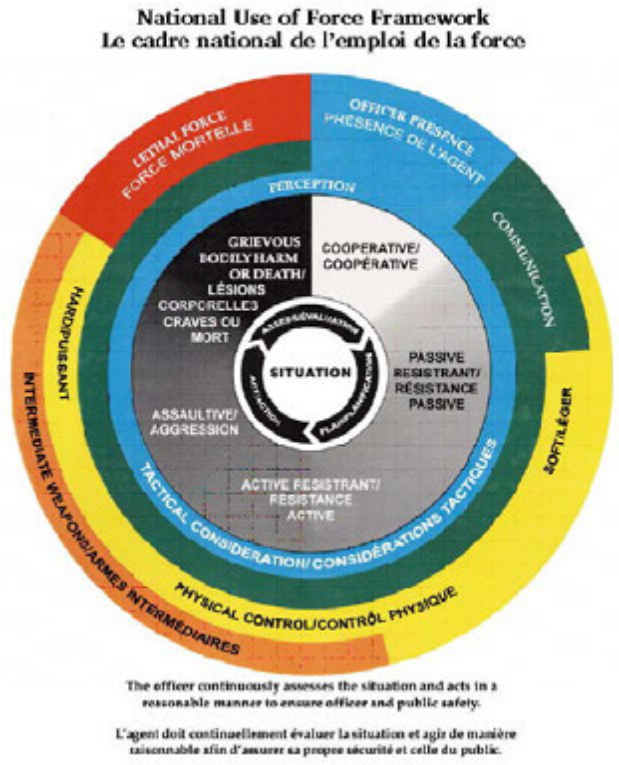


Figure 5 – Canadian National Use of Force Framework - Provided by research advisor

Regarding officer experiences, they tended to be very excited as recruits; becoming a police officer is a dream job to many. Over time, however, they tend to get desensitized and each day just becomes "another day on the job". Despite this, an officer cannot afford to be complacent. An officer's experience, training, and mentality will always be at the forefront, and they must maintain a proper situational awareness to be ready to act at any moment. A situation can have a very high intensity, with an officer having high levels of adrenaline. The research advisor provided a graphic for the national use of force framework in Canada (see Figure 5). It portrays the gradual increase in force used as per the resistance of a suspect with communication being a constant throughout. The advisor explained an important component to this framework is to "assess, plan, act." An officer needs to be able to assess the situation, create a plan, and act on it.

A common teaching in police training is the "21-foot rule," where twenty-one feet is the approximate distance that an officer has time to react to a threat and draw their weapon before the suspect reaches them. The overarching theme is keeping an appropriate space between the officer and any threat or avenue of attack in order to leave enough time to react and respond accordingly. When handling a dangerous call, officers are to prioritise their own safety as they cannot help anyone if they blindly run in and get injured. For example, with an armed and barricaded suspect with a hostage, the first responders would arrive on the scene, cordon off and secure the area, and call and wait for backup, emergency medical services, negotiators, or tactical units. In the end, they must still put the safety of civilians above all else. If there is a serious and immediate threat, such as a suspect with a firearm, officers must intervene, and if shots are fired, there is no time to wait for backup. As a situation evolves,

different officers will be delegated different tasks, such as maintaining the perimeter or interviewing witnesses and bystanders while specialists handle the main task. In regions that are less densely populated or more rural, this can play out differently, as it may only be one officer and their partner alone.

2.1.3 User Observation – Activity Mapping

To gain further insight on user activities and actions, a user observation is needed. Due to the nature of the topic involving scenarios where one may face bodily harm, a video user observation was opted for over an in-person observation. The goals of this were to observe:

- How the user enters a scene
- How the user reacts to hostility from a suspect
- What the user does to respond accordingly
- Any points of contact where conflict or injury may occur

Step-by-Step Observation

The chosen video covered body camera footage from two New York Police Department officers who were escorting a domestic violence victim to their home to retrieve their belongings, and potentially make an arrest, when the suspect returns to the scene and opens fire on the officers and victim. The observation will be broken down into individual tasks with screenshots and descriptions to capture what is happening at each moment.

#	Task	Image	Description
1	Preparation		• Victim entered precinct to report domestic violence • Victim is afraid to enter house to retrieve her items alone and wants a police protection/escort • Two officers performed initial interview with victim • Officers decide to accompany the victim back to her residence
2	Arrival		• Officers arrive at residence where incident occurred • First officer informs the victim of what is going to happen and what to do • Both officers are keeping an eye out for the suspect
3	Assessing the Situation		• Officers escort the victim back into the house • They perform a basic search of the premises • They assess the situation by verifying the presence or absence of the suspect and any weapons • Question the victim to gain more info on what to do moving forward
4	Threat Recognition	 	• The victim notices the suspect returning at the door • Officers had about 3 seconds to determine if he posed a threat to their safety

5	Response		• Suspect started shooting at officers on sight • First officer was shot in the leg and second shot in both hands before returning fire to end the threat
n	Report in/ Call for aid	 *Figure 6a-g - Step-by-Step Observation - Retrieved from https://www.youtube.com/watch?v=i2wxAPelbIA*	With the immediate threat stopped, officers report the situation and call for appropriate backup to secure the area and emergency medical services to handle any injuries *Task *n* can happen at any point as a situation evolves

Table 3 - Step-by-Step User Observation

User Activity Mapping

	Task 1	Task 2	Task 3	Task 4	Task 5	*Task *n*
User Goal	Preparation	Arrival	Assess the Situation	Threat Recognition	Response	Report In/Call for Aid
User Actions	• Receive the crime report • Listen to the victim's story • Plan to escort victim back to their home	• Drive to the residence • Survey the area • Inform the victim of what they can do to help, and social services they have access to	• Enter the house • Perform a search of the building • Ask the victim for any extra info about the incident • Heighten situational awareness	• Maintain a safe distance to react • Isolating the suspect and victim from each other • Checking for body language or aggression • Look for a weapon	• Move the victim out of the line of fire • Dodge/take cover and make it harder to be hit • Return an appropriate use of force	• Report the situation to dispatch • Request backup to secure the area • Request EMS to tend to injuries
User Thoughts	• "We need to help this victim" • "The suspect needs to be arrested"	• "Where is the house?" • "We should stay here to protect the victim"	• "Could the suspect still be here?" • "Are there any weapons here?" • "I need to be on guard in case the suspect returns" • "Should be aware of the entrance"	• "Is the suspect armed?" • "Will the suspect cooperate?" • "Will I be able to restrain them?" • "They're going to attack me or the victim"	• "The suspect is shooting at us" • "I'm hit" • "Need to protect the victim/ bystanders" • "I have to return fire to stop the threat"	• "The suspect is down" • "It hurts" • "Need backup" • "Need medical assistance" • "Check for other injuries"
Storyboard	N/A					

Table 4 - User Journey Map

A user journey map (see Table 4) was formed from the video user observation to categorise the different key tasks and codify what the user actions should be. It also includes potential thoughts that may have been going through the user's minds as events unfolded to build an image of the user's struggles. This mapping will be explored and analysed in more depth in Chapter 3.2 Analysis – Usability.

Advisor Commentary and Feedback

The video was also sent to the research advisor to review for commentary and feedback on how the users in the video handled the situation. This has the goal to:

- Find out what the user(s) did correctly
- Discover any errors or shortcomings in user actions
- Determine any vulnerabilities of the involved user(s)
- Determine the impact of the environment on the user(s)

The advisor pointed out some key errors that could have allowed for the shooting to be avoided, or at least mitigate the damage. The first mistake was that the officers did not go upstairs with the woman to clear the building fully and keep her safe. The second is that one of the two officers could have kept watch and maintain access control to the house to spot the suspect as they arrived. The third is not calling for backup when there was a potential for a suspect to be armed. Aside from that, the users in the video handled the shooting almost perfectly, as no innocent parties were injured and the suspect was stopped before they could commit any further harm.

Conclusions and Takeaways

There was a lot of information to gleam from the short video. The major ideas and takeaways from this video user observation with advisor insights are as follows:

- Close-quarter engagements are high-risk
    - Manoeuvrable equipment with smaller physical footprint is better
    - Suspect has advantage in domestic cases
- Timing is everything
    - A situation can escalate from verbal discussion to lethal force in seconds
    - In extreme cases, drawing their weapon is all an officer has time to do
- The location must be secured
    - Communication is important for securing a perimeter and ensuring that civilians are safe
- Situational awareness is key
    - Officer training and experience plays a large role, but one needs to be aware of what is happening around them at any given moment

2.1.4 User Observation – Human Factors of Existing Products

Figure 7 - Toronto Police Equipment on Vest, Steven Zhou - Retrieved from https://www.nationalobserver.com/2018/09/21/opinion/do-toronto-police-favour-far-right

Ergonomics and human factors play an important role in equipment designed for law enforcement use. Through the advisor interview, a list has been made of key pieces of equipment that all Canadian law enforcement officers should have:

- Duty belt
- Tactical vest (body armour)
- Handcuffs
- Baton
- Firearm
- Body camera
- Notebook and pen
- Shoulder-mount radio
- Flashlight

- First-aid kit
- Taser

All of the listed equipment needs to be carried either on the duty belt or vest- which are mandatory- with the exception of the first-aid kit likely being kept in the patrol car and taser not being issued to every law enforcement department or individual officer. This presents many factors to potentially account for, ranging from the handheld objects to body-worn equipment.

2.1.5 User Observation – Safety and Health of Existing Products

Health and safety are key to law enforcement gear and utility. It ensures that officers are less at risk of fatality, civilians and other bystanders are not in danger, and accidents with equipment do not happen. Body armour in North America is certified through standards set by the U.S. National Institute of Justice to be rated for different levels of protection against certain bullet calibres. Firearms-related fatalities in the United States in 2020 were the highest reported cause of death unrelated to Covid-19, as reported by the National Law Enforcement Officers Memorial Fund (2020).

Regarding weapons, firearms typically have a safety switch or system to prevent misfiring when not in use, and some manufacturers create versions of their weapons specifically for law enforcement use with adjustments made from consumer variants, such as Glock GmbH with law enforcement only variants of certain pistols shown on their website.

Body armour might be mandatory, but it can only cover the torso to still remain practical for regular use, while the use of less-than-lethal or lethal equipment is used to end a threat. Other equipment is typically for utility and responsibility is on the officer to stay safe.

2.2 Product Research

Before any design work can begin, it is necessary to understand what kinds of products and solutions are already available on the market and what they offer the user over another. The method used is product benchmarking to compare similar products or a range of products utilised by a particular user to gather any insights or information of what they are used to.

2.2.1 Benchmarking – Benefits and Features of Existing Products

The list provided by the research advisor of necessary equipment that an officer needs to carry was used as a basis for conducting a market search of existing products and equipment that are used. In the end, a range of seven different kinds of products were chosen to be benchmarked for any features or benefits that would aid a law enforcement officer. The products range from weapons- both non-lethal and lethal- modes of transport, protection, and utility. A short list of key benefits was created to look for when benchmarking. These preliminary key benefits are based on insights from research, advisor interviews, and video user observations.

- Easy-to-use
- Lightweight
- Strong and durable
- Non-cumbersome

Product	Image	Benefits	Features
Axon Taser X26P	 *Figure 8 - Axon Taser X26P - Retrieved from https://www.axon.com/products/taser-x26p*	• Small frame, easy to handle • Easy front-load system • Blast doors make cleaning maintenance easier • Dual-sided safety switch improves usability for left-handed users	• Compact design • Ergonomic handle • Blast doors protect cartridge • Front-facing reload system • Trilogy logs record device operation and performance
Glock G17 Gen4	 *Figure 9 - Glock Pistol - Retrieved from https://us.glock.com/en/pistols/g17-gen4*	• Improved useability for left-right hand operation • Customizable grip allows user to improve comfort • New recoil assembly reduces maintenance needs	• *Modular Back Strap design allows for customisable grip* • *Rough texture* • *GLOCK dual recoil spring assembly* • *Reversible magazine catch*
Colt Canada C8	 *Figure 10 - Colt Canada C8 - Retrieved from http://military-today.com/firearms/c8.htm*	• Telescopic buttstock improves useability for different users • Shorter barrel for improved handling and comfort	• Iron sights integrated into carry handle • Picatinny rails (later models) • Telescopic 4-position stock • Standard NATO 5.56x45mm • 368mm barrel
Ford Police Interceptor Utility	 *Figure 11 - Ford Police Interceptor Utility - Retrieved from https://www.ford.com/police-vehicles/hybrid-utility/*	• Safer crash structure • Hybrid powertrain improves fuel economy • AWD provides improved traction • Improved cargo space for equipment	• Hybrid/AWD powertrain • Cargo space • *75-MPH Rear-Impact Crash-Test Rated* • *Side Protection and Cabin Enhancement Architecture* • *Police Perimeter Alert* auto secures car

SafariLand Shift 360 Plate Carrier	 *Figure 12 - SafariLand Shift 360 - Retrieved from https://safariland.com/collections/tactical/products/shift-360-scalable-plate-rack-system-shift_360*	• Lightweight, easy to carry • Modular attachment system allows for improved protection • Improved adjustability for user fitment • More functional attachments	• Uses SAPI plate system • Bottom loading front and rear plate pockets • Lightweight, durable internal lining system • Ergonomic shoulder support system • AWS MOLLE webbing for attachments
Horse	 *Figure 13 - Toronto Mounted Police Unit - Retrieved from https://www.blogto.com/city/2019/05/why-we-still-have-mounted-police-toronto/*	• Provides better viewpoint for spotting crime • Easier to manoeuvre through crowds • Faster than foot • More approachable and friendly to civilians	• Higher viewpoint • Crowd control and manoeuvrability in crowded area • It is a horse
Axon Body 3	 *Figure 14 - Axon Body 3 - Retrieved from https://www.axon.com/products/axon-body-3*	• Easy wireless activation, better focus on the situation rather than hitting record • Officer tracking improves safety when separated	• Live alerts, tracking, and streaming through network • Secure and encrypted data • Sleek and rugged design • Video retrieval up to 18h audio-free if recording fails to activate

Table 5 - Product Benefits and Features Table

A table was created to compare each product's advertised benefits and features (see Table 6). From this benchmarking, a list of common key benefits can be summarised:

- Safety
- Better performance
- Improved usability
- Sleek
- Easier to use
- Ambidextrous

When looking at the benefits and features of each product, there are several main takeaways. Ergonomic considerations need to be made for multiple user types and handedness, with some degree of adjustability allowing for improved user comfort or experience. Lightweight, easy-to-handle equipment reduces weight load and can allow quicker reactions. There should also be a secureness to the product and emphasis on safety.

2.2.2 Benchmarking – Functionality of Existing Products

The functionality of products varies given the many different types and purposes for each piece of equipment. Weapons, both lethal and non-lethal are handheld pieces of equipment. Given the mandatory-carry nature of a firearm and common use of tasers, they need to be relatively small and easy to handle. They also need to be useable by both right- and left-handed users, and the same applies to higher-calibre weapons, such as rifles. Concerning modes of transport, they offer the advantage of being faster, safer, or more practical for getting from one point to another. Typical police cruisers and interceptors offer the utility of a car for carrying extra equipment and police computers, as well as the ability to transport suspects and

detainees. Some law enforcement agencies still employ mounted horse units for officer visibility and outreach, as well as improved line-of-sight and manoeuvrability in crowds. Utility tends to be purely functional, such as body cameras, and easily mountable to a shirt or vest. They also put some emphasis on ruggedness or durability. Protective gear generally only extends as far as ballistic vests for every day-use by officers, which are mandatory. Most departments provide soft-armour vests that use technology such as Kevlar, however, some allow the insertion of ballistic plates for increased protection. Most body armour is equipped over the head and secured with Velcro straps to cover the torso.

2.2.3 Benchmarking – Aesthetics and Semantic Profile of Existing Products

When viewing products designed for law enforcement use, they tend to follow a similar trend. Physical forms tend to be the result of utility and practicality, and law enforcement work tends to demand a ruggedness or strength and durability to products. Squared, angular, or reinforced components are common, such as in Axon Taser X26P or Body 3 camera. Handheld items are either designed to fit the contours of a user's hand, such as with a taser or firearm, or cylindrical in flashlights and batons. The forms and textures typically indicate a product's purpose. Colours are minimally used, opting to use grey or black for most equipment and utility, while high-visibility colours are reserved for less-than-lethal and other special equipment. Likewise, body armour is made to blend with uniforms and usually coloured black or navy. Visually, their form has remained unchanged for many years. Equipment also has a matted or rubberized finish often due to potential for high wear and tear and shock absorption.

2.2.4 Benchmarking – Materials and Manufacturing of Existing Products

Regarding the materials and manufacturing methods used in common law enforcement products, there is not a lot of info explicitly stated, with the primary focus on the function and various features and benefits of a particular item. Equipment and utility, such as tasers, firearms, and body cameras, are usually constructed using a polymer housing due to the balance of affordability, durability, and ability to easily mass produce. The Axon Taser 7 specifies a "high impact polymer." This would also mean, that injection molding is the most common manufacturing method. Concerning ballistic vests, law enforcement typically uses soft body armour, meaning that they use materials such as Kevlar, as opposed to hard steel or ceramic ballistic plates. The exterior layers vary, with the main material of the outer being variations of polyester. Straps and loops tend to be nylon, with Velcro pads to secure and adjust certain parts. The nature of the materials used in ballistic vests leads to sewing being the most efficient and secure method of construction. Law enforcement equipment is manufactured in very traditional manners, and leaves opportunities for new material technologies or methods to achieve different results and experiences for the user, such as smart technology.

2.2.5 Benchmarking – Sustainability of Existing Products

As mentioned in section 2.2.4 Benchmarking – Materials and Manufacturing of Existing Products, much of the emphasis in product descriptions are the function and features. As such, there is not a very big push for sustainability or renewability with the focus on the quality of the product and safety of the individual. Since many products are made from some form of polymer, they are not the most sustainable. A common plastic, acrylonitrile butadiene styrene (ABS), is typically injection molded, which can be an expensive and power-consumptive process.

The other side to this, however, is the increased requirement for a durable material for law enforcement equipment. While plastics might not decompose very well, Rogers (2015) explains that ABS is a thermoplastic, meaning that it liquefies and can be recycled into new molds.

Ballistic vests tend to have polyester outer layers, which involves the use of synthetic fibres. While recycled polyester exists, which uses plastic fibres made by recycling materials such as plastic water bottles, there are still a few challenges. A ballistic vest tends to demand a degree of resilience that other, more eco-friendly fabrics may not offer. Additionally, recycled polyester is not renewable, biodegradable, or compostable (Assoune, n.d.), and since a ballistic vest needs to be replaced once damaged, there is a lot of material waste. There is a challenge to overcome in meeting demands of sustainability and functionality, but still an opportunity to find a compromise.

2.3 Summary of Chapter 2

This chapter revealed a lot of important information through the different avenues of research. A good understanding has been gained about the primary users involved in law enforcement, such as the first responders and backup responders. Their attitudes are very optimistic and excited at the beginning, but they soon settle in and have to become situationally aware and ready to assess a situation, make a plan, and act appropriately as needed. Officers need to put the safety of civilians above all else, but still prioritise their own safety too. They should always leave enough time to react to a possible threat as any situation can become deadly in seconds. When arriving at a scene, if possible, first responders need to secure the area and call for backup, however, this is not always possible for more rural regions. Officers can often find themselves in a variety of potentially dangerous situations. Assault cases

are among the highest in frequency and likelihood of danger due to the uncertain presence of weapons, followed by domestic violence cases where the environment is often very close-quarters and the suspect has the advantage in their own house.

In addition, law enforcement officers utilise a wide range of products in their line of work. These can vary from weapons, to transportation, protective equipment, and utility. Benefits and features also vary as a result, however, common talking points include improved safety, ease-of-use, performance, and usability by different types of users. Each product has a set of functionalities dictated by their purpose, with aesthetics that match the utilitarian nature of law enforcement products.

Chapter 3 – Analysis

In order to benefit from research, one has to make sense of it first. This chapter will dive into the analysis of user needs and actions. A deeper look will be conducted into the human factors that affect how users interact with a product, as well as the aesthetics and semantics that direct those interactions. The goal behind this is to find opportunities to innovate.

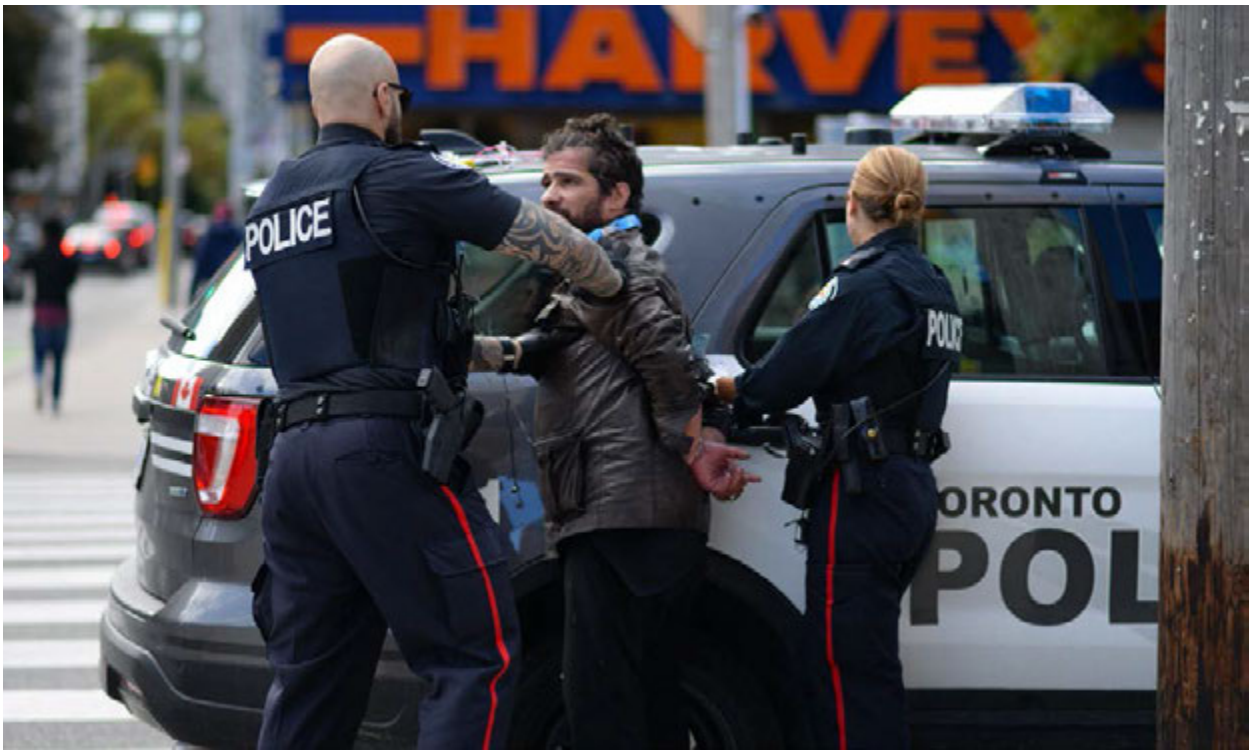


Figure 15 - Toronto Police Making Arrest, John Bauld – Retrieved from https://www.blogto.com/city/2020/08/toronto-police-scammers-pretending-spoofing-number/

3.1 Analysis – Needs

3.1.1 Needs / Benefits Not Met by Current Products

Currently, products on the market are very traditional in their approach to functionality and how they serve the user. For example, Product A can do *x,* and Product B is capable of doing *y.* As noted by the research advisor in Chapter 2.1.4, there are a set list of items and

equipment that law enforcement officers are required to carry at any given time. All of these items are loosely attached either to an officer's duty belt or tactical vest. This presents a point of conflict between the use of individual items and a user's experience having to carry all of that equipment daily.

In the product benchmarking of benefits and features from Chapter 2.2.1, common benefits could be described as being sleek, being easier to use, offering better performance, and improved usability. Each product on its own may offer what they advertise, but a law enforcement officer is not carrying and using only one product, they can be carrying up to 30lbs of equipment, according to Srubas (2016). There is a need for something that is either truly lightweight, or that reduces the bulk of several loose pieces of equipment.

3.1.2 Latent Needs

Latent Need	Benefits Statement
Ease-of-use	• Ease-of-use allows a user to use a product naturally, as if it were an extension of their body. • It mitigates any fumbling that may occur when using a product in high-intensity situations.
Security	• Makes a user feel protected by their equipment
Operability	• Accommodates different body types and handedness

Table 6 - Latent Needs

3.1.3 Categorization of Needs

A major component of analysing user needs is categorizing them according to priority, determining what is immediate and the most important, what is a latent need the user may not be aware of, and what can be considered as a bonus; a want or wish.

Immediate Needs	Benefits Statement	Correlation
Safety	• Protects the user from harm or fatal injury	**Strong**
Awareness	• Improves reaction time and decision-making when situation gets violent	**Strong**
Speed	• Allows for better and quicker use of equipment in high-intensity scenarios	**Strong**
Latent Needs	**Benefits Statement**	**Correlation**
Ease-of-use	• Allows a user to use a product naturally, as if it were an extension of their body and mitigates fumbling with hands	**Strong**
Security	• Makes a user feel protected by their equipment	**Moderate**
Operability	• Accommodates different body types and handedness	**Moderate**
Wants / Wishes	**Benefits Statement**	**Correlation**
Lightweight	• A lightweight product ties in to ease-of-use and allows for more precise handling, and reduces weight strain on body	**Strong**
Comfort	• Improves ability to carry out tasks without feeling pain or discomfort	**Strong**
Sleekness	• Reduced bulkiness allows user to not worry about equipment obstructing their movements	**Moderate**
Durability	• Less energy spent worrying about whether something will break or need maintenance	**Moderate**

Table 7 - Categorization of Needs

3.2 Analysis – Usability

Mapping out a user's steps and experience when doing different tasks can help to gleam new insights and lead thinking down different pathways. One of the ways this can be done is with a journey map and a user experience map.

3.2.1 Journey Mapping

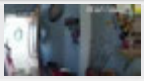
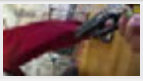
	Task 1	Task 2	Task 3	Task 4	Task 5	*Task *n*
User Goal	Preparation	Arrival	Assess the Situation	Threat Recognition	Response	Report In/Call for Aid
User Actions	• Receive the crime report • Listen to the victim's story • Plan to escort victim back to their home	• Drive to the residence • Survey the area • Inform the victim of what they can do to help, and social services they have access to	• Enter the house • Perform a search of the building • Ask the victim for any extra info about the incident • Heighten situational awareness	• Maintain a safe distance to react • Isolating the suspect and victim from each other • Checking for body language or aggression • Look for a weapon	• Move the victim out of the line of fire • Dodge/take cover and make it harder to be hit • Return an appropriate use of force	• Report the situation to dispatch • Request backup to secure the area • Request EMS to tend to injuries
User Thoughts	• "We need to help this victim" • "The suspect needs to be arrested"	• "Where is the house?" • "We should stay here to protect the victim"	• "Could the suspect still be here?" • "Are there any weapons here?" • "I need to be on guard in case the suspect returns" • "Should be aware of the entrance"	• "Is the suspect armed?" • "Will the suspect cooperate?" • "Will I be able to restrain them?" • "They're going to attack me or the victim"	• "The suspect is shooting at us" • "I'm hit" • "Need to protect the victim/ bystanders" • "I have to return fire to stop the threat"	• "The suspect is down" • "It hurts" • "Need backup" • "Need medical assistance" • "Check for other injuries"
Storyboard	N/A					

Table 8 - User Journey Map

A journey map can be broken down by tasks, within which the user's primary goal is stated, along with the actions they perform to achieve said goal and any possible thoughts or feelings they may be having at that moment.

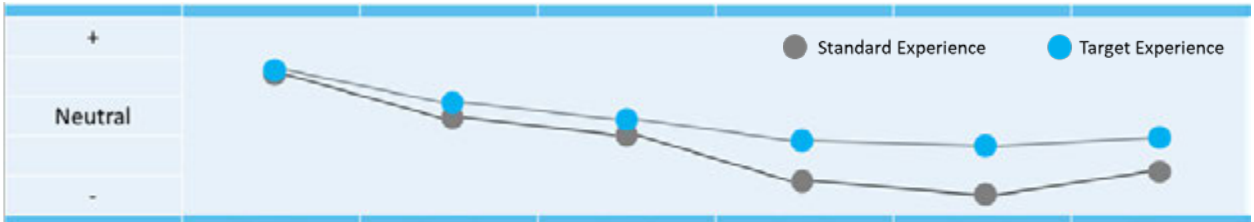
Task 1 is the preparation phase where an officer would receive a call or report of a crime. This is the least stressful part of the journey and can be filled with a sense of duty as the user wants to help. Task 2, arrival, is when a user needs to be entering a different mentality to prepare for what may come next. Here is when the user will need to start becoming more vigilant and asking themselves questions, such as, "Where is the suspect?"

Task 3, assessing the situation, is one of the most important parts of the process. It is at this point that a user should begin to heighten their situational awareness to prepare for any possible threats while they gather more information on the location, what happened, and decide what to do next. This relates to the Canadian National Use of Force Model (see Figure 5)

and the part that the research advisor emphasised about officer's being able to assess, plan, and act. Task 4, threat recognition, also ties in with Task 3 and the Use of Force Model. This step can be one of the more stressful parts of the user's journey because the user does not know exactly what another person will do. The user needs to maintain a safe enough distance to react to any possible threats while assessing whether or not the person(s) in front of them will pose any to begin with. Moreover, a situation can go from calm to deadly in a matter of seconds, and thoughts of whether or not they can reason with the suspect or if they have a weapon can easily be a focus for the user, as is any checking for body language that could telegraph a sudden attack.

Task 5, response, is a very crucial step. Adhering to the National Use of Force Model (see Figure 5), the user needs to make a quick judgement call on how to respond based on the amount of resistance a suspect puts up. In the event of an attack, particularly one involving firearms, the user needs to act immediately. Any innocent bystanders will need to be moved out of harm's way while they return the appropriate amount of force. Task *n*, reporting in and calling for aid is a miscellaneous task that can happen at any time from preparation leading into post-response. The key aspects of this are updating supervisors and dispatch on the situation and if help is required, whether it be reinforcements or emergency medical services.

3.2.2 User Experience



	Task 1	Task 2	Task 3	Task 4	Task 5	Task *n*
User Goal	Preparation	Arrival	Assess the Situation	Threat Recognition	Response	Report In/Call for Aid
Problems/ Challenges		• Not all situations may not allow for safe arrival at a scene	• Close quarter environments can leave officer open • Weather conditions can affect visibility or ability to give chase	• Suspect cannot always be reasoned with peacefully • A situation can go from peaceful to deadly in seconds • Potential for hostages	• Risk of stray bullets hitting an unintended target • If lethal force is required, there is little time to do anything else but open fire	• Suspect can still be at large when call is made • Backup officers can be exposed on arrival • Negotiators need to be close to perp
Ideas/ Takeaways		• Protected vehicle/ mode of transport	• Equipment that can survey an area • Product suited to specific weather	• Worn or always in-use equipment • Shield for use by victim/bystanders	• Device that deploys rapidly or with weapon	• Device that does not distract officer or need them to fumble with hands

Table 9 - User Experience Map

Building upon the user journey map, a user experience map (see Table 9) was created to visualise the user's experience from the video observation and problems or challenges that they may have encountered in each task. Also included are ideas and takeaways from the previously mentioned challenges and a projected line for an improved target experience.

As stated in the prior section, Task 1, preparation, is the least stressful and most hopeful step. As such, there is not much that can be said to its problems as they relate to the topic of this thesis report. Task 2, arrival, presents a minor challenge in getting to a scene safely, however, this is also a problem that can be handled by the user's actions.

Tasks 3 through 5 are where this thesis project aims to focus on, with the user's standard experience projected to be at its lowest during Task 4, Threat Recognition, and Task 5, Response. The reason for this is because this is where any scenario can easily deteriorate. The environment may not be advantageous to the user, such as with the tight spaces of a

residential house or apartment building, or variable weather conditions. In addition, the suspect may not be cooperative and require physical force to subdue, at which point a situation can quickly go from peaceful to deadly within seconds. An aggravated or intoxicated suspect may fight back with a weapon, and if that poses a threat of grievous bodily harm, there is little time to do anything else besides open fire.

There are a few key ideas or takeaways from this mapping of the user experience. First, a potential solution could be adaptive to the environment and survey an area. Another idea involves something that is worn or always in-use since the user does not need to think about using it. If not, a product that deploys rapidly or at the same time as a weapon and does not distract the user can address the issue of the importance of timing. The end goal is to improve the user's experience to the projected target experience in blue (see Table 9). These are scenarios that run the likelihood of being high-stress, high-intensity, and high-adrenaline where lives could be at risk. Therefore, the projected increase is not exaggerated, but kept moderate.

3.3 Analysis – Human Factors

Just about every product involves human interaction in some capacity. Therefore, it becomes necessary to properly reference human ergonomic factors and measurements when designing for humans. These can be done through diagrams and a 1:1 scale physical study.

Introduction

One of the most universally common pieces of equipment for North American law enforcement officers is a ballistic vest, or body armour. As something that is typically always worn on-duty, it needs to be ergonomically fit for the user, in addition to the litany of other

equipment that adds weight across an officer's torso and hips. Sheets (2018) and Srubas (2016) have reported on the weight carried on duty belts being a leading cause of back and hip problems for officers. Load-bearing vests have been noted as improvements, but still leave a root cause open. Ergonomic considerations will need to be taken and tested for wearable equipment, while still accommodating an adequate amount of coverage for ballistic protection.

3.3.1 Product Schematic – Configuration Diagram

Literature Review

The general dimensions of a 50th percentile female and 99th percentile male was referenced for this ergonomic study to account for a typical ergonomic range of law enforcement officers, as discussed with a research advisor. The numerical figures were derived from the Tilley & Dreyfuss (1993) book, *The Measure of Man and Woman*, with measurements being recorded primarily for the upper body (e.g., shoulder width, chest width and depth, waist, etc.) and hands (e.g., hand breadth, circumference).

Ergonomic Diagrams

The ergonomic references in the Figure 16 focus on showing the typical measurements for the upper body of a 50th percentile female and a 99th percentile male, as well as their stature for general reference. Since typical body armour primarily covers the torso, these were deemed to be the most important dimensions to work with. Key measurements were noted for:

- Shoulder width
- Chest width
- Waist width

- Hip breadth
- Shoulder-to-waist length
- Chest depth
- Abdomen depth

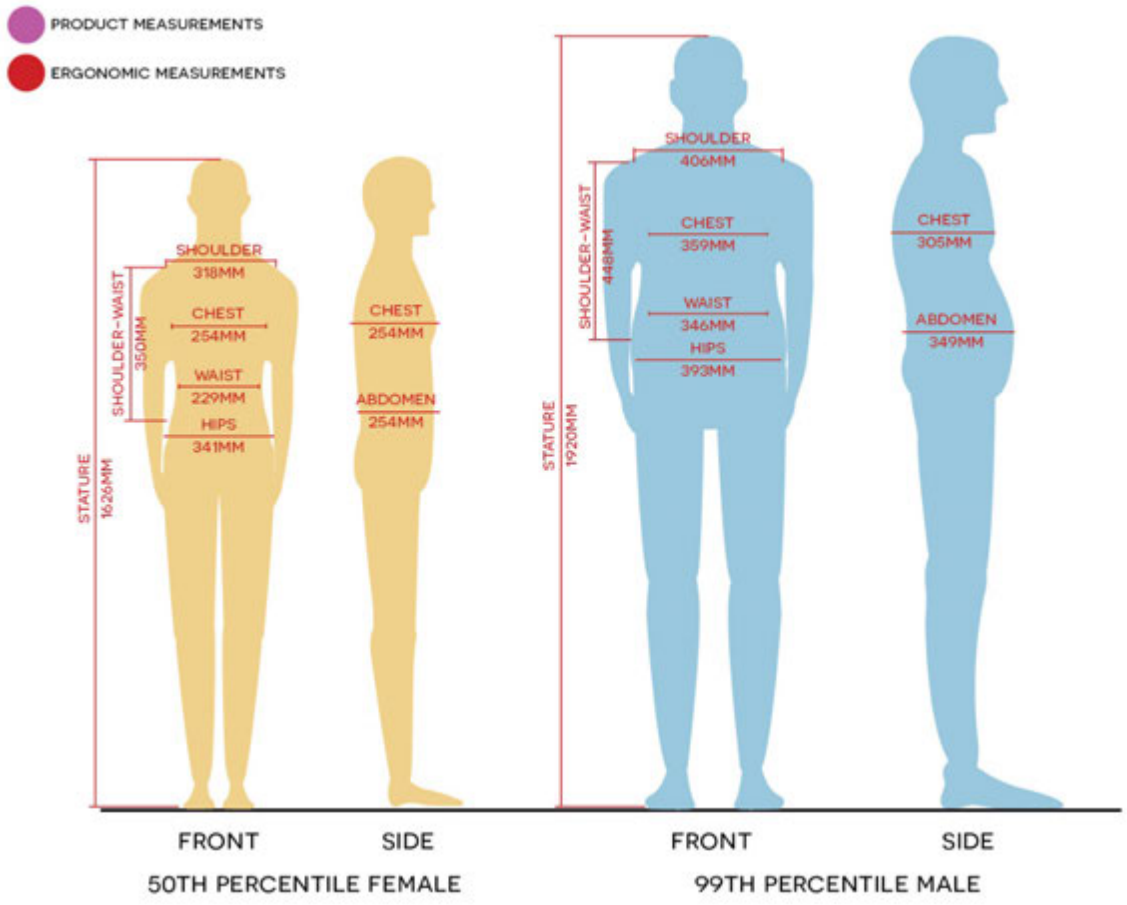


Figure 16 - Diagram of Ergonomic Human Body Measurements

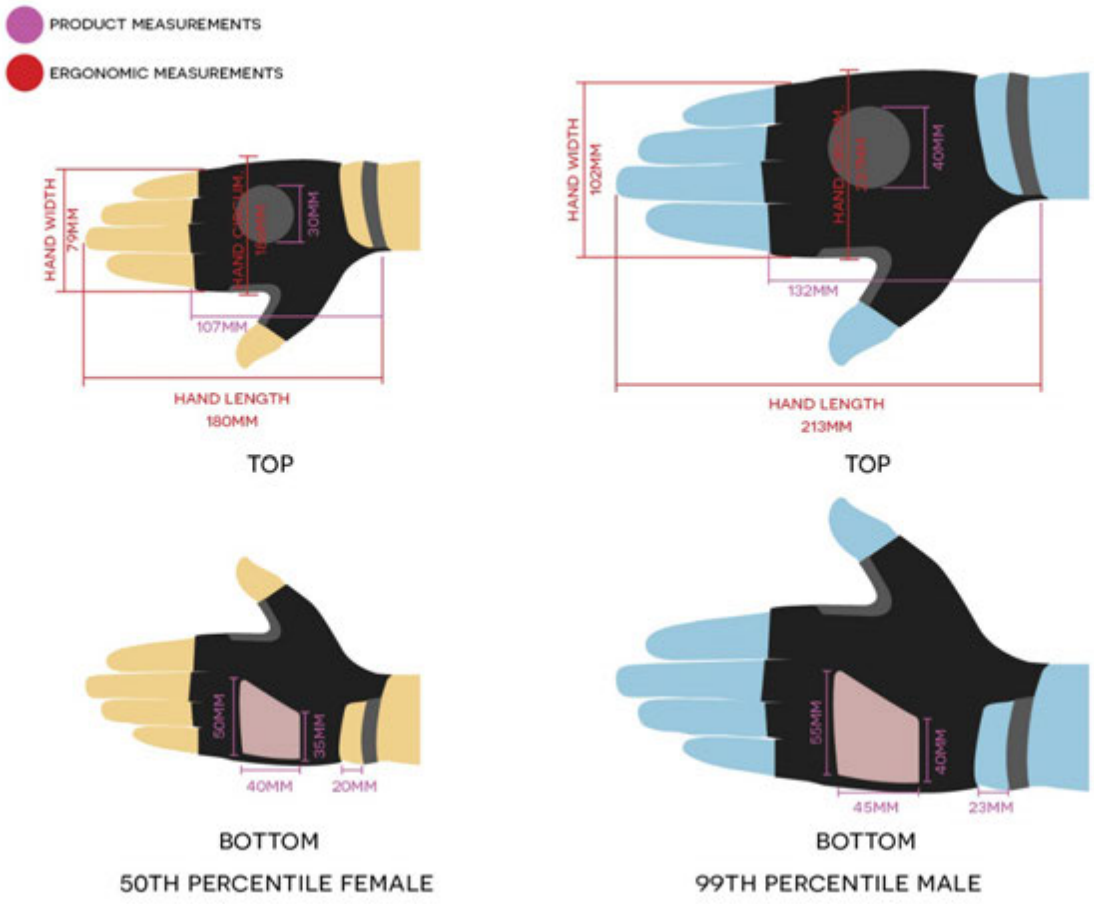


Figure 17 - Diagram of Ergonomic Hand Measurements and Glove Schematic

Figure 17 makes reference to a few key hand measurements that can be applicable to gloves. The glove schematic also includes smart interactive elements to show where on the hands they can be accessed. Key measurements were taken down for:

- Hand width
- Hand length
- Hand circumference

The wearable components were given general dimensions for key components. Measurements are based on the diagram from Figure 16 and adjusted to better accommodate a human body. The upper torso pieces are intended to cover at least the major vitals (e.g., lungs, heart). The side panels from the duty belt are to wrap around the user's waist without getting in the way of the underarms or stomach. The device that attaches to the vest is meant to extend far enough for a user to view without straining the neck downward. An external raid carrier vest (see Figure 19) was also included to fit over the pieces in Figure 18.

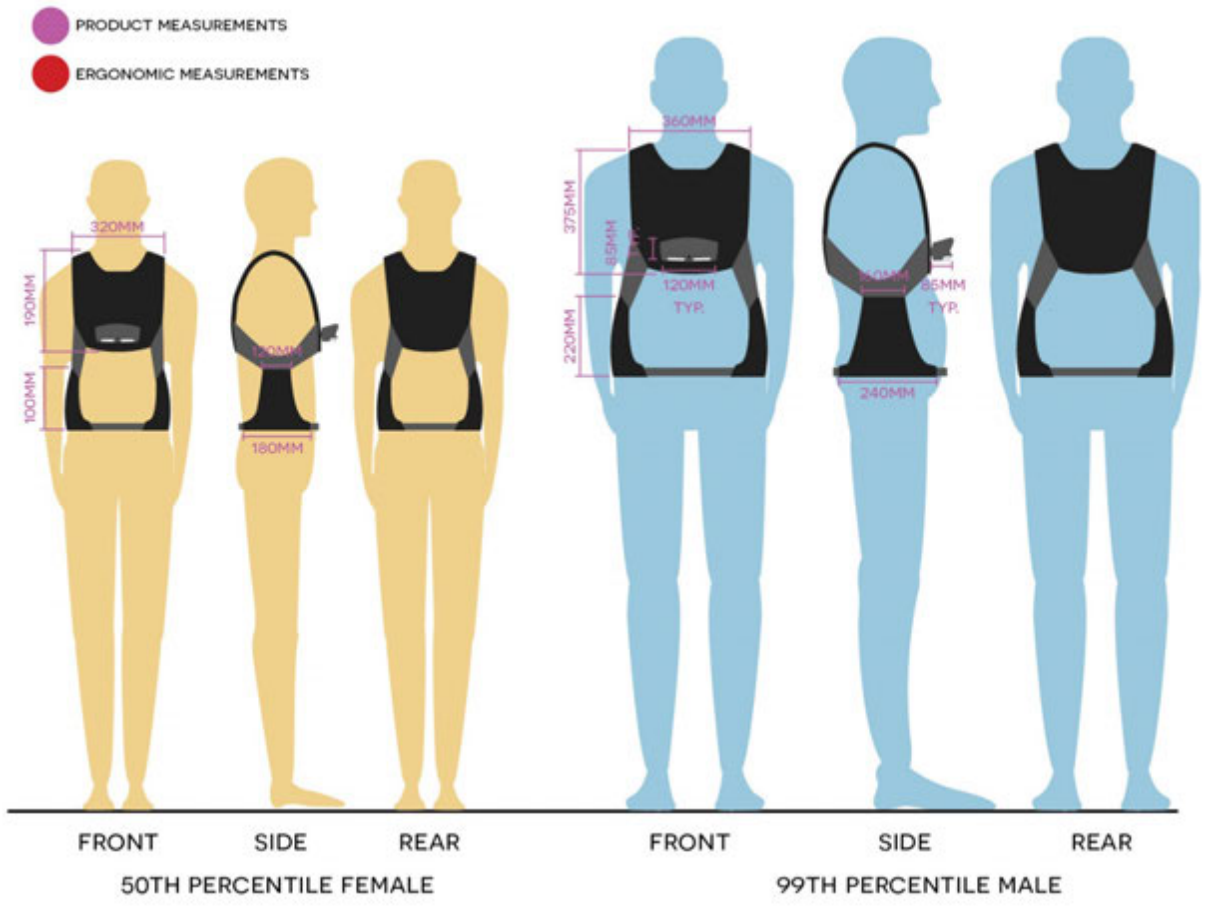


Figure 18 - Main Vest and Belt Schematic

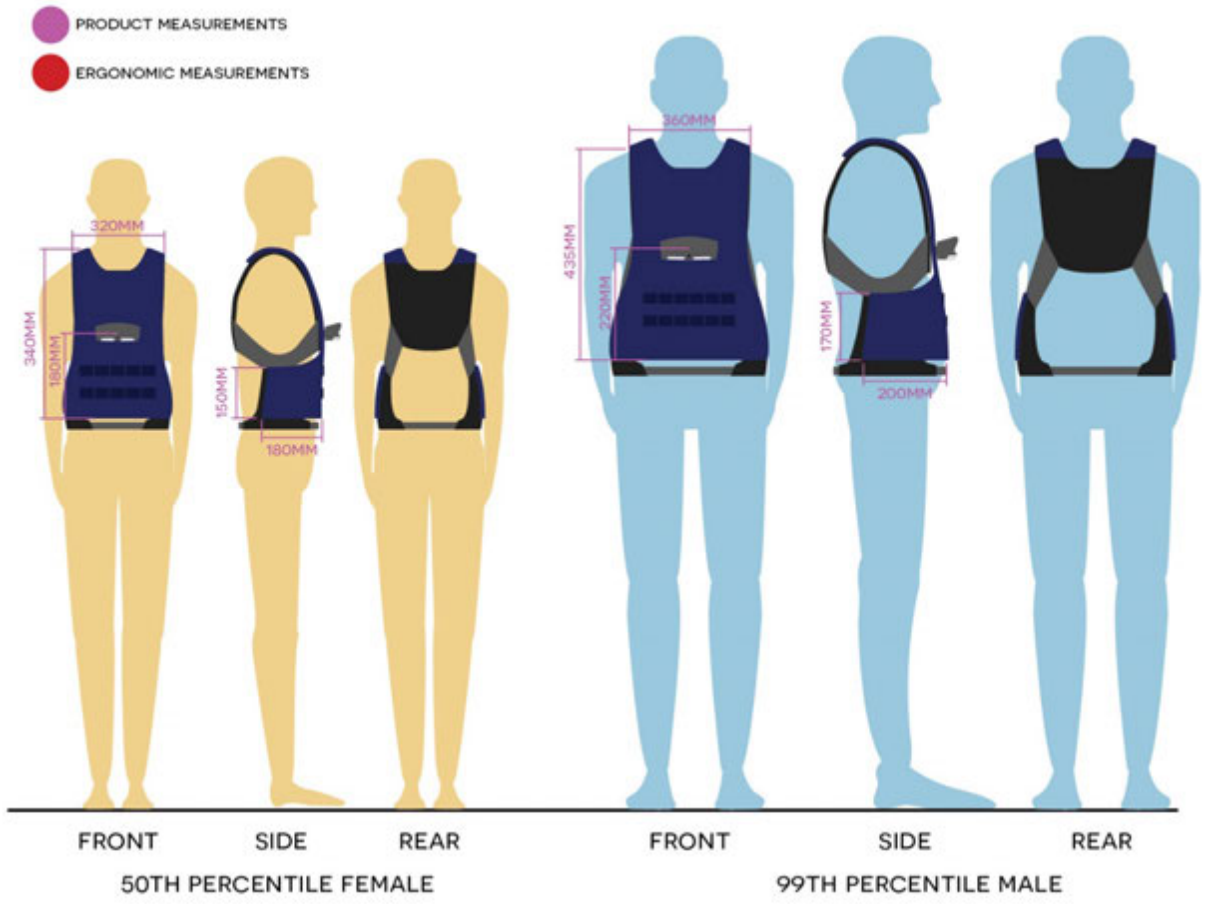


Figure 19 - External Raid Carrier Schematic

3.3.2 Ergonomic – 1:1 Human Scale Study

Target User(s)

The sizing and dimensions of this ergonomic buck were based on a 99th percentile male. This decision was made due to the number of male law enforcement officers still being the overwhelming majority in Canada at 78% in the year 2019 (Jeudy, 2021). Despite this, notes will be taken on better ways to accommodate female users from this study.

Methodology

In order to perform this ergonomic study, a 1:1 scale cardboard mock-up of each main component was created to test on a real user. The components made include:

- Upper torso vest
- Duty belt and Velcro pad
- Raid carrier vest
- Smart glove
- Main hub device

The purpose for testing each of these components is that they are always in contact with the user or being interacted with in some form. As a result, it will be necessary to check for any discomfort or obstructions while a user has their gear equipped.

Evaluation

This ergonomic buck will be used to evaluate potential issues that may arise while using the equipment in different configurations. These include:

- Wearing alternate duty belt (hips, waist, torso)
- Wearing upper torso vest and raid carrier vest (torso, chest, shoulders, arms)
- Using smart gloves (hands)
- Interacting with hub device (head, neck, hands)
- Reaching for equipment on vest or belt (hands, arms, torso)

The model was tested on a 60^{th} percentile male (upper body ergonomic dimensions ranged from a 50^{th} - 75^{th} percentile male).

Ergonomic Buck Testing

Duty Belt with Velcro Pad

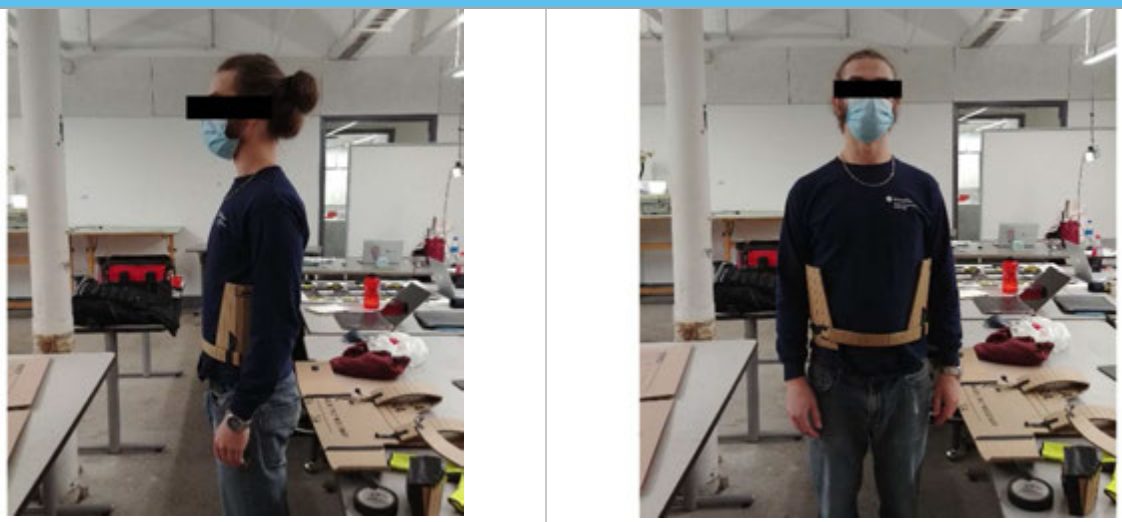


Figure 20a-b – User Wearing Duty Belt with Velcro Pad

Figures 20a-b shows a 60th percentile male wearing the duty belt with side Velcro pads. The belt is adjustable to the user and wraps around the waist, sitting right above the hips. The Velcro pads reached up halfway up the torso, but did not impede movement or comfort.

Main Vest and Duty Belt

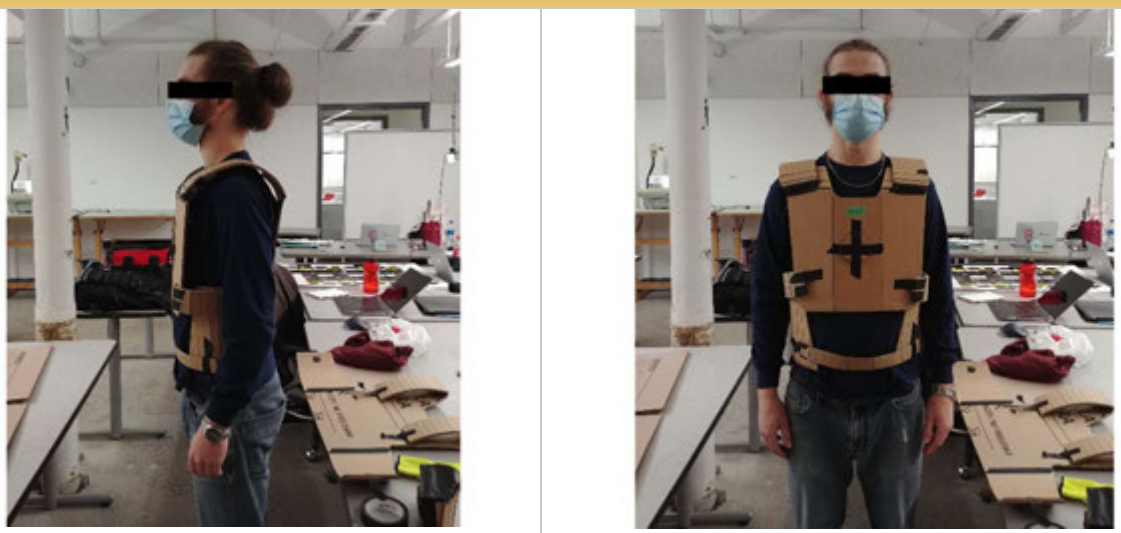


Figure 21a-b – User Wearing Main Vest and Duty Belt

The primary vest provided coverage of the majority of the 60th percentile male's upper torso. The shoulder and torso straps are adjustable to the user. The side straps overlap the Velcro pad from the duty belt for this user, which allow the vest to take on part of the load from the duty belt's weight, however, this may not align on a user with a longer torso.

Full Gearset Equipped

Figure 22a-b – User Wearing Full Gearset

The 60th percentile male is shown wearing the raid carrier vest in Figures 22a-b. The raid carrier offers extended protection to the user's abdomen, and the shoulder and torso straps are adjustable. The extended coverage still leaves space for the duty belt and any potential equipment that would be mounted to it. The user reported a sense of security.

Interaction with Central Device

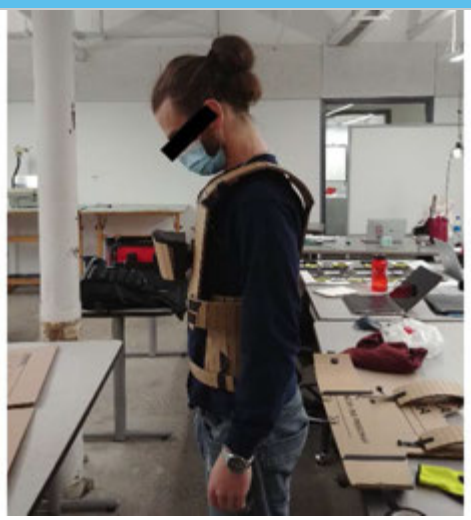


Figure 23a-b - User Interacting with Central Device

The user is viewing and interacting with the main device in Figures 23a-b. Viewing the display does not require the user to strain their neck. Reaching for any buttons on the device is within reach and fits the user's hand.

Other comments from secondary observers brought attention to the main device extending too far out; an area of focus for future revision.

Smart Glove Interactions

Figure 24a-b - User Interacting with Smart Glove

In Figure 24a, the user is interacting with the gesture pad on the top of the glove without any issues. The circle pad is large enough to locate and use without looking.
In Figure 24b, they are extending a hand out as a motion gesture for the palm light. Given the construction of a glove, there are no impediments to movement, although the wrist area should be of focus.

Full Gearset While Holding Weapon

Figure 25a-b - User Wearing Full Gearset with Weapon

The 60th percentile male is wearing the full gear configuration while holding a weapon. The main device has no impact on the user's arms.
The first major conflict, however, is shown in the width of the armour as it obstructs the user's upper arms when held forward, circled in red. Possible limitation of cardboard used in mock-up, but still another area noted for revision.

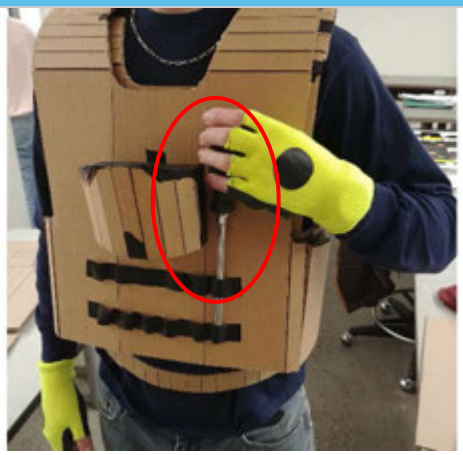
Interacting with MOLLE Webbing	
 *Figure 26 - User Interacting with MOLLE Webbing*	The user is interacting with the MOLLE webbing on the raid carrier (see Figure 26). The width of the main device can cause potential interference with long objects held in the straps, circled in red.
Seated Position Testing	
 *Figure 27a-c - User Wearing Main Vest and Duty Belt While Sitting, Driving, and Bending Over (from left to right)*	
Figures 27a-c show the 60th percentile male wearing the primary vest and belt configuration in a seated position. In Figure 27a, they are imitating writing at a desk. Figure 27b displays a slightly reclined position akin to an SUV seating position. Figure 27c shows the user bending over in a seated position. Throughout each activity, the user reported no issues with comfort aside from the aforementioned width of the chest piece impeding the arms.	

Table 10 - Ergonomic Buck Testing Breakdown

Analysis

Law enforcement officers in most departments across North America, particularly in Ontario, as learned in the research advisor interview, are mandated to wear body armour, along with numerous other utility and equipment. These mandatory pieces of equipment include handcuffs, a baton, firearm, body camera, flashlight, shoulder-mounted radio, and pen and notebook, with many including a taser as well. All of this must be equipped either on the duty belt or vest. The amount of weight added from all these pieces can put extra strain on a user, especially in a police department that does not allow an external carrier. Additionally, this is a lot of separate pieces of equipment that need to be accounted for in a solution.

The main hub device aims to mitigate this issue by incorporating a body camera, flashlight, and radio into one device with added functionality and mounted centrally on the user's chest. A potential area for improvement with the main device is to shrink its physical footprint. A secondary observer to this ergonomic buck testing had pointed out concerns with the depth of the device and how far it extends from the user's chest. The component that takes up the most space depth-wise is the screen. While the intended dimensions are around 120mm x 85mm x 85mm (L x W x H), there is still an opportunity for a more compact iteration, or to have the screen be collapsible and only open when needed.

The proposed design for the main vest is smaller in footprint to a typical ballistic vest, as it only extends coverage to the upper torso. The main hub device takes up the centre-mount position, leaving little room for extra utility. While the equipment that has become integrated into the hub device typically used to be mounted on a user's vest, as seen through observations and image searches, with all the extra equipment that still remains, it has to be held by the duty

belt. The revised duty belt has side panels that extend 220mm up from the waist and hips, based on a 99th percentile male. When tested on the 60th percentile male, and later a 50th percentile male, there were no issues with the panels interfering with the underarms, leaving at least 50mm clearance. The adjustability of the belt strap allowed for a secure and comfortable fit to the individual. The intention of the side panels is to make the user feel secure and to connect with the upper vest to reduce the weight load on the user's hips.

The primary vest panel is 375mm x 360mm (L x W), intended for a 99th percentile male. When tested on a 60th and 50th percentile male, the panel covers the intended region of the upper torso and does not obstruct the duty belt. Upon further analysis, the length of the upper vest can end up covering most of a user's torso and leave only a small portion of their abdomen exposed. This is a point of further revision to the design to account for varying coverage due to ergonomic variance. The main hub device can be mounted centrally on the armour piece and accessed easily. It also maintains a low enough profile that the raid carrier vest can be attached over top of the main wearable and still attach the hub device.

The raid carrier follows the same profile as the previous vest panel, but extends to 435mm long down the torso for full coverage. The inclusion of MOLLE straps on the raid carrier allow for increased utility that may be needed in different situations, such as more less-than-lethal options, extra magazines for a firearm, and specialised utility. Placement of the main hub device and MOLLE webbing, however, could be a point of conflict, where the size of an attachment or equipment might not be as easily accessible due to the size of the device. The size or profile could be minimised, and given the prominence of the screen, it could be made more compact or collapsible.

An important discovery during this ergonomic testing was an issue with the width of the armour panel. When the user held their arms out in front of them, the panel would obstruct their upper arms. This can lead to an altered shape and cut-out to accommodate users with varying shoulder widths that fall into different percentile categories and is an important area of focus so as to not obstruct any freedom of movement for a user.

Gloves are a more forgiving form, with materials that can be made to stretch to conform to larger hands. A one-size-fits-all approach can be more feasible given the fingerless design, as that is usually where most issues tend to arise with ill-fitted gloves. The wrist area where the heartrate monitor would be located is a key position to note, as it will require a tight-fitting band or strap to ensure that connection. The location of the gesture pads is easy to reach on the back of the hand, however, potential issues could arise from accidental activation.

When testing the ergonomic buck in a seated position, there were no concerns, as the intended configuration with only the duty belt and upper vest is made for permanent wear. The user is able maintain a desk position, driving position, and bend forward without feeling the product get in the way. Overall, the user reported a sense of security or comfort in a neutral position while wearing the gear.

Limitations and Conclusion

While it was clear before that a wearable product needs to come in different sizes to accommodate different-sized users, it was made more obvious that a one-size-fits-all solution is impossible- if not- very difficult and could lead to unwanted compromises to a final product. Likewise, males are not the only type of law enforcement officer. A solution that can

accommodate a female user's needs is also required. Due to time constraints, a physical model for ergonomic testing on a 50th percentile female was not able to be completed, however, female insight can be used to assess more options. Areas that require more attention include:

- The method which the upper vest connects with the side panels of the duty belt
- The overall size of the armour panel to account for differing shoulder widths
- Adjusting the size of the shoulder straps to be less intrusive
- Physical footprint of the main hub device and its viewing angle
- Placement of MOLLE webbing relative to the main device
- Activation methods for smart glove gesture pad
- Gender-appropriate design options

Further development of the concept moving forward can investigate the possibility of a collapsible hub device and deeper exploration into mobile technology. More research into body armour usage can aid in the development of armour related pieces, and a modular panel system could be used to account for user variance within similar percentile groups.

3.4 Aesthetics & Semantic Profile

As discovered in Chapter 2.2.3 Benchmarking – Aesthetics and Sematic Profile of Existing Products, many existing products designed for use by law enforcement officers are utilitarian in nature, taking geometric forms and with rugged or reinforced appearances.

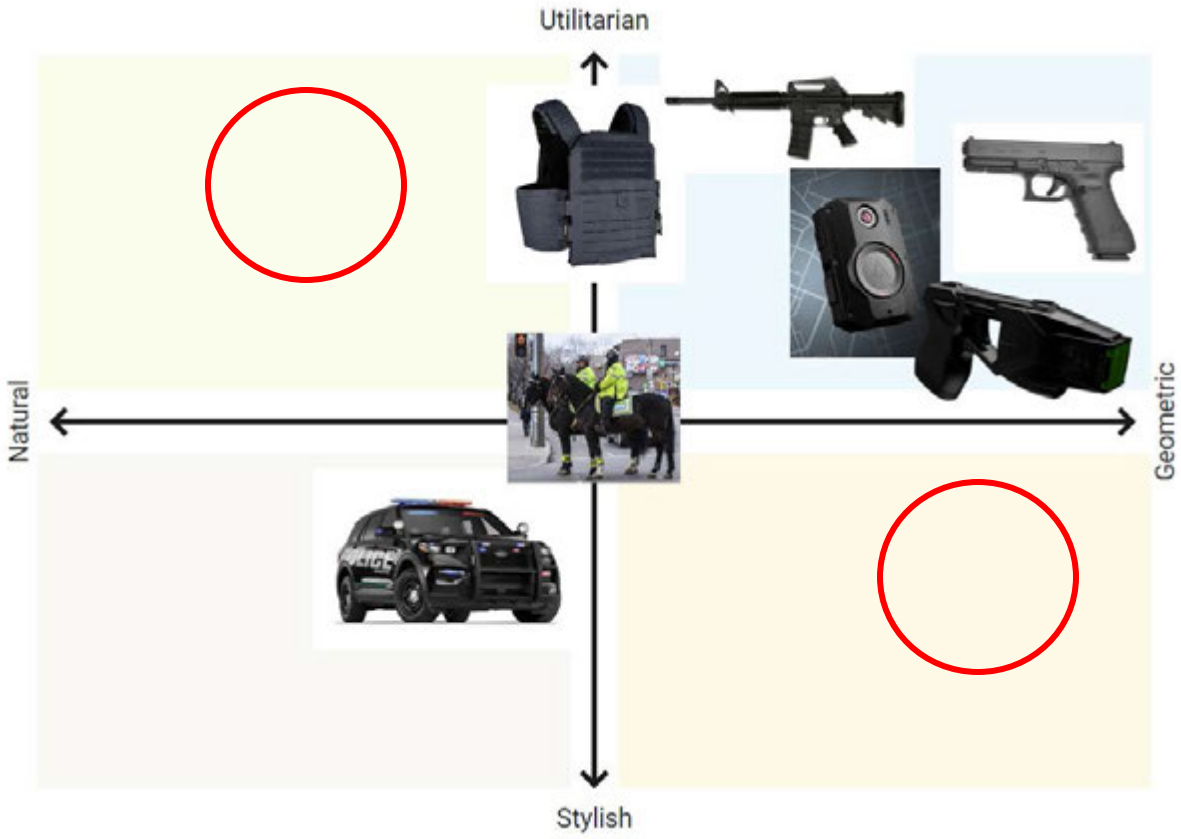


Figure 28 - Product Aesthetics and Semantics XY Matrix

Existing products can be analysed through an aesthetics and semantics XY matrix (see Figure 28). It can be seen that existing products are overwhelmingly geometric and utilitarian, with the exception of the Ford Interceptor which is designed as a mass market vehicle first before being retrofitted for law enforcement. Handheld products, such as firearms, utility, such as body cameras, and body armour are largely similar in their aesthetics, and can all place somewhere in the top-right quadrant of the XY matrix. Given this trend, it would make sense to let it act as a guide for possible design styling, however, there is some room to explore slightly more natural or stylish forms, as noted by the red markings in Figure 28. This would be an opportunity to differentiate a solution visually from existing products, yet, still appear similar to what a user may expect or subconsciously make connections with.

3.5 Sustainability – Safety, Health and Environment

The use of plastics, such as ABS, and fabrics, such as polyester and nylon, have no notable negative side effects on users. There are, however, potential health concerns connected to harvesting materials, manufacturing, and disposal. Due to how much equipment officers typically carry, the concerns are more related to physical health from all the weight.

3.6 Innovation Opportunity

3.6.1 Needs Analysis Diagram

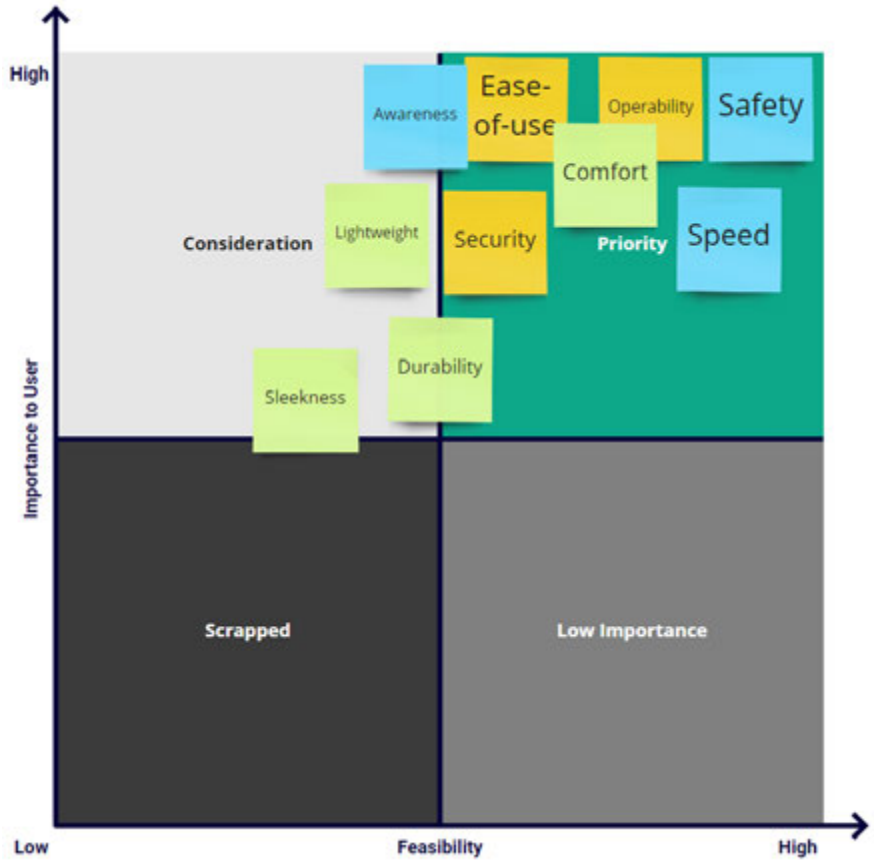


Figure 29 - Prioritization Grid of User Needs

While the user's needs were determined and categorised in Chapter 3.1 – Needs, it is not always possible to act on every lead. A prioritization grid (see Figure 30) will be used in

order to narrow focus and effort on which needs are most feasible to design for. The needs are coloured according to Table 7 - Categorization of Needs, and the immediate needs, represented in blue, take the highest priority to act on. Next, the latent needs, highlighted yellow, fall neatly within the priority section. The wants and wishes, in green, are more scattered considerations due to them not being as strong an impact, with the exception of comfort.

Needs Statements

Insights gained from the usability analysis reveal that there is a concern for individual safety, with the risk of a suspect attacking an officer and having to enter a dangerous situation where civilians may be endangered. There is also a challenge maintaining situational awareness in high-stress scenarios, where a user can easily become tunnel-visioned when threatened. Knowing this, further developed needs statements can be expressed for the higher priority needs from the diagram in Figure 30. The user needs to:

- **Communicate clearly** because they need to **interact with people regularly**
- **Feel safe or secure** because it can **reduce anxiety**
- **Have physical protection** because their **safety is at risk**
- **Be aware of their surroundings** because it allows them to have **better control of a situation**
- **Use their equipment quickly and easily** because scenarios can **become deadly in a matter of seconds**

3.6.2 Desirability, Feasibility & Viability

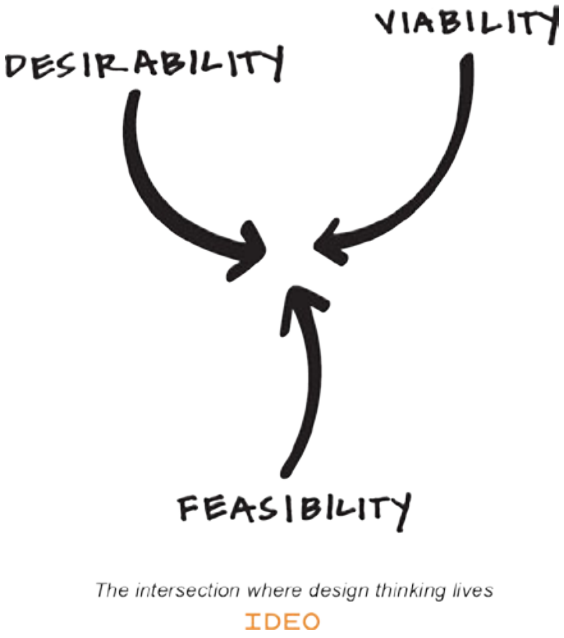


Figure 30 - IDEO Model for Design Thinking - Retrieved from https://designthinking.ideo.com

In order to innovate or create a successful design- something that will make an impact- multiple factors need to be taken into account. One such example are the facets of desirability, feasibility, and viability (see Figure 31) where the goal is to find a balance somewhere in the middle where each point can meet. Desirability is the facet of design thinking that represents the user. A product that is desirable can garner user interest and drive sales, providing a reason to design something new. Feasibility represents the practical and physical ability to execute a design; what is technologically possible. Viability approaches design from the business angle, where the costs to manufacture or produce a product and deliver it to the market are factored.

Desirability

As it applies to law enforcement, officers enter high-risk scenarios regularly. Their best protection is a ballistic vest, the nearest piece of cover, and their experience. Law enforcement

agencies and officers will always want to protect themselves. Many officers also face health problems from the weight of all the equipment they need to carry. Furthermore, for many officers, this is their dream job, and being able to do it with confidence and increased protection from harm is a benefit. Therefore, a new product that attempts to address the ergonomic issue while also aiding a user in a dangerous scenario is an opportunity.

Feasibility

With the progression of ballistic protection research and technology having been developed for years now, such as Kevlar, and many law enforcement agencies mandating the use of body armour, it is entirely possible to incorporate ballistic protection into a design without the uncertainty of a new technology. Additionally, smart technologies have also progressed to a point where they are practically ubiquitous and becoming widely accessible, with new technologies being explored every year.

Viability

Ballistic protection technology has been around for years and continuously improved upon. Many law enforcement agencies also receive large funding, which, combined with the increasing accessibility of ballistic and smart technologies and a desire to protect oneself, there is a business case to be made.

3.7 Summary of Chapter 3 – Defining Design Brief

Before one can start efficiently designing anything, there needs to be restrictions or guidelines that direct the process. For this, a design brief is needed. Law enforcement can be

very dangerous and puts an officer's safety at risk regularly. There is an opportunity to provide officers with more options to increase their safety or likelihood of avoiding injury.

Thus, the goal of this thesis project is to design an easily deployable and usable device that provides an officer with more methods of communication and information gathering. The design brief will utilise ten objectives that will guide the design process, and can be broken down into the following categories:

Category	Objectives
Ergonomic	• Reduction of lower back and hip strain to ease the day-to-day pains of carrying heavy equipment • Adjustable to different user body types, handedness, and personal preferences
Communication	• Provide the user with more options for communication with other officers and civilians • Provide supervisors with real-time information of on-field officers to better support them
Usability	• Does not distract the user from using their equipment effectively when in a high-risk scenario • Aid the user's situational awareness to improve their control and understanding of a situation • Allow easy access to- and removal of- body armour for treating injuries or working off-field
Benefits	• Comfort and breathability of materials to allow continued use over long work periods • Reduce the number of loose equipment to save space and weight on the user's body
Aesthetics & Semantics	• Resemble any utility and equipment that gets replaced without appearing over-militarised

Table 11 - Design Brief

Chapter 4 – Design Development

Gathering the information learned in Chapter 2 – Research and Chapter 3 – Analysis allows the design phase to begin. Research will inform decisions, potential ideas, and solutions to the problem definition moving forward.

4.1 Initial Idea Generation

4.1.1 Aesthetics Approach & Semantic Profile

Figure 31 - Inspiration Board

Taking the analysis of existing product aesthetics and semantics into consideration, an inspiration board of forms or features has been made (see Figure 31). Additionally, several key phrases have been chosen to further guide the aesthetics of future design possibilities:

- Utility
- Smart

- Rugged
- Sharp
- Flow
- Space

4.1.2 Mind Mapping

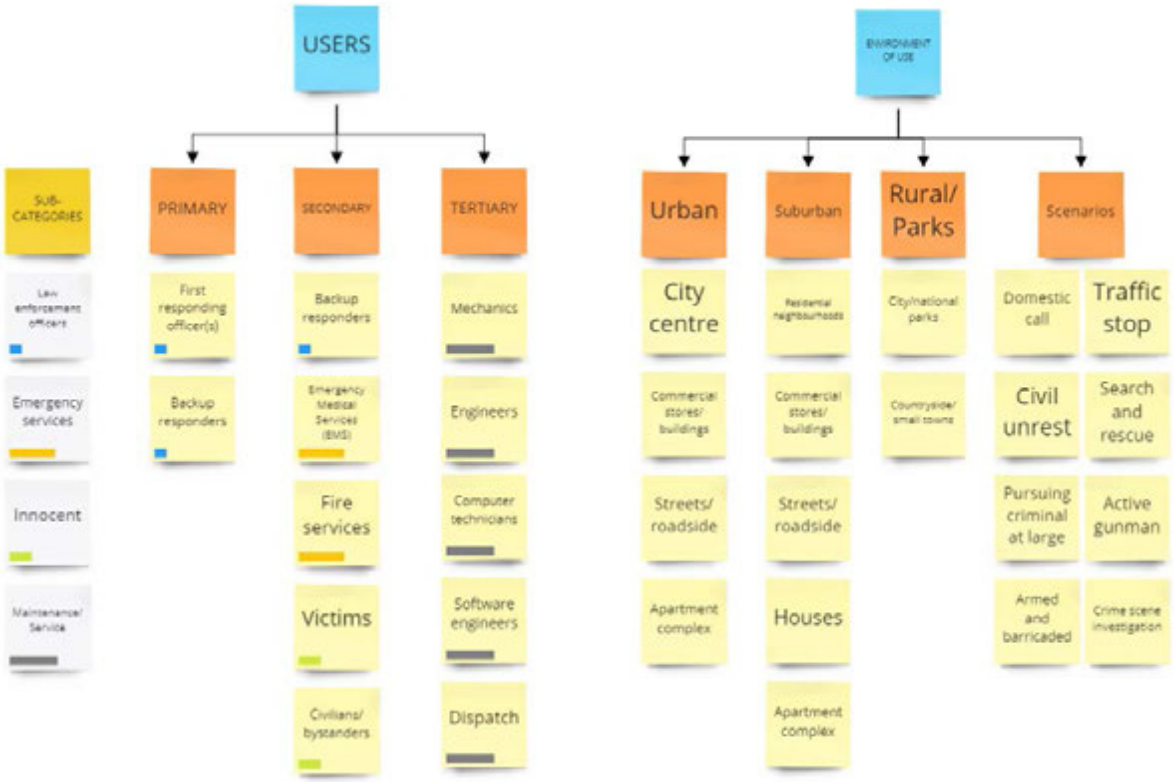
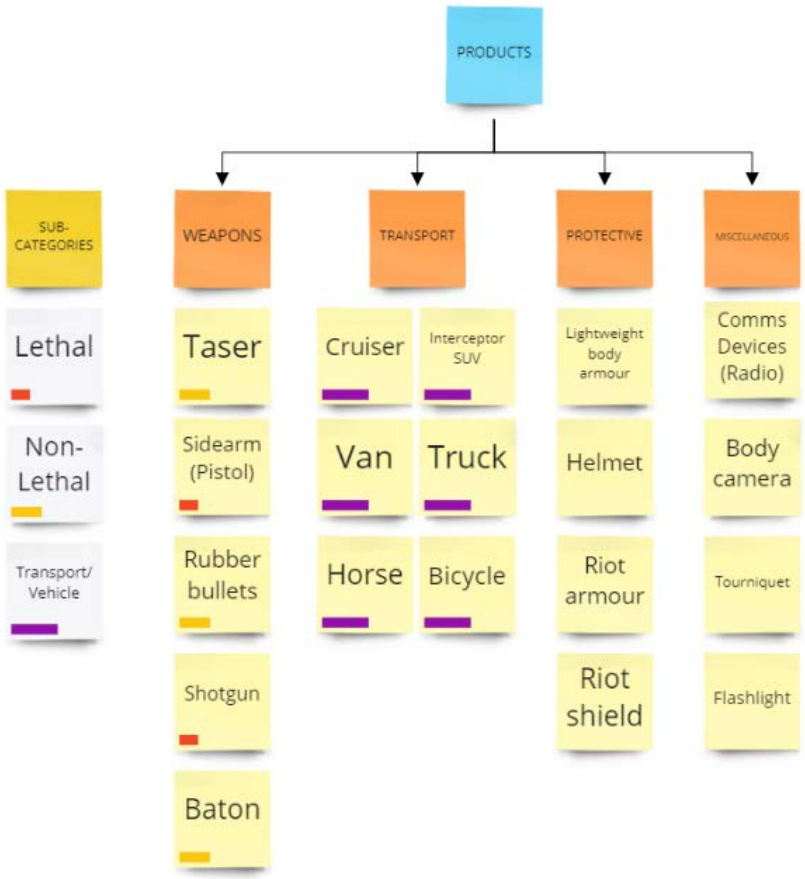


Figure 32 - Mind Mapping



An affinity map (see Figure 32) was used to brainstorm and categorise different aspects related to the topic. Users were categorised as primary, secondary, and tertiary users. Products were separated into categories of weapons, vehicles, equipment, and protective gear, with weapons being further divided by level of lethality. Lastly, various different scenarios and environments of use were considered and noted. This helps to get a quick understanding of the potential users, what they might be doing, and what they might be interacting with.

4.1.3 Ideation Sketches

From the previous two steps, it is now possible to begin the ideation phase and brainstorm early concept ideas and directions. Six initial ideas of differing directions were used

to kickstart the design phase. Ideas ranged from reconnaissance, utility, communication, and physical protection, as these were all factors deemed important to law enforcement.

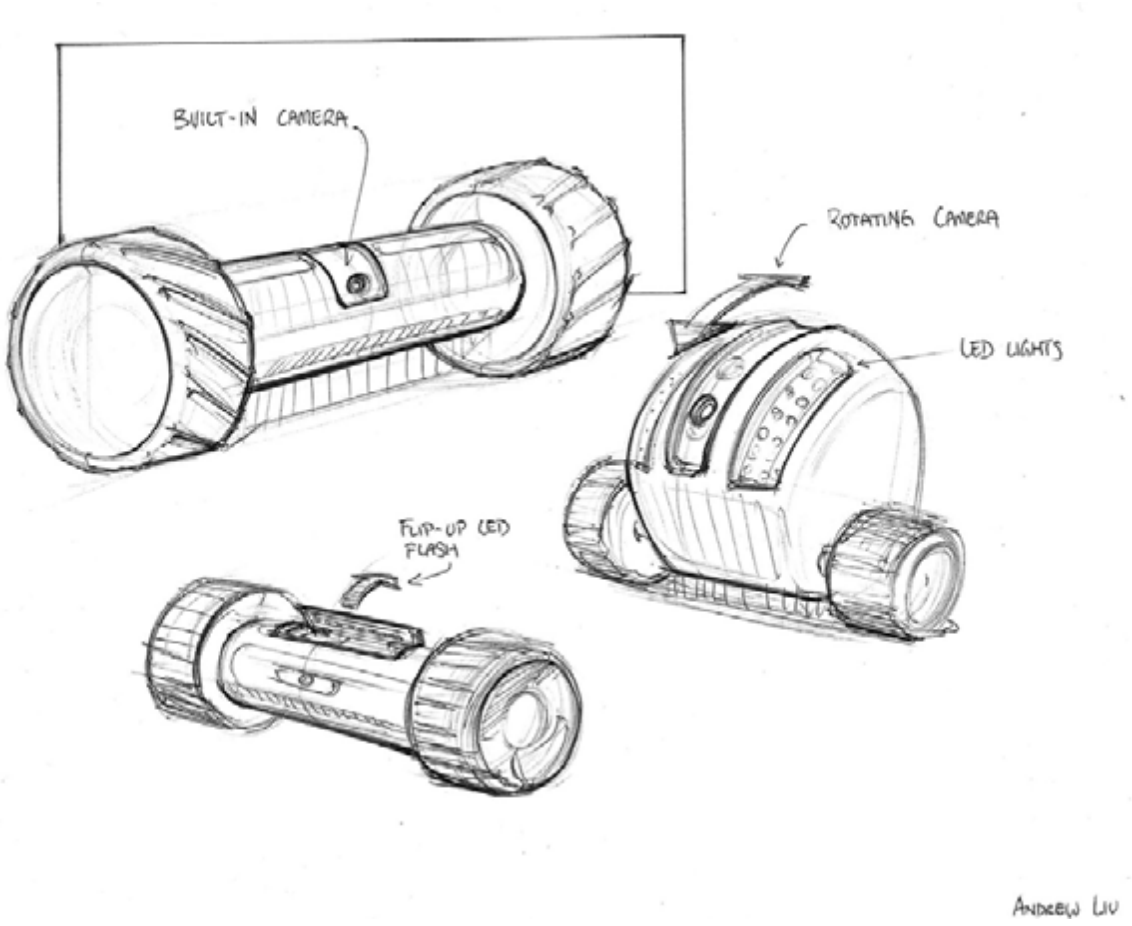


Figure 33 - Ideation Sketch 1 - Recon Drone

Ideation one focuses on providing officers with more options for reconnaissance. One determining factor of any engagement is information, and entering an area, building, or room blindly can be fatal. This idea aims to act as a drone with a camera to safely scout ahead before making any moves.

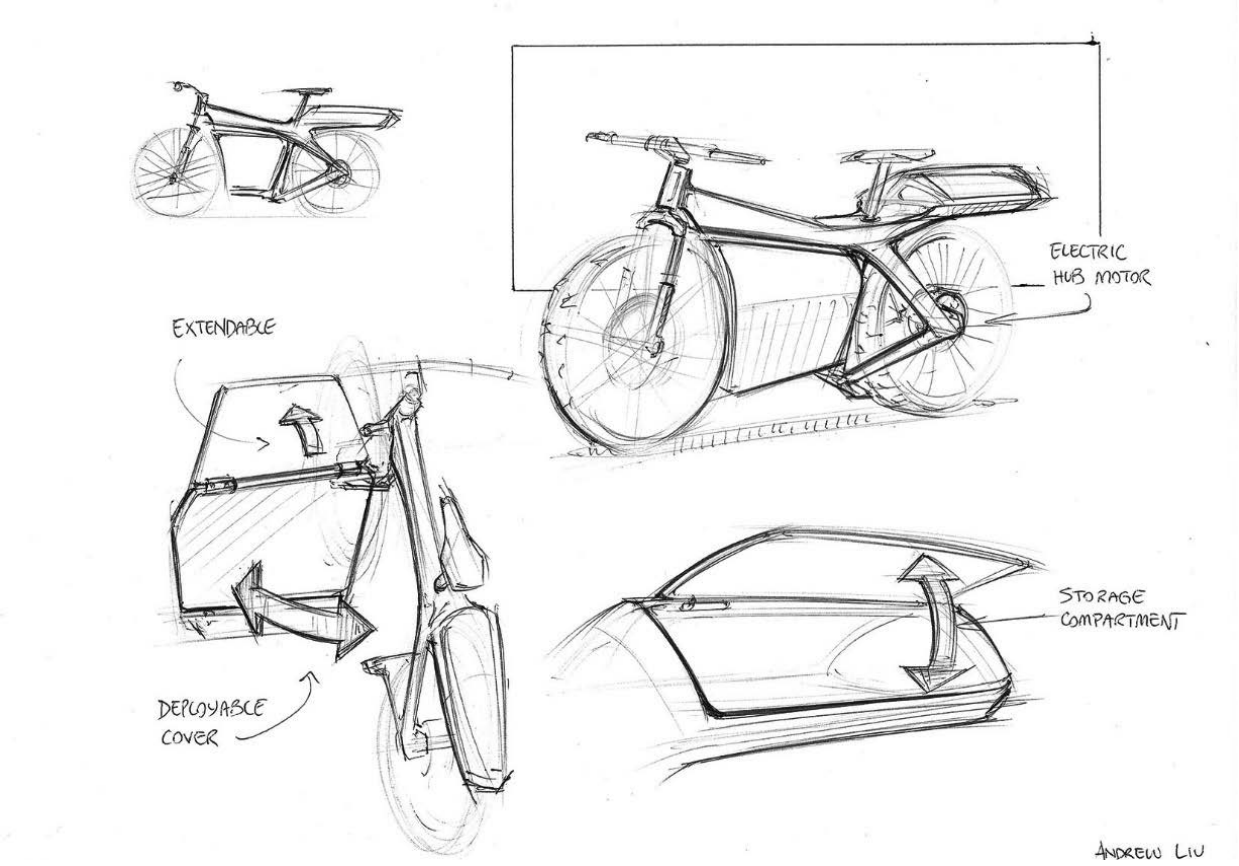


Figure 34 - Ideation Sketch 2 - Deployable Bike Cover

Ideation two focuses on bike police. The purpose of police on bikes is that they can reach certain areas and tight corridors within cities that a typical cruiser car cannot. The trade-off with a bike is, of course, that the user is completely exposed. In the event that an officer finds themselves being attacked while on the bike, they do not have many options for protection. That is where the deployable shield comes into play.

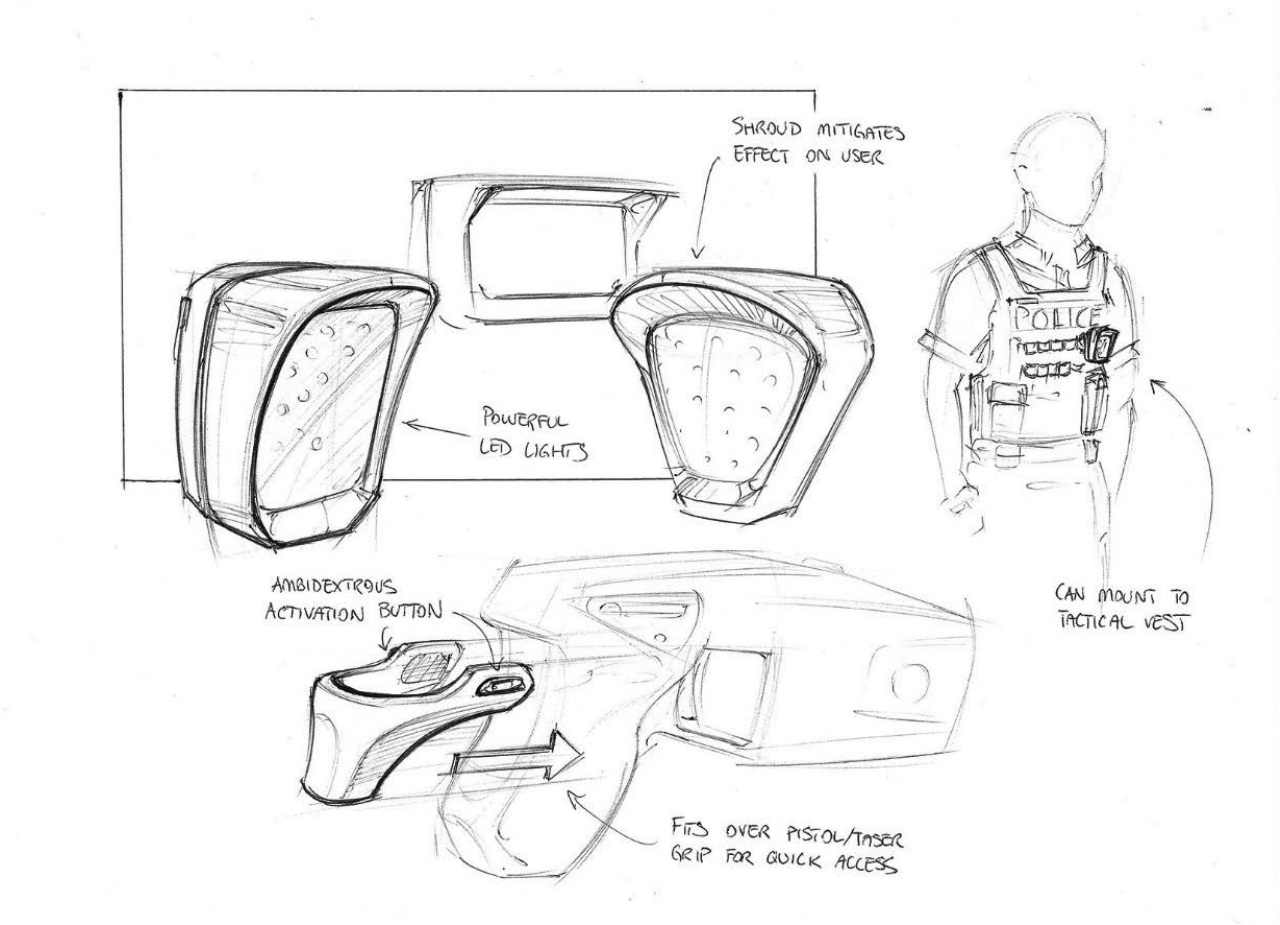


Figure 35 - Ideation Sketch 3 - Flash & Blind Device

Ideation three builds upon the knowledge that situations can unfold in seconds, without a lot of time left to react. This flash device works in a similar manner to a flashbang grenade, made to temporarily blind and impair the recipient. By making it something controllable and worn on-body, the officer could activate it as they are drawing their weapon, making it more seamless to subdue or apprehend a resisting suspect.

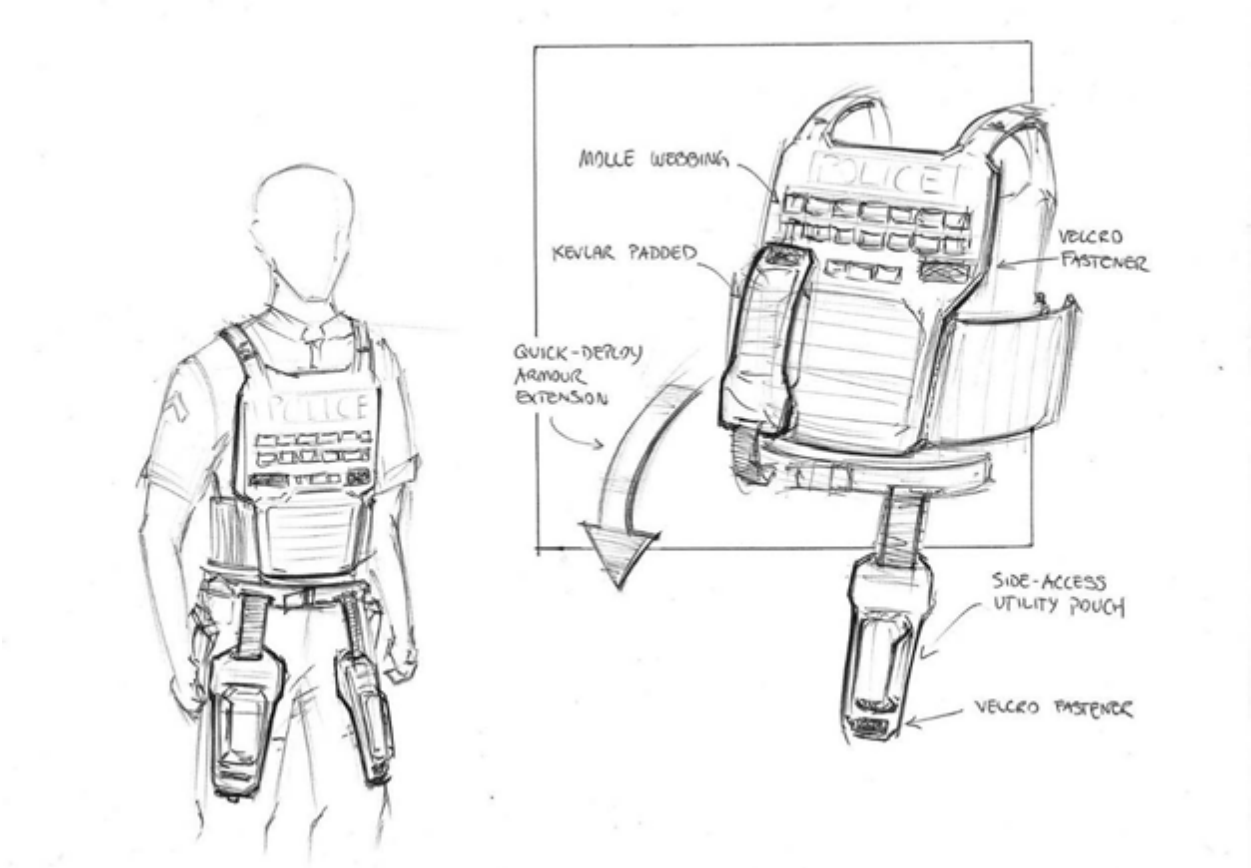


Figure 36 - Ideation Sketch 4 - Quick-Deploy Armour

The intention behind ideation four is similar to three in the sense that time is of the essence, and an officer does not always that luxury. Having a wearable body armour that can extend when needed provides extra protection when shots are exchanged, while the panels can be stowed away when not used to reduce the clunkiness of extra armour during standard wear.

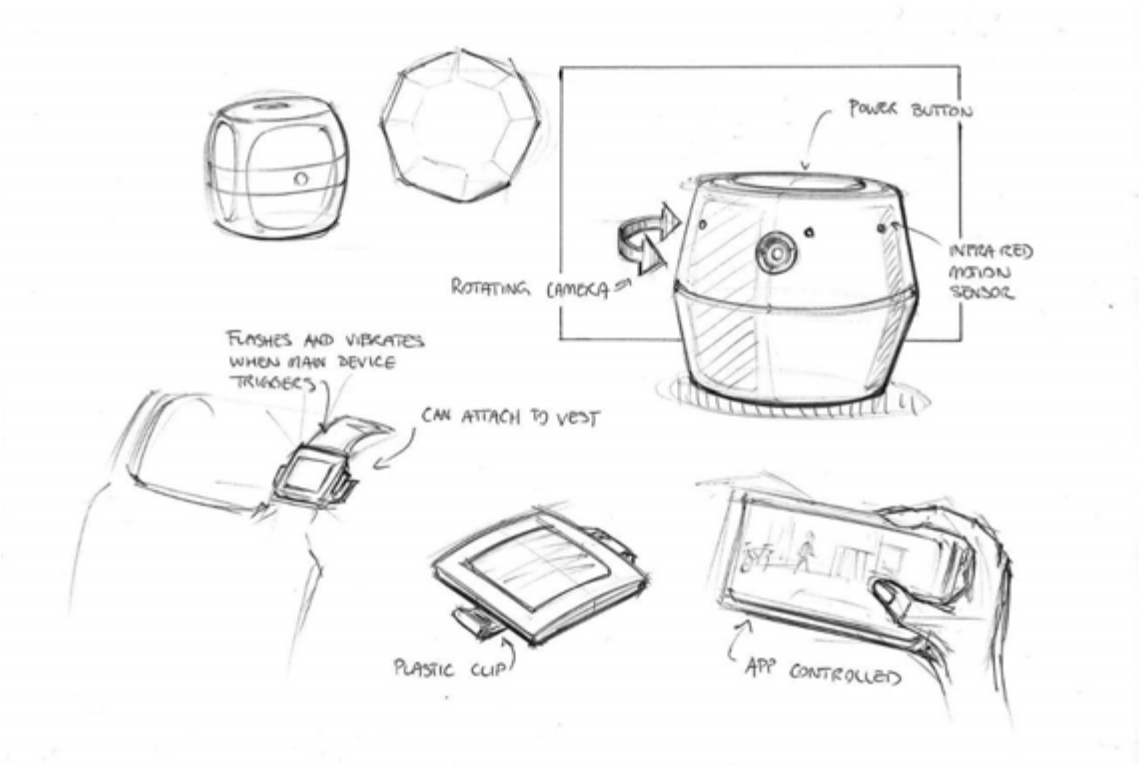


Figure 37 - Ideation Sketch 5 - Perimeter Watch Camera

The fifth ideation continues with the idea of providing extra intel to officers securing a scene. In the video observation, the suspect got the jump on the officers because they were not aware of his presence when returning. This idea would act as a perimeter watch to track what happens around the area if another officer cannot be stationed to keep guard.

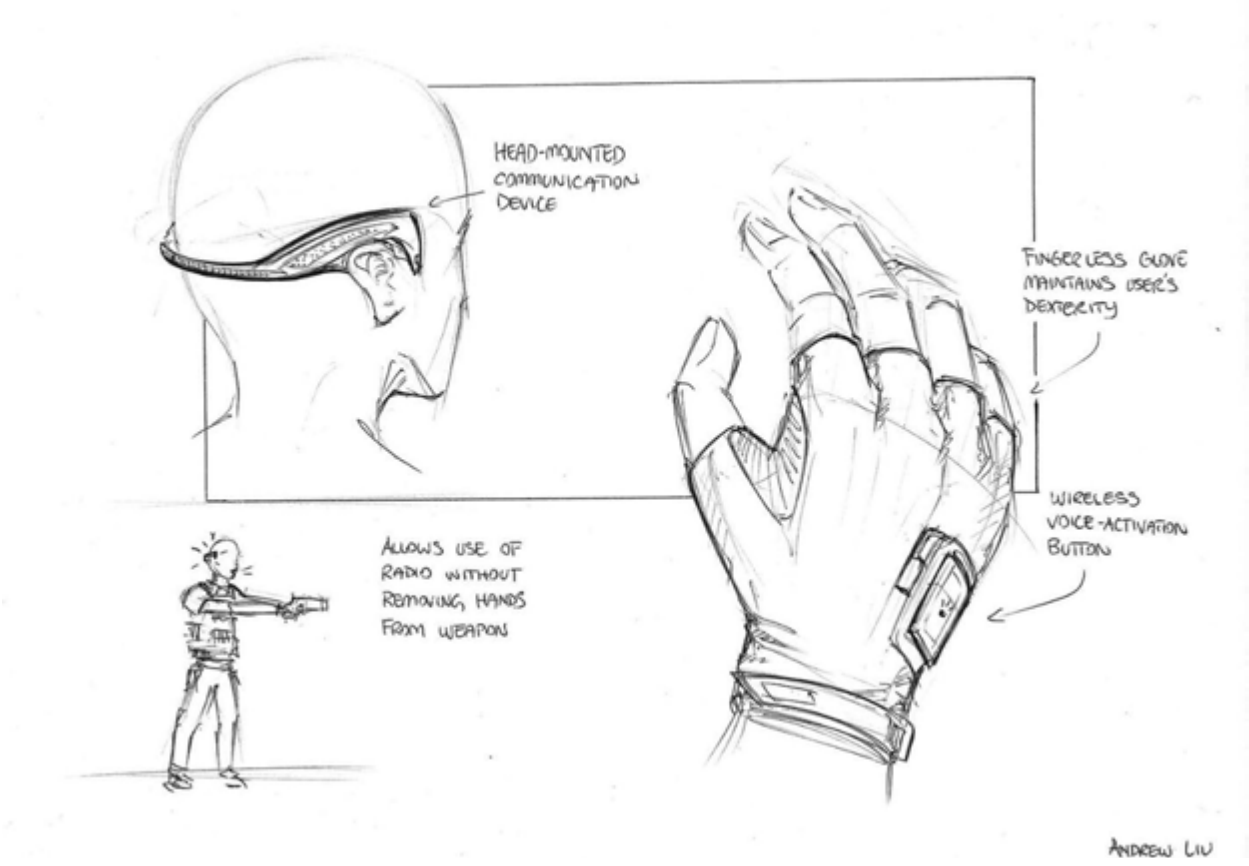


Figure 38 - Ideation Sketch 6 - Communication Device

The sixth ideation follows in line with the notion of using equipment swiftly when things rapidly escalate. Glove-mounted controls make it easier for the user to activate their equipment, a radio in this case, without fumbling with other utility or removing their hands from their weapon.

4.2 Concepts Exploration

Building upon the initial ideation stage, three more developed concepts were derived and expanded on. Each concept needed to have a distinct direction to explore the different possibilities and use-cases for law enforcement officers.

4.2.1 Concept One

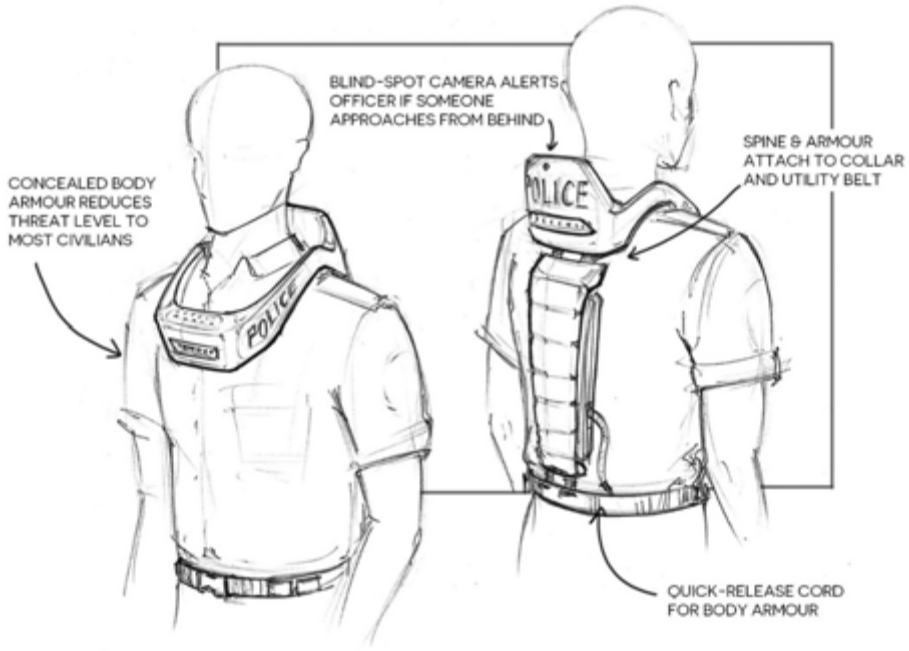


Figure 39 - Concept One - 1

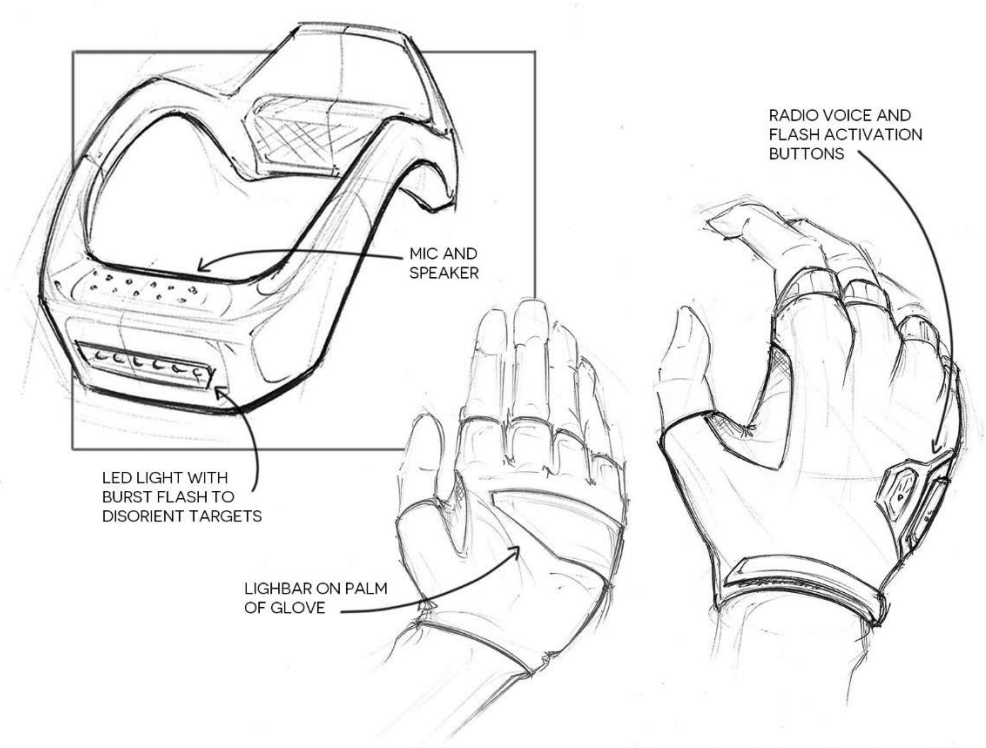


Figure 40 - Concept One - 2

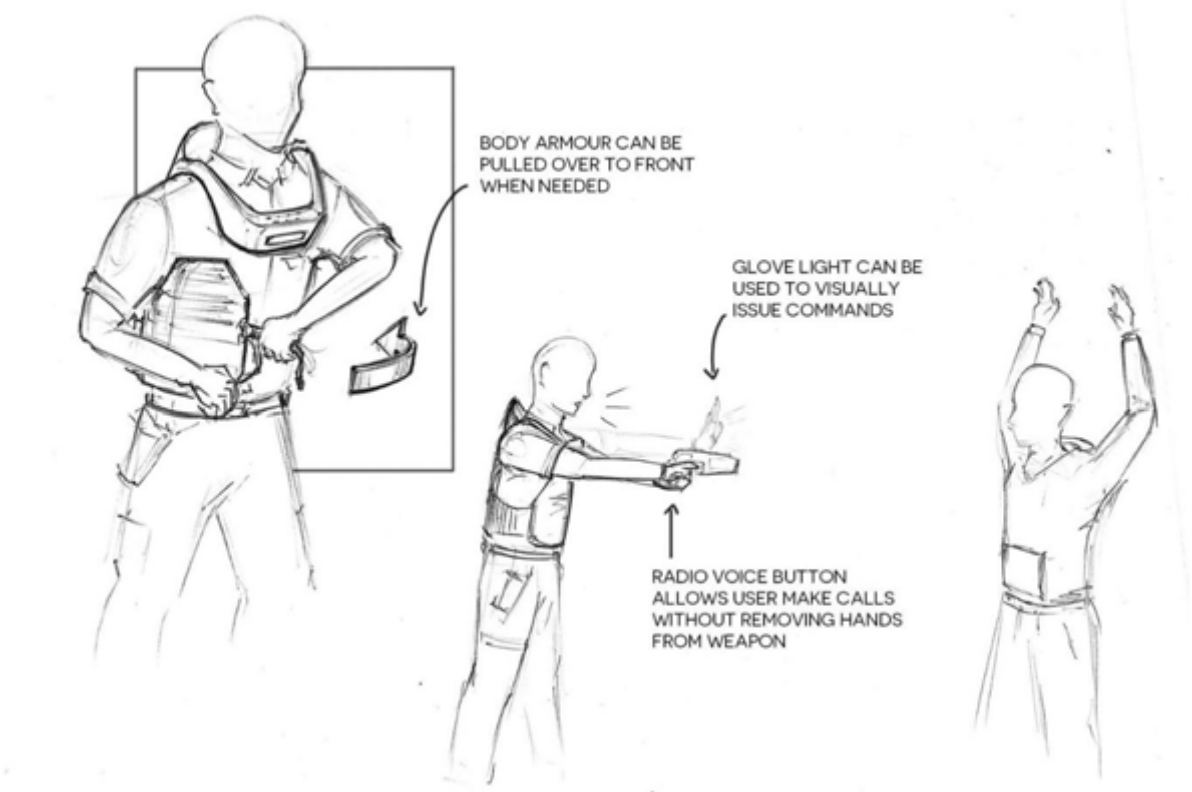


Figure 41 - Concept One - 3

Concept one integrates features of ideation sketches 3, 4, and 6. The intention with this concept is to provide an officer with a wearable, multi-functional device that they always have equipped. It combines the radio and flashlight into one device with gesture-activated controls from the glove. Armour is concealed in an attempt to address concerns of police militarization, but still allow quick access for the user when needed.

4.2.2 Concept Two

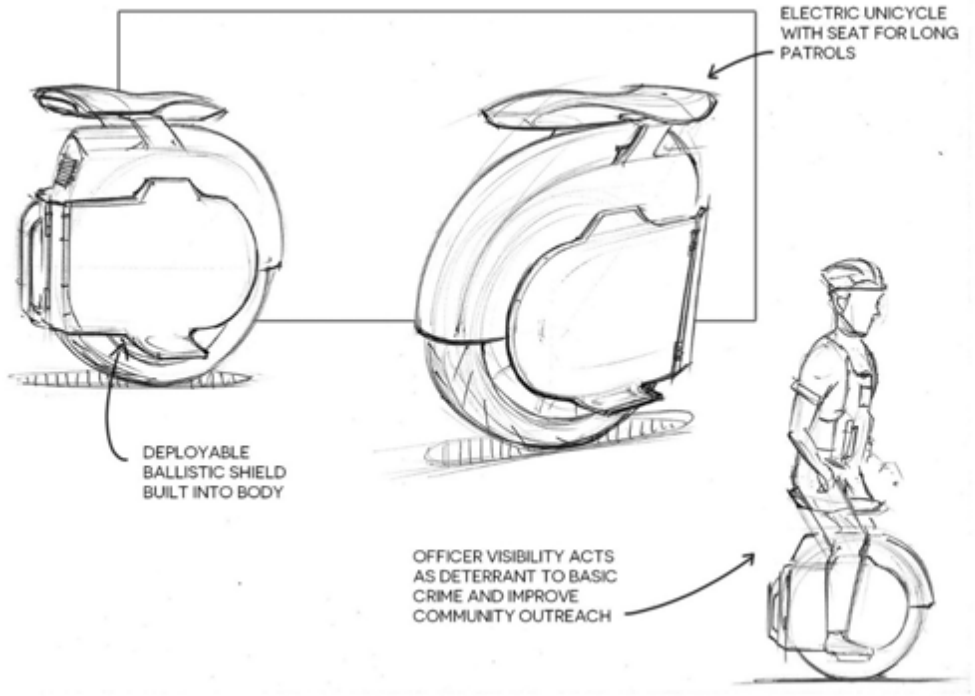


Figure 42 - Concept Two - 1

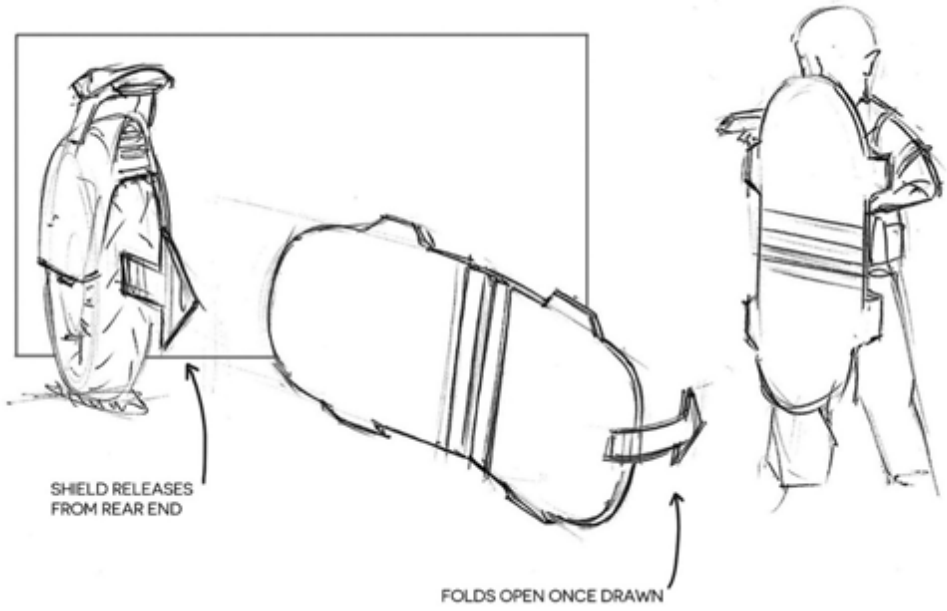


Figure 43 - Concept Two - 2

Concept two takes from ideation sketch 2 and aims to use a more novel form of personal transport for use within urban centres. The enhanced officer visibility can improve community outreach, and act as a basic level of crime deterrence. When needed, an extendable ballistic shield is integrated into the frame of the vehicle for quick-use and access.

4.2.3 Concept Three

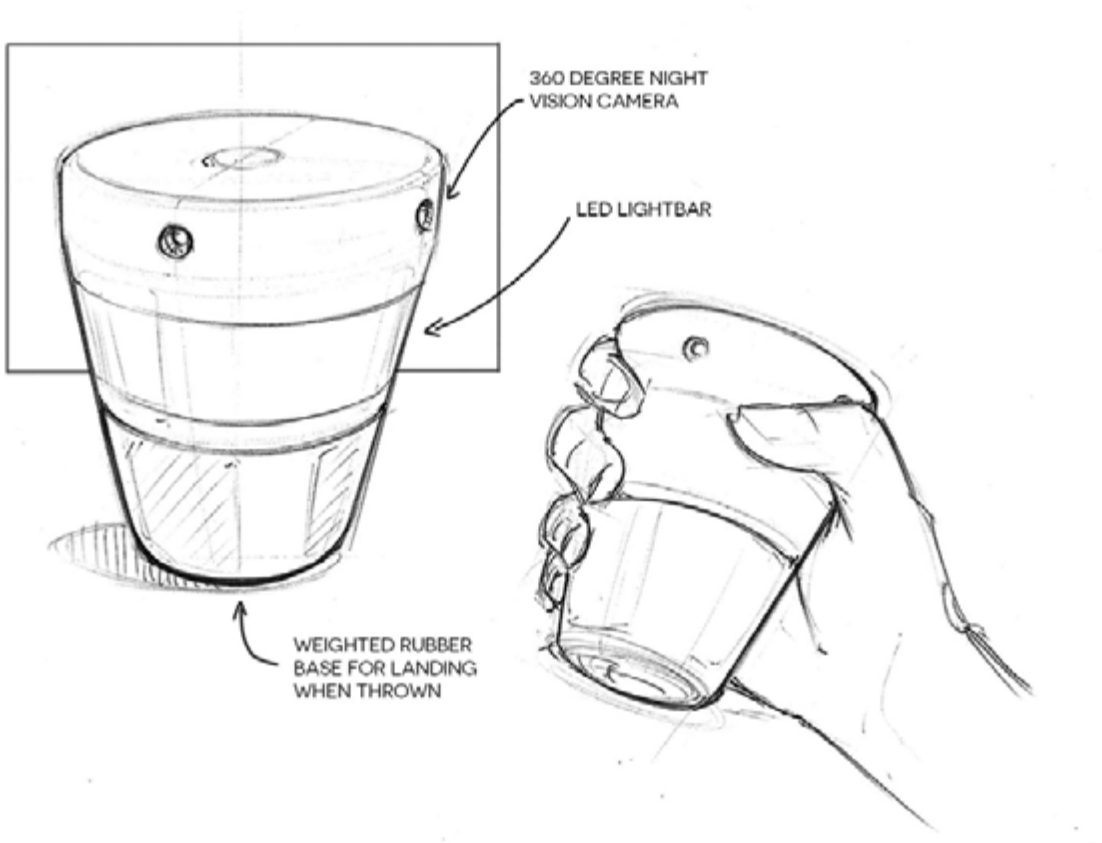


Figure 44 - Concept Three - 1

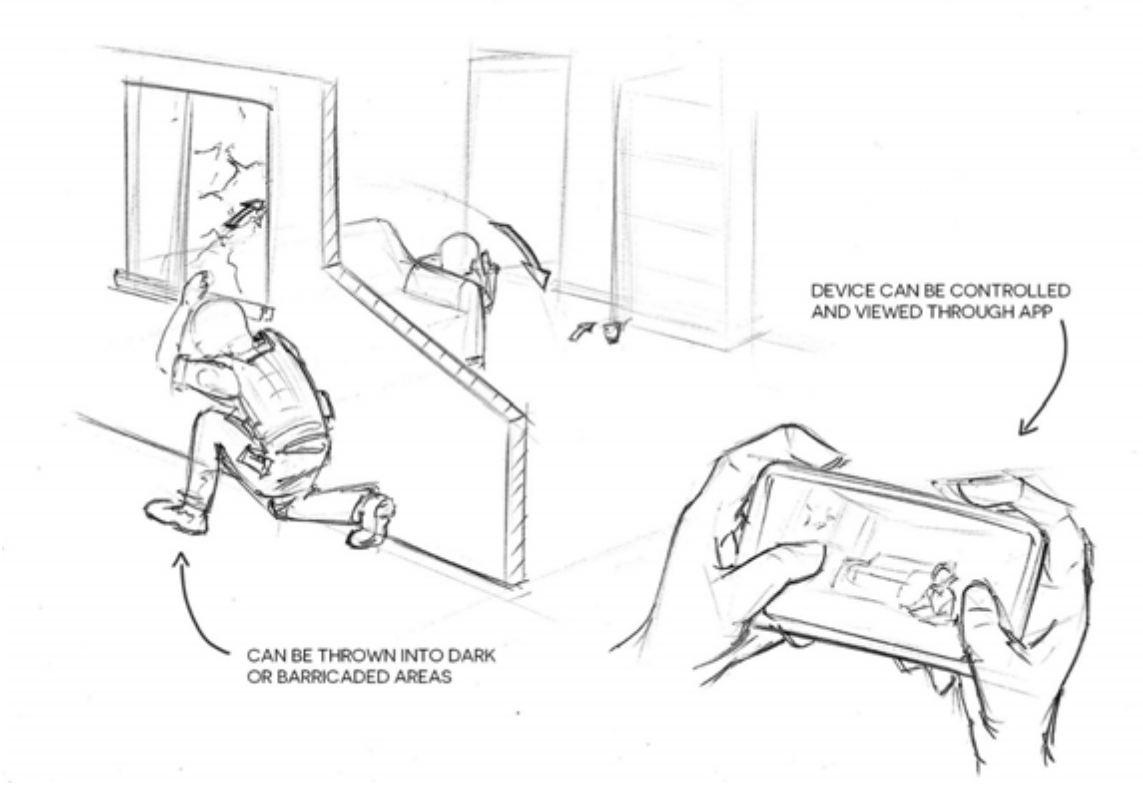


Figure 45 - Concept Three - 2

Concept three takes after ideation sketch 1 and 5, with the idea being a sturdy device that can be tossed into a room or building and survey the immediate area for any threats using an integrated smartphone app. An included 360-degree light would also help to illuminate any movement or dangers before entering.

4.3 Concept Strategy

4.3.1 Concept Direction & Product Schematic One

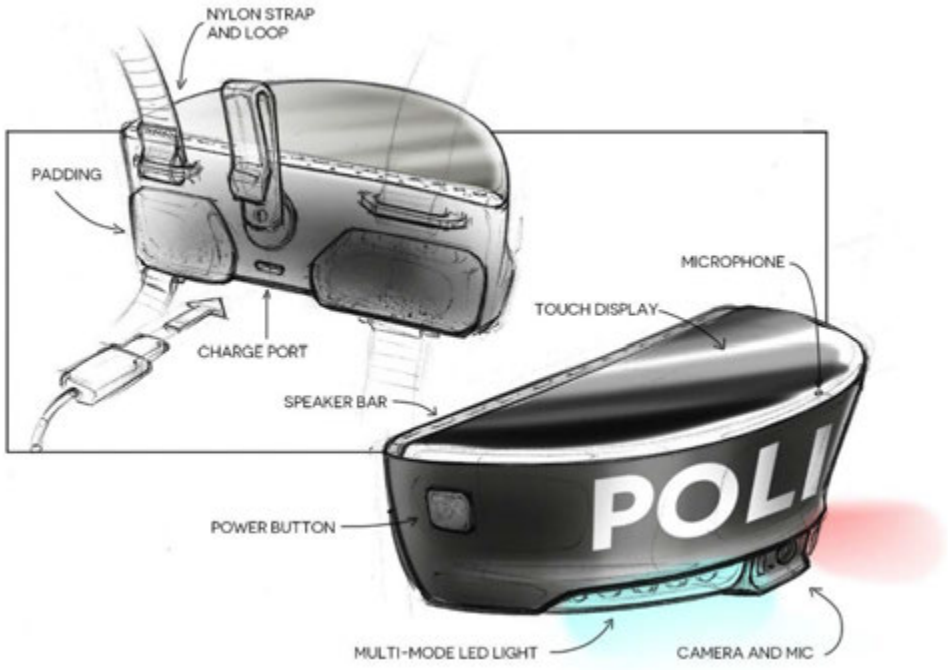


Figure 46 - Concept Direction One – 1

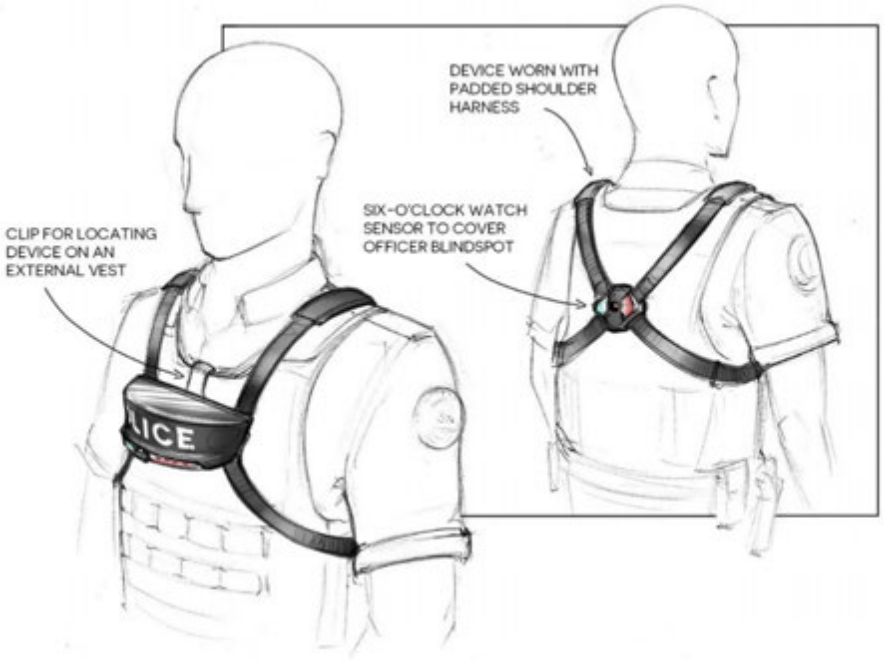


Figure 47 - Concept Direction One - 2

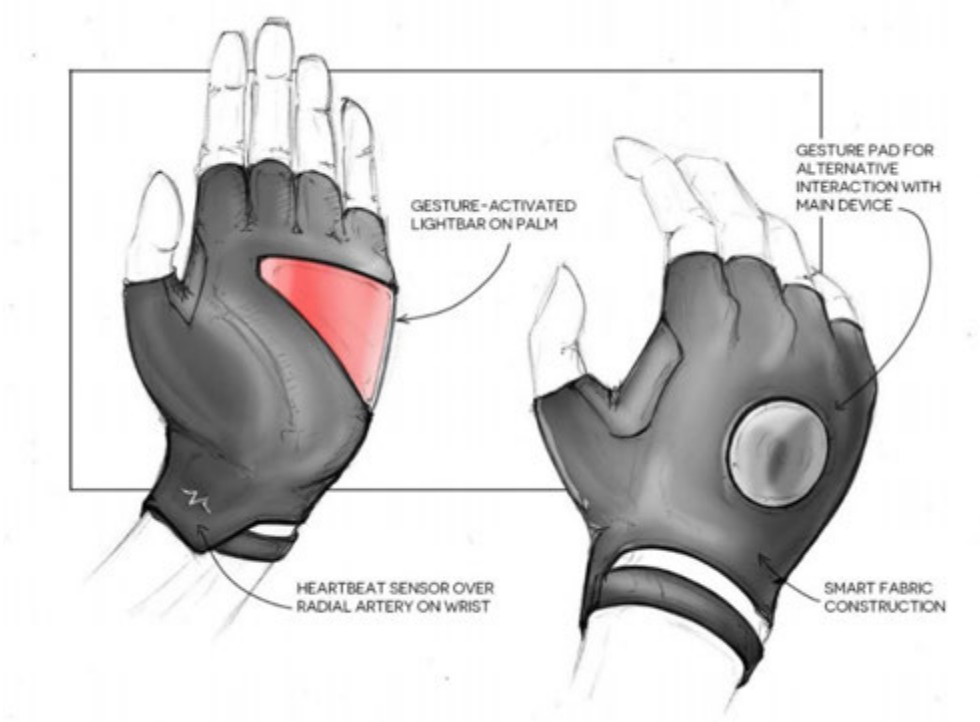


Figure 48 - Concept Direction One – 3

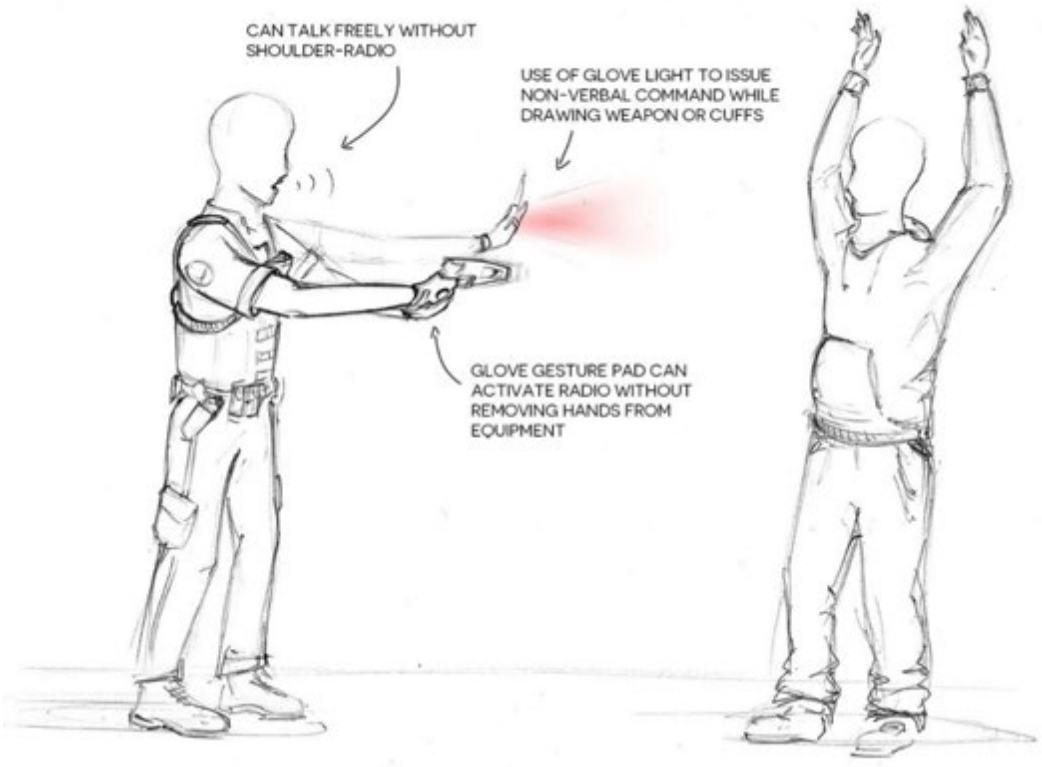


Figure 49 - Concept Direction One - 4

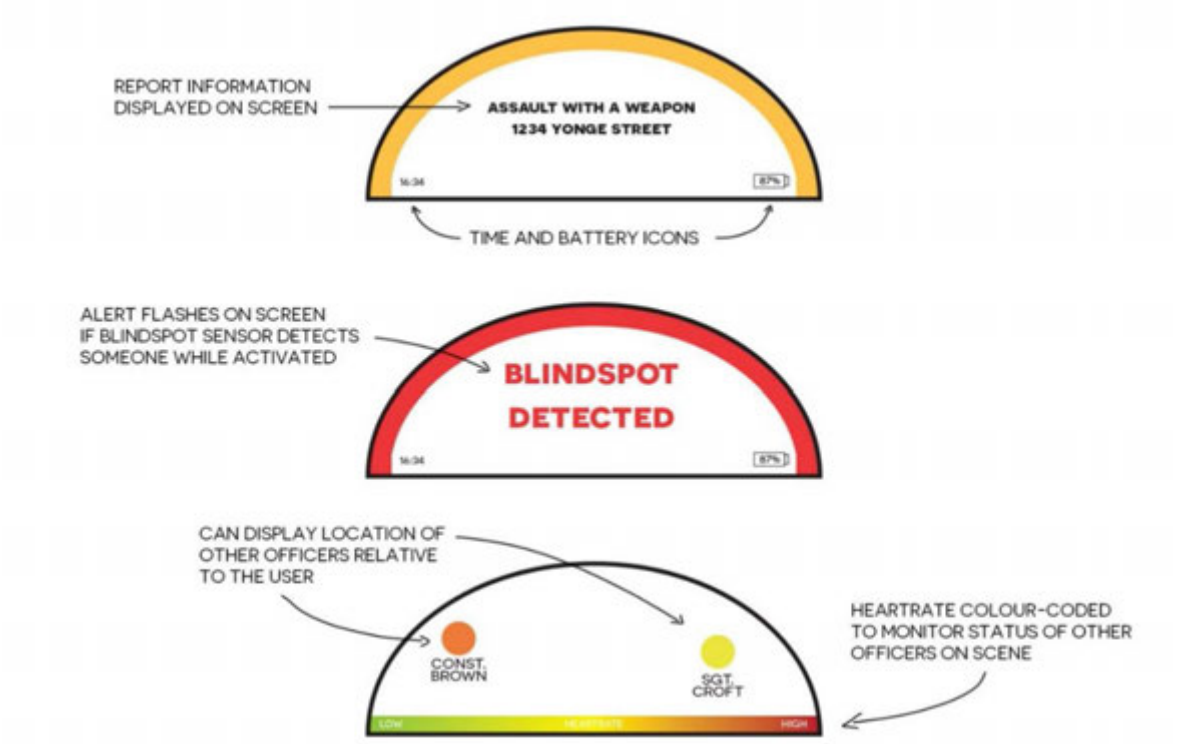


Figure 50 - Concept Direction One - 5

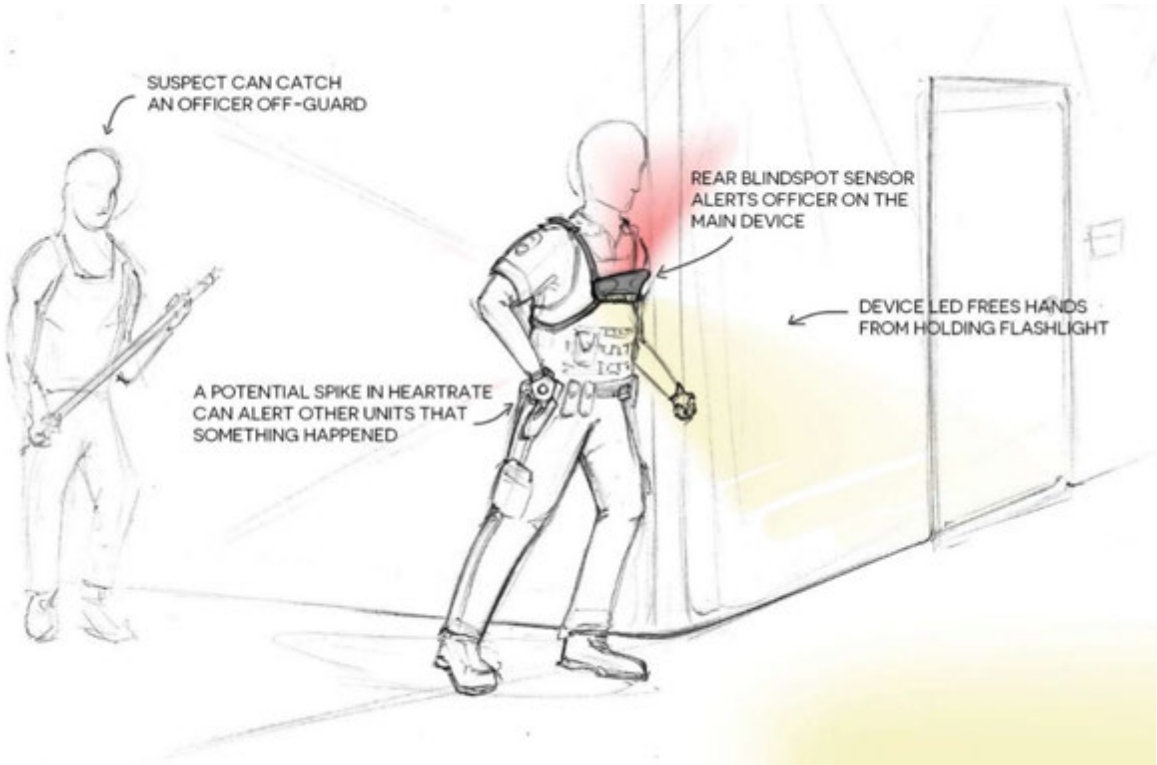


Figure 51 - Concept Direction One - 6

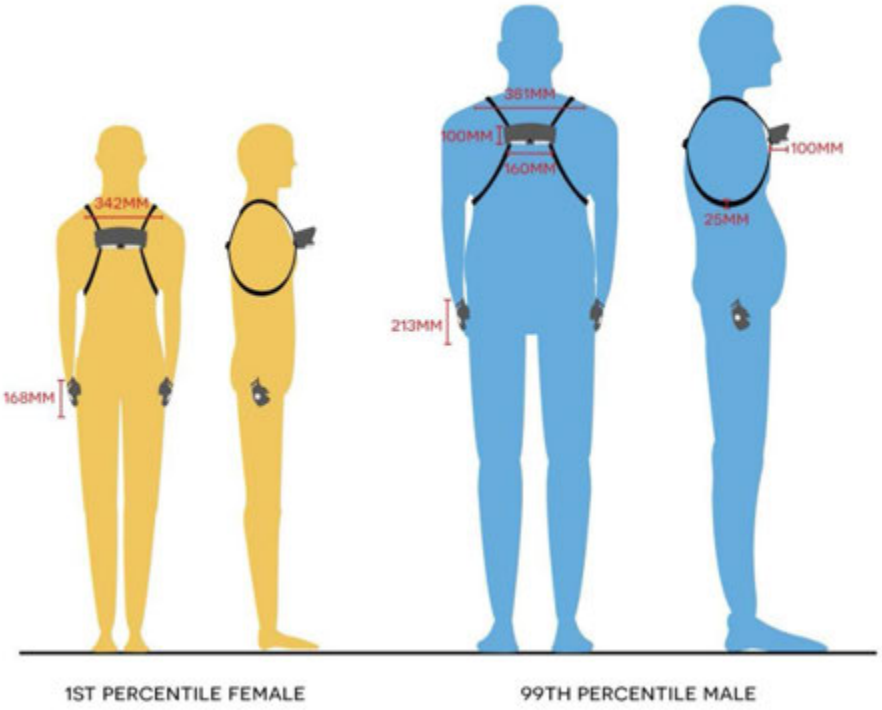


Figure 52 - Concept Schematic One - 1

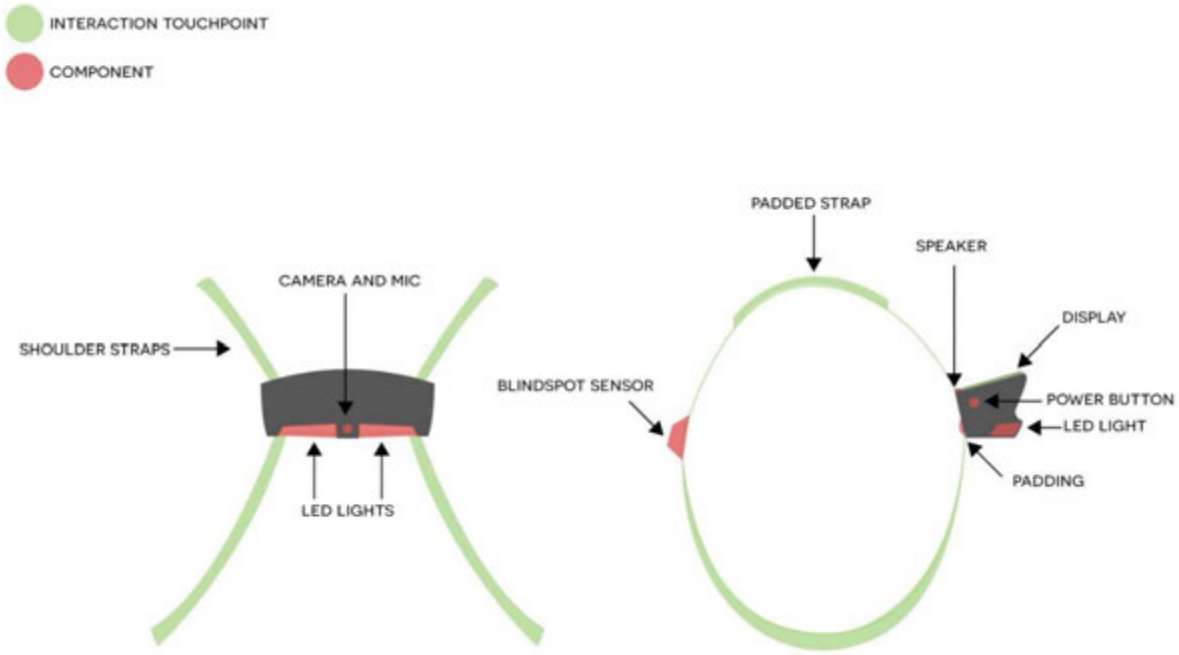


Figure 53 - Concept Schematic One - 2

Concept one was chosen for further development with the intent of developing a wearable, multi-functional safety and communication device. This device is intended to aid the user's situational awareness and ability to use their equipment easily in situations where seconds matter and there is no time to think. Initially, the concealable body armour was foregone due to it being mandatory full-time wear, however, this will be expanded upon in Chapter 4.4 – Concept Refinement & Validation. A preliminary product schematic was created for this concept with measurements included.

4.3.2 Concept Direction & Product Schematic Two

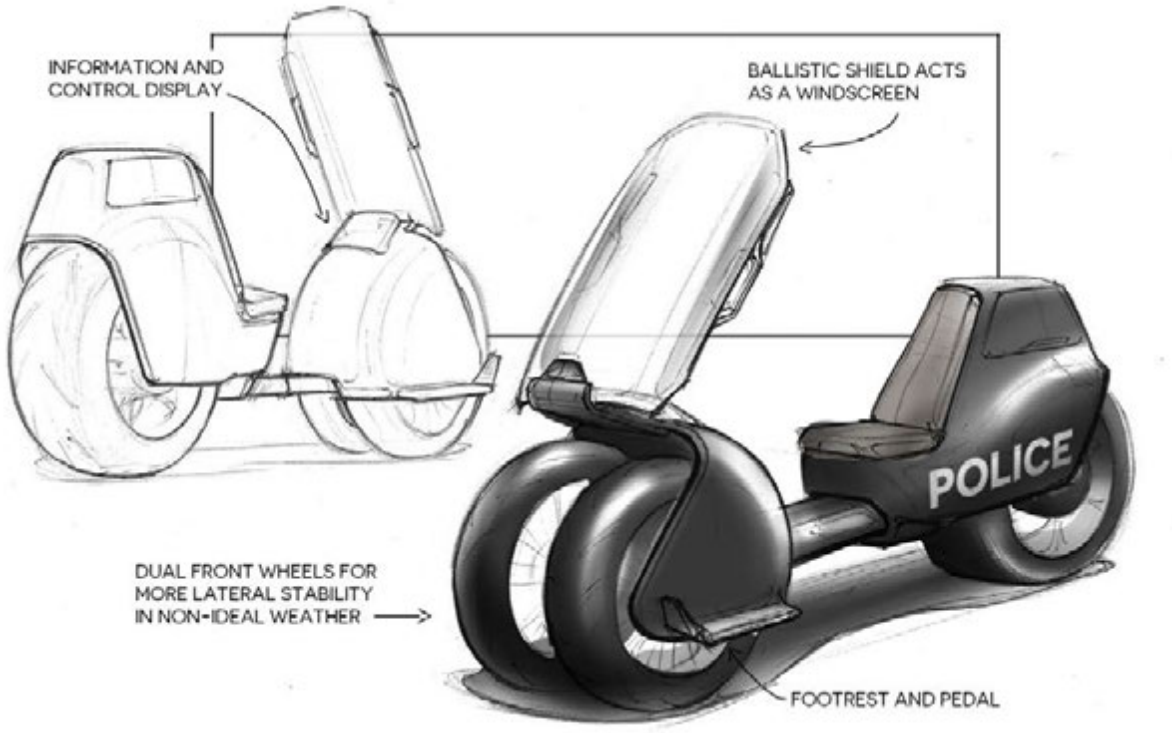


Figure 54 - Concept Direction Two - 1

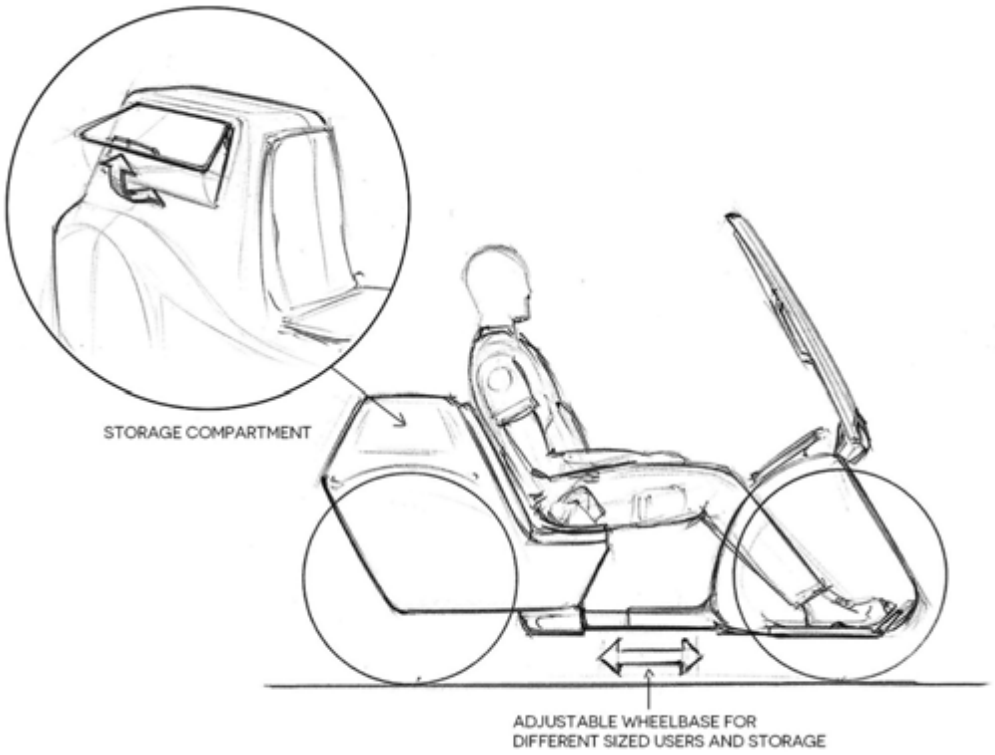


Figure 55 - Concept Direction Two - 2

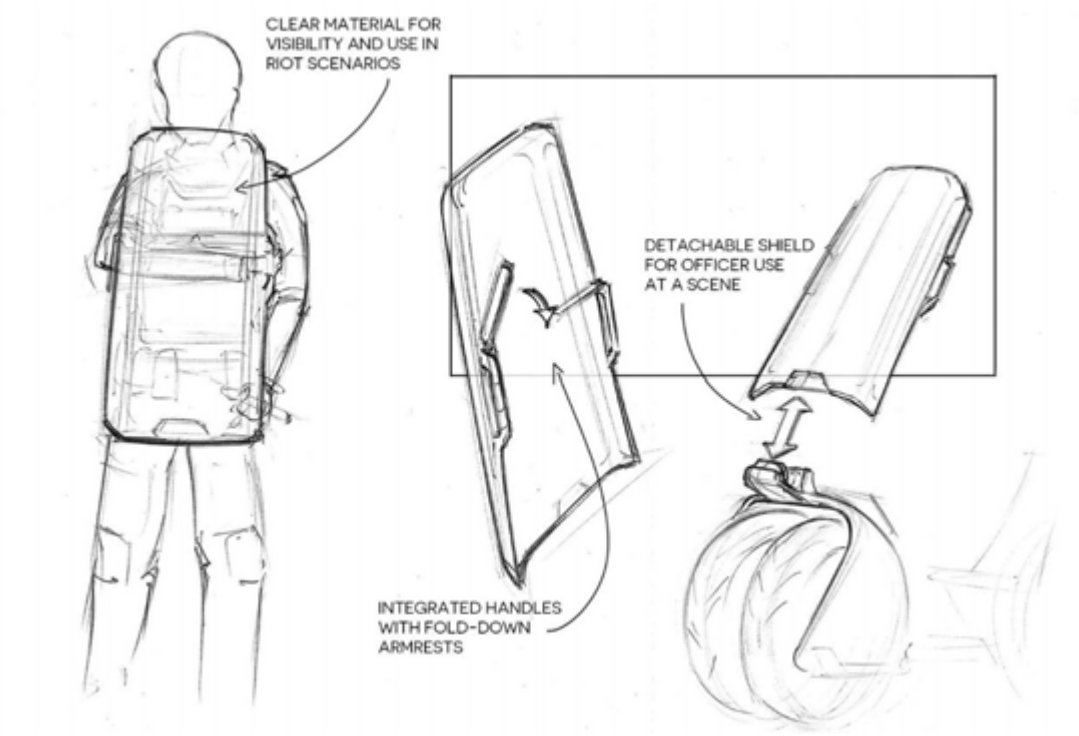


Figure 56 - Concept Direction Two - 3

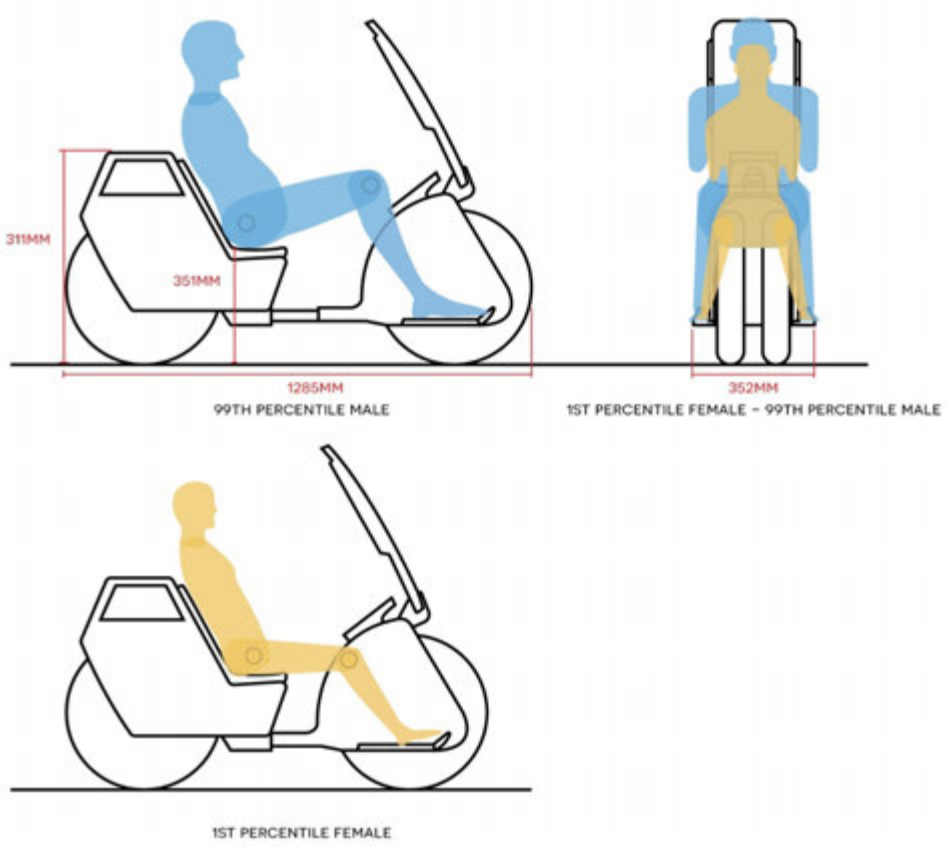


Figure 57 - Concept Schematic Two - 1

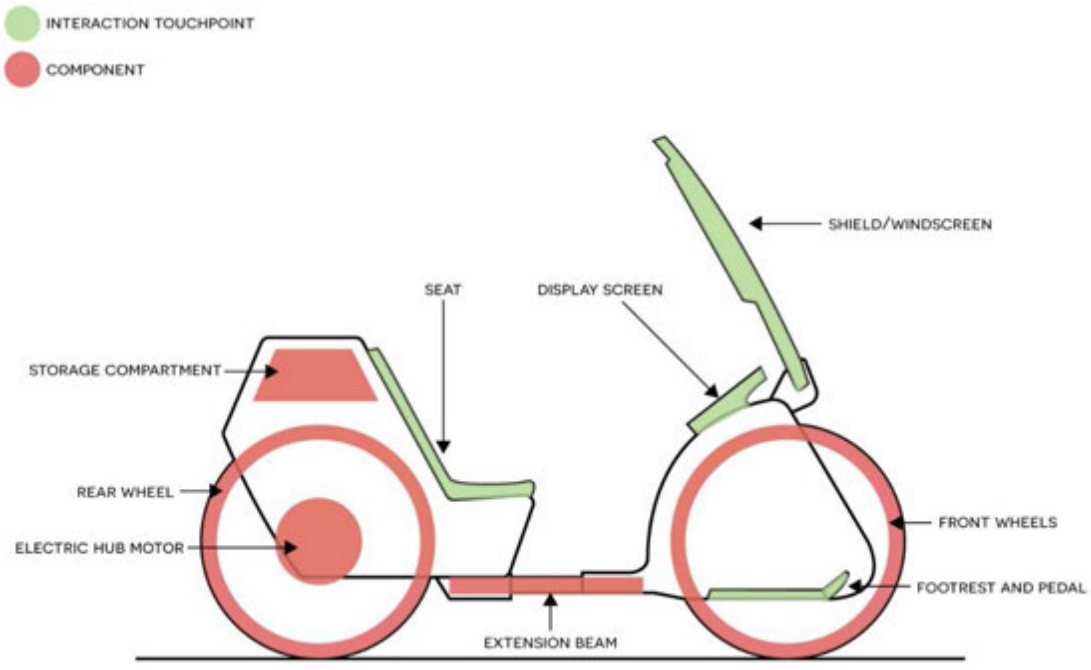


Figure 58 - Concept Schematic Two - 2

Concept direction two revisited the bike idea with an adjustable size to accommodate different users and include more utility storage space. The ballistic shield is now integrated as a windscreen to provide a user with more protection when arriving at a scene and retains its quick-release functionality. It also uses an electric motor to power the vehicle, conserving the user's energy for when they need to be in action.

4.4 Concept Refinement & Validation

Concept direction one was the chosen path for this design project as it has the most potential to target an opening in the market. Further revisions and refinements were needed to expand upon the idea and delve into some of its intricacies.

4.4.1 Design Refinement

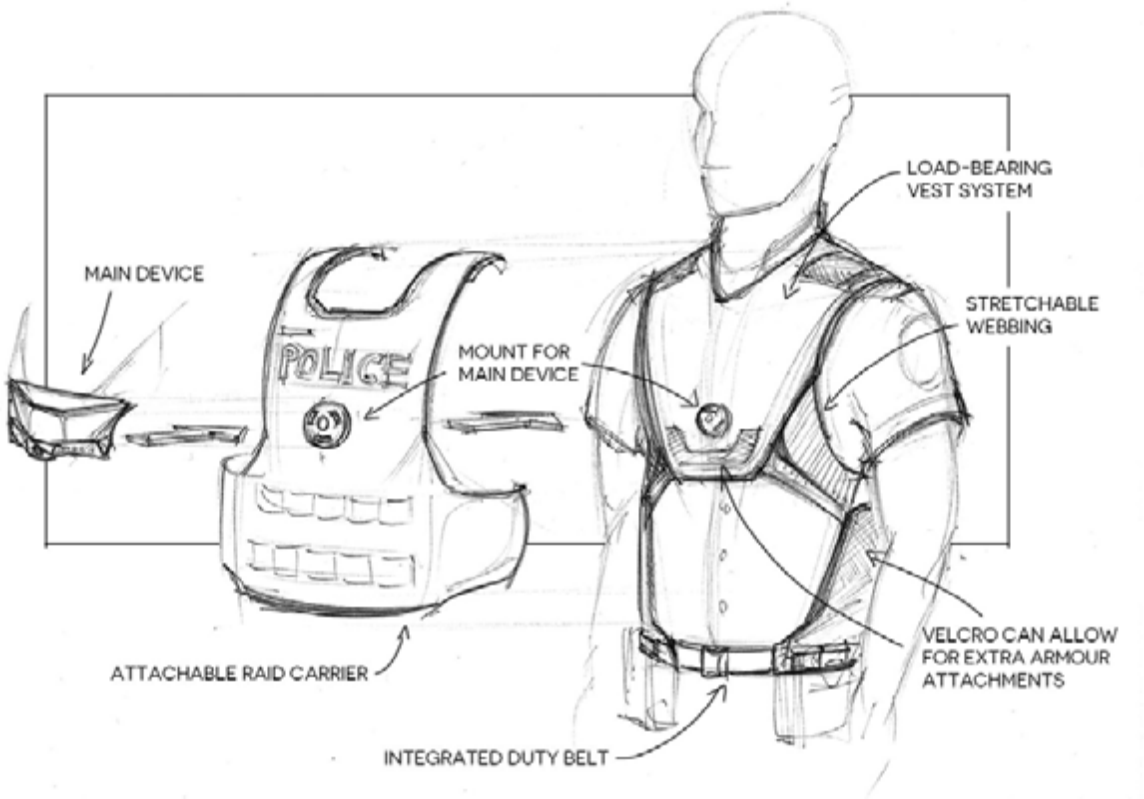


Figure 59 - Design Refinement - 1

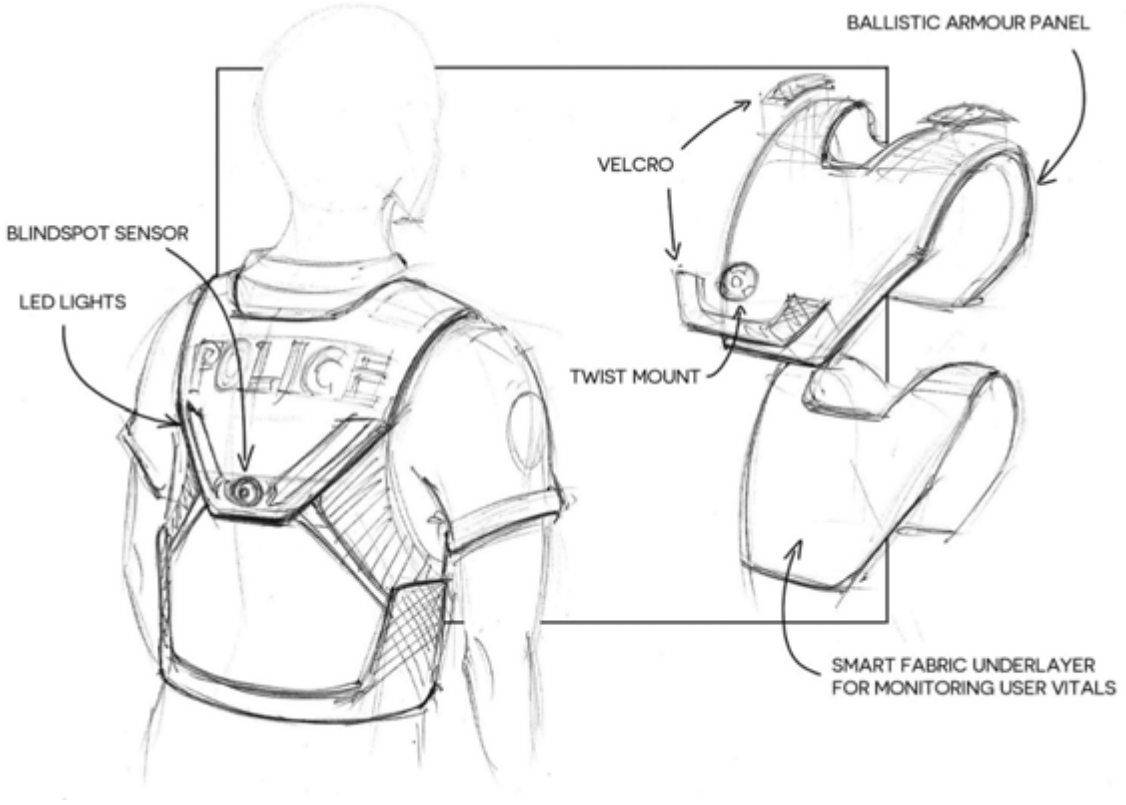


Figure 60 - Design Refinement - 2

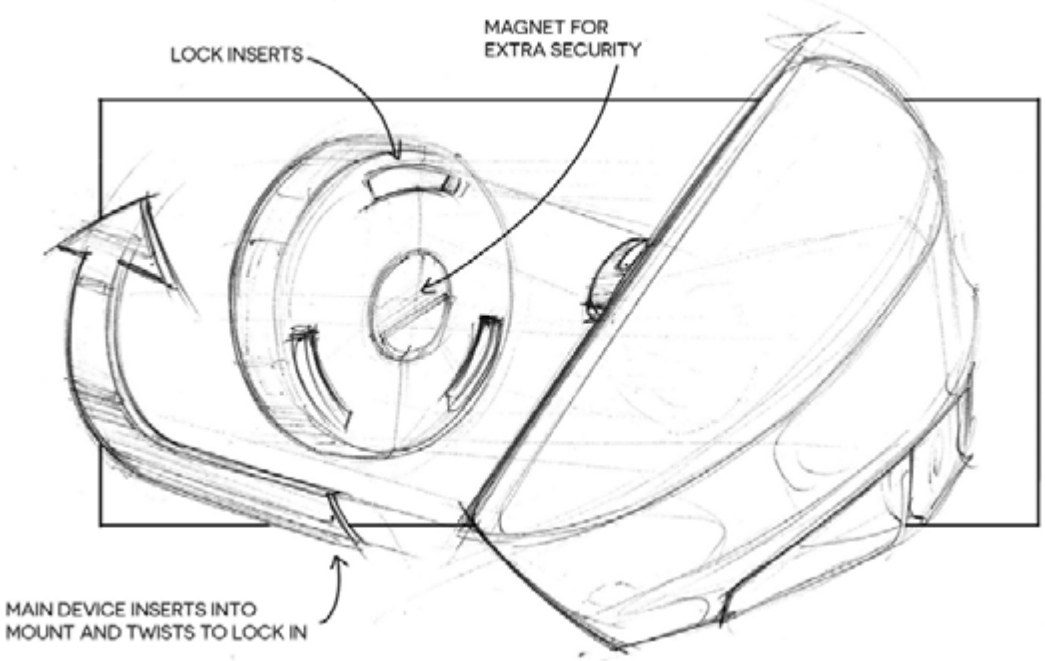


Figure 61 - Design Refinement - 3

The updated direction from Chapter 4.3.1 – Concept Direction & Schematic One was lacking in terms of what it could do due to removing the armour portion of the concept. This was revisited for refinement by re-integrating an armour panel to the design and adding support for the duty belt, which is a key point of non-combat-related injury. The intention is to have body armour that does not appear overtly militaristic, with an external raid carrier used for more utility in high-risk scenarios.

After testing and consultation with the research advisor, a full-coverage body armour would more likely be necessary, as the exposed abdomen could be more risk to the user and may not be worth the trade-off for a potential change in public perception. Additionally, the design of the upper panel is not conducive to every user's body type and size, especially females. Another revision is needed to work out the concept, as will be explored in the next section, 4.4.2 – Detail Development.

4.4.2 Detail Development

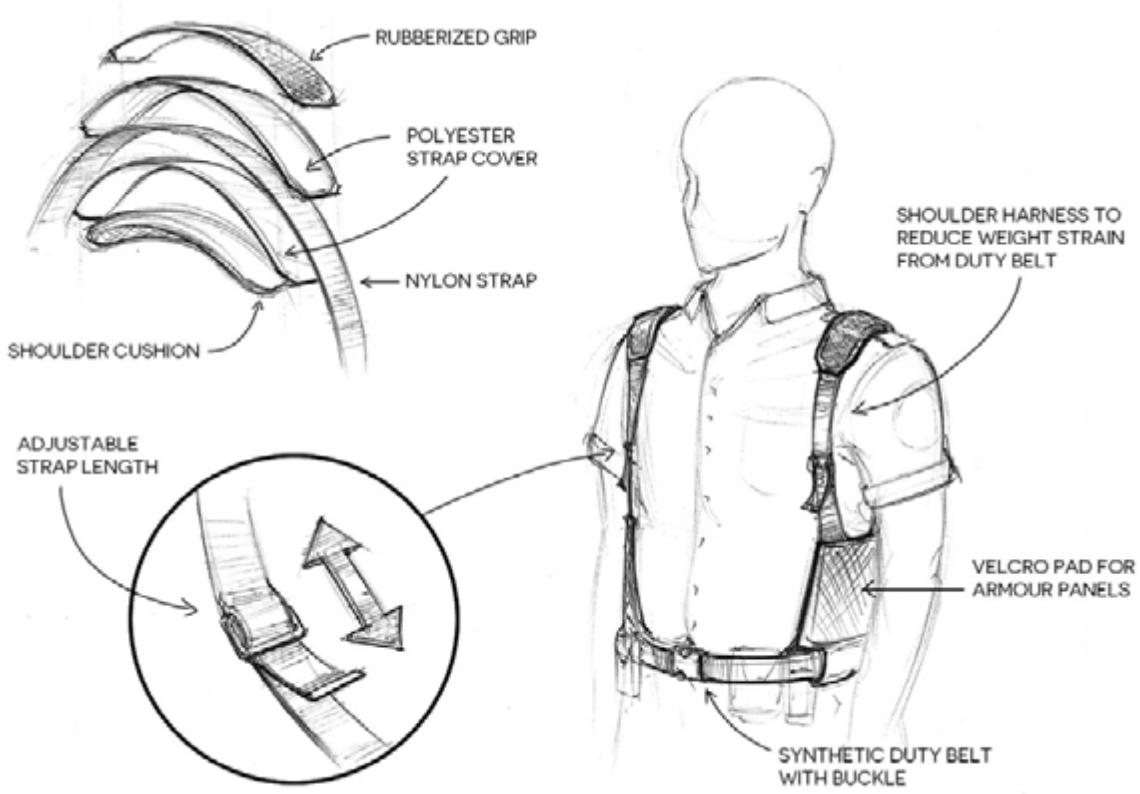


Figure 62 - Detail Development – 1

The load-bearing idea for the duty belt was re-designed as a shoulder harness with adjustable strap lengths to account for variance in user torso lengths. The shoulder pieces are padded for added comfort, and the duty belt is a synthetic make-up since leather belts would add extra weight for the user to wear. The Velcro pad along the sides is retained for equipping the armour vest.

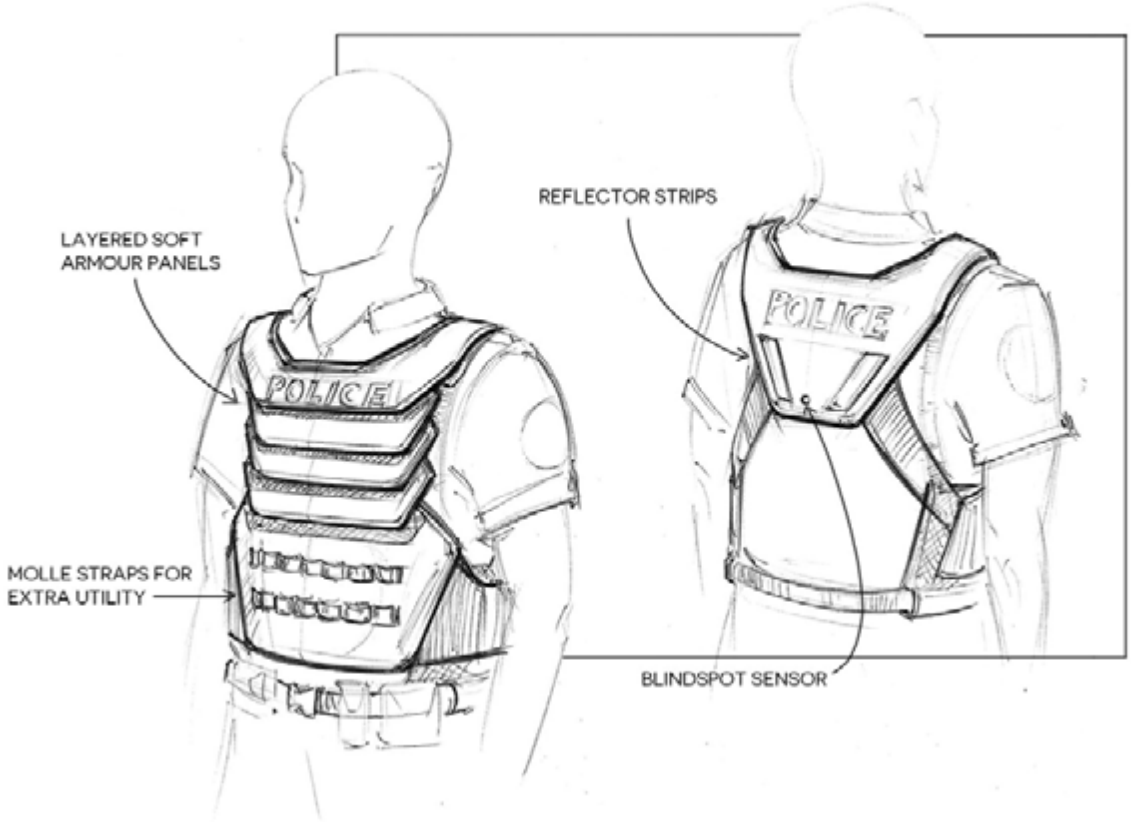


Figure 63 - Detail Development - 2

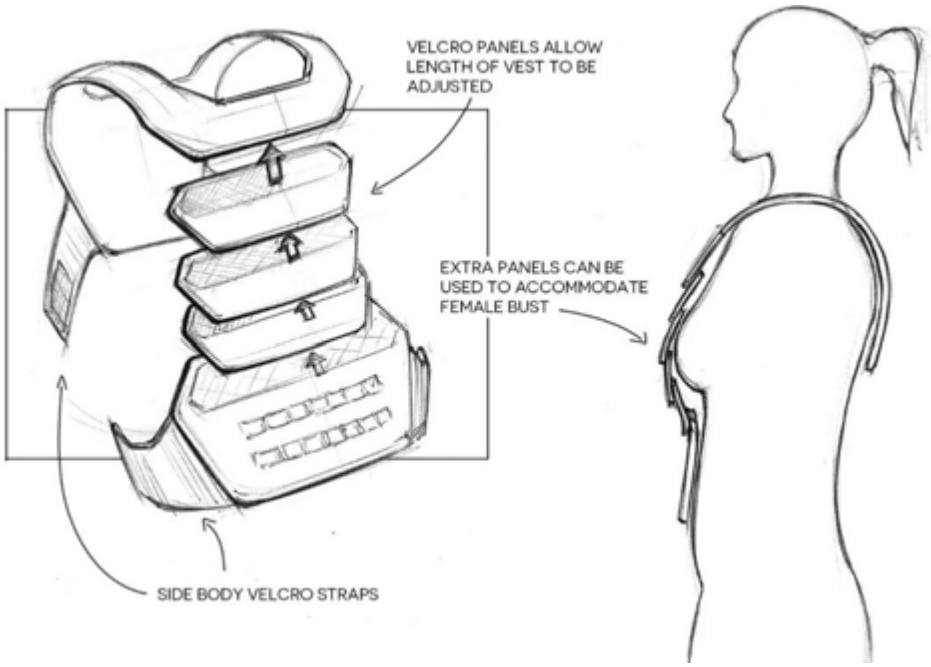


Figure 64 - Detail Development - 3

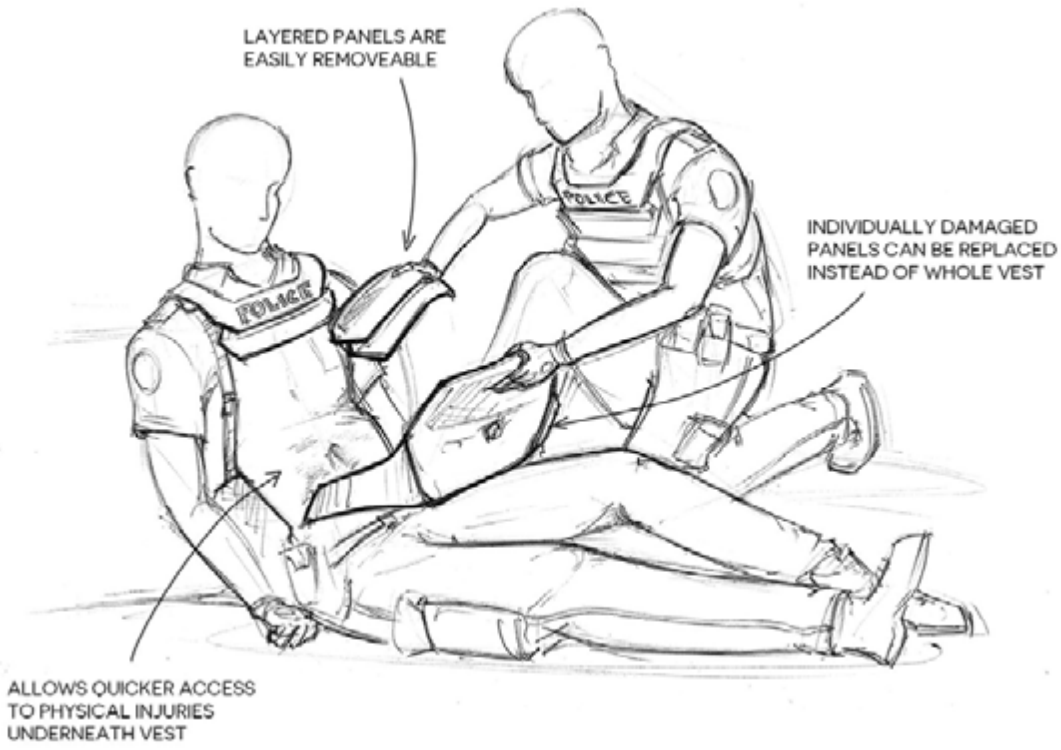


Figure 65 - Detail Development – 4

Using insights from the ergonomic buck testing in Chapter 3.3 – Analysis – Human Factors, a revised, modular armour panel system was devised in order to accommodate the variance within user percentile groups, as well as the difference in body type with males and females. Velcro pads allow a user to customise the length of the vest to their torso, while females can add extra panels or adjust the placement of their currently equipped vest to accommodate different bust sizes. This modular panel system also makes it easier for another officer or emergency medical services to quickly access wounds and injuries beneath the vest without having to pull the whole vest over the user's head. Moreover, this can potentially reduce the cost of replacing a whole vest and only replacing the panels that were damaged.

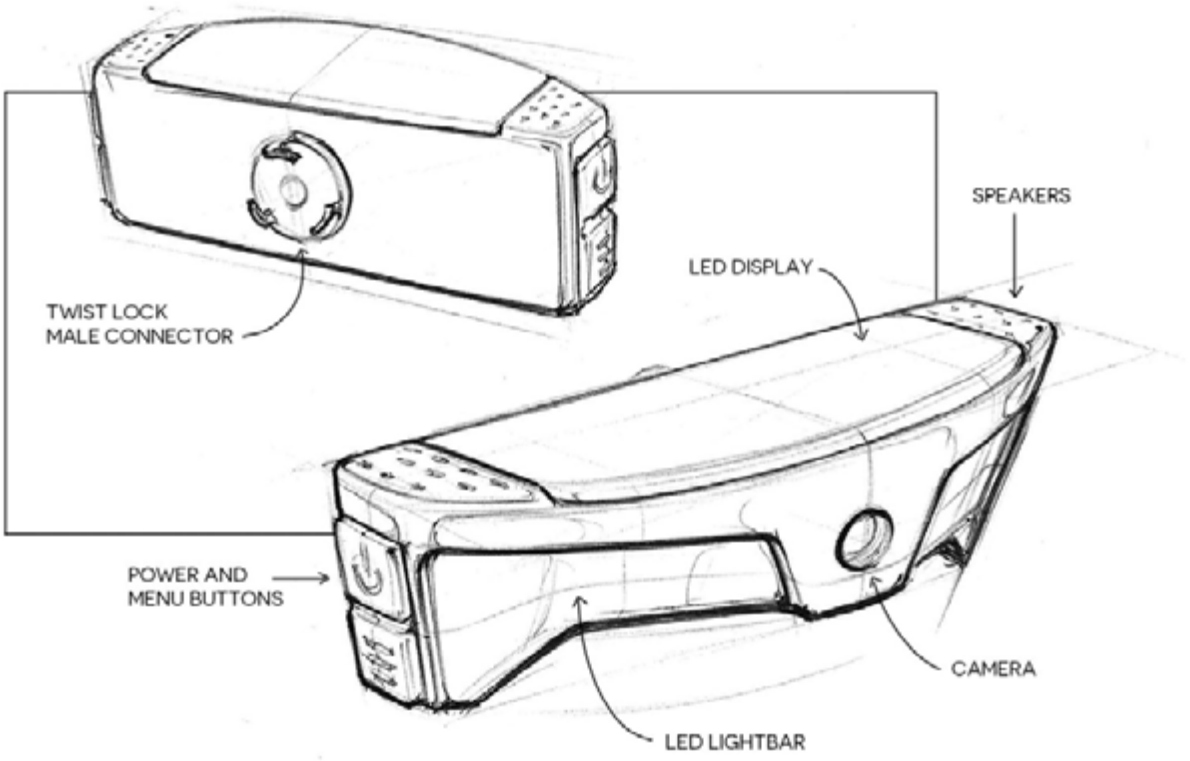


Figure 66 - Detail Development - 5

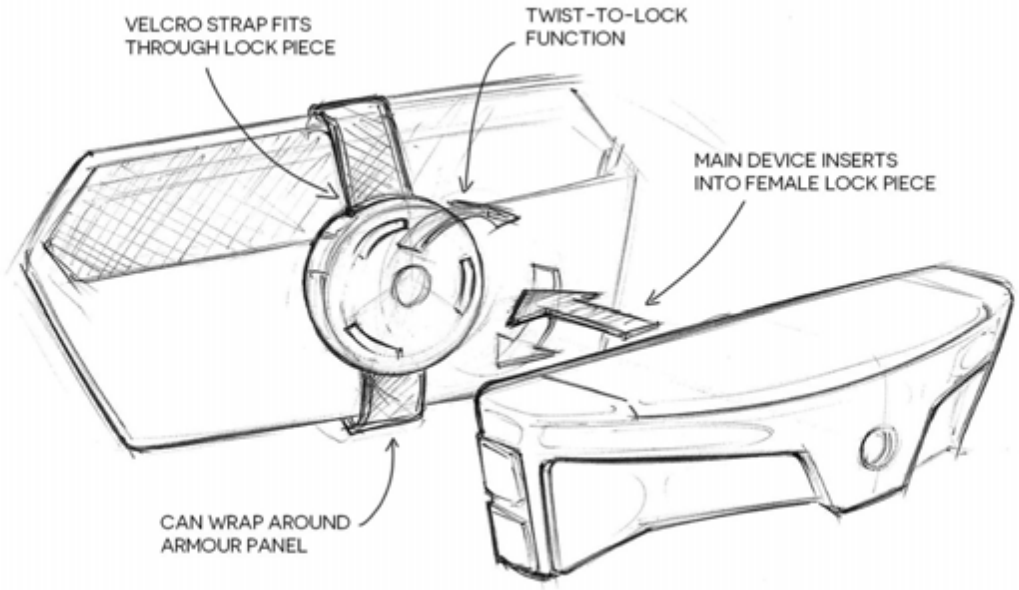


Figure 67 - Detail Development - 6

Minor revisions were made to the main device, primarily slimming down the depth of it to reduce the amount of overhang in front of the user and streamline the overall physical footprint. The twist-to-lock mount was retained from the refinement stage and now attaches to the armour panels separately rather than being integrated. A Velcro strap runs through the female lock piece and can be attached to one of the modular armour panels. This can allow a user to customise the height and location of the main device, while also leaving the potential for other devices to use a similar mechanism.

4.4.3 Refined Product Schematic & Key Ergonomic

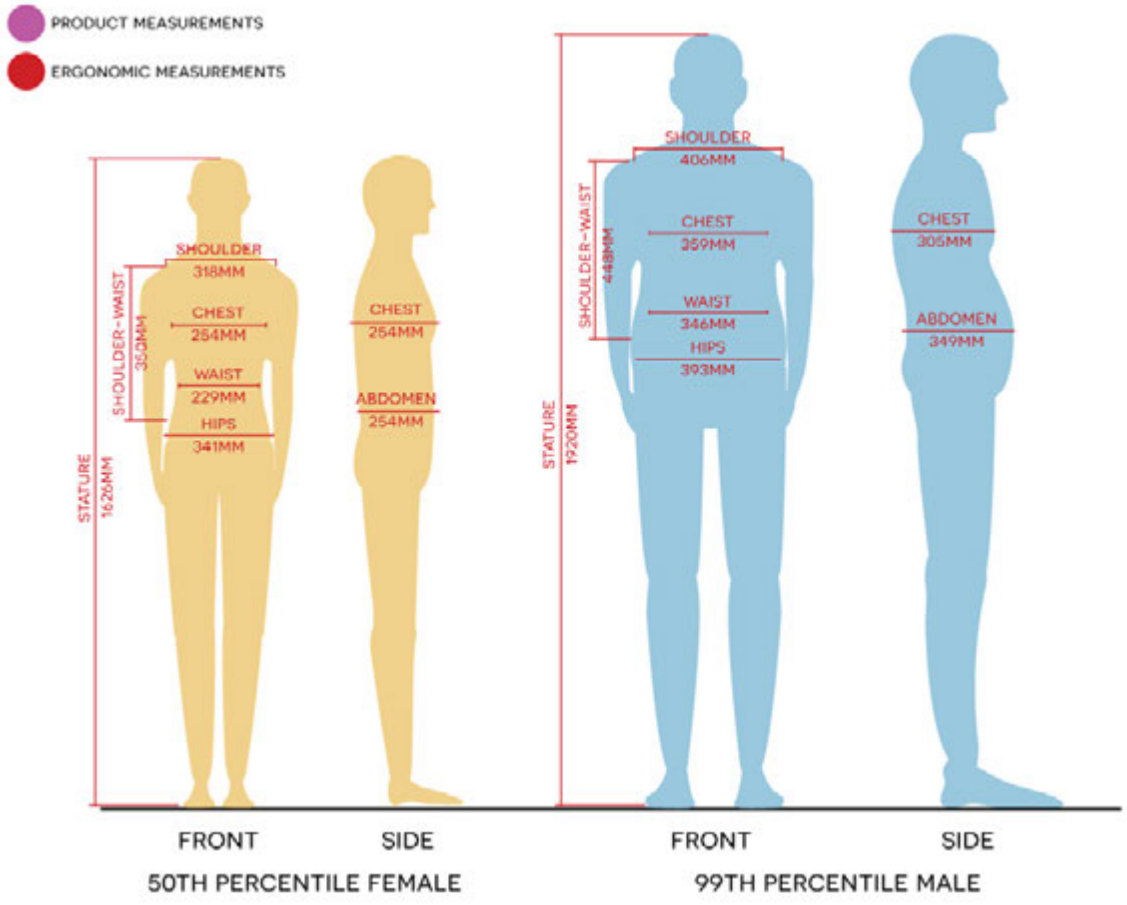


Figure 68 - Refined Schematic – 1

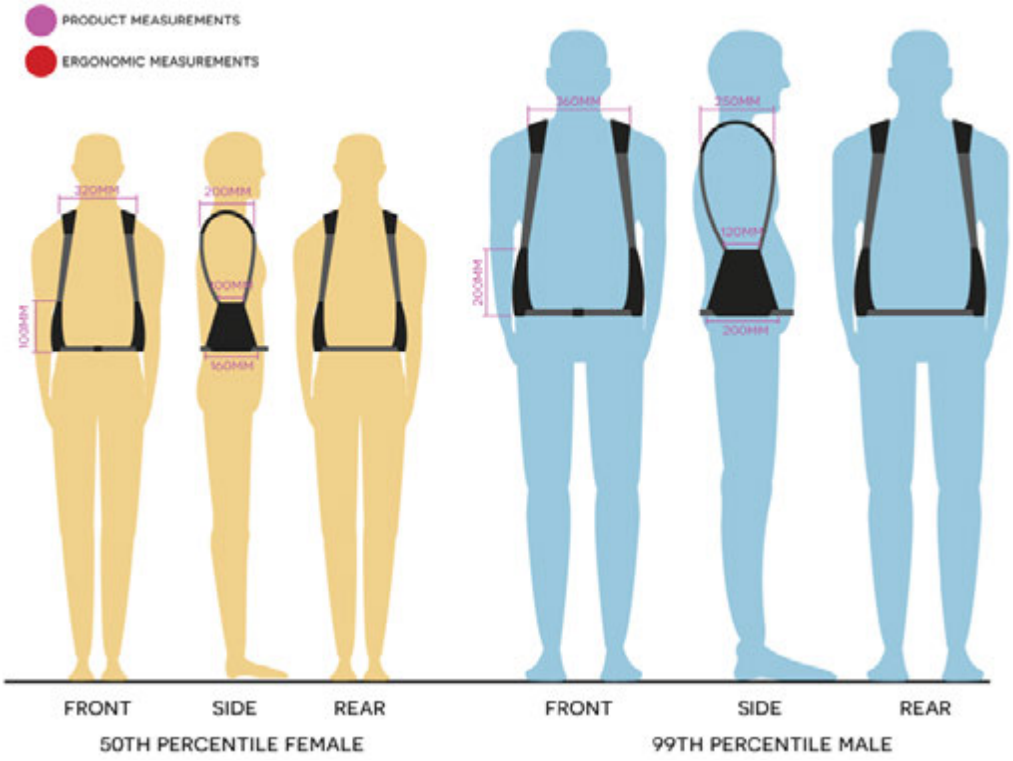


Figure 69 - Refined Schematic - 2

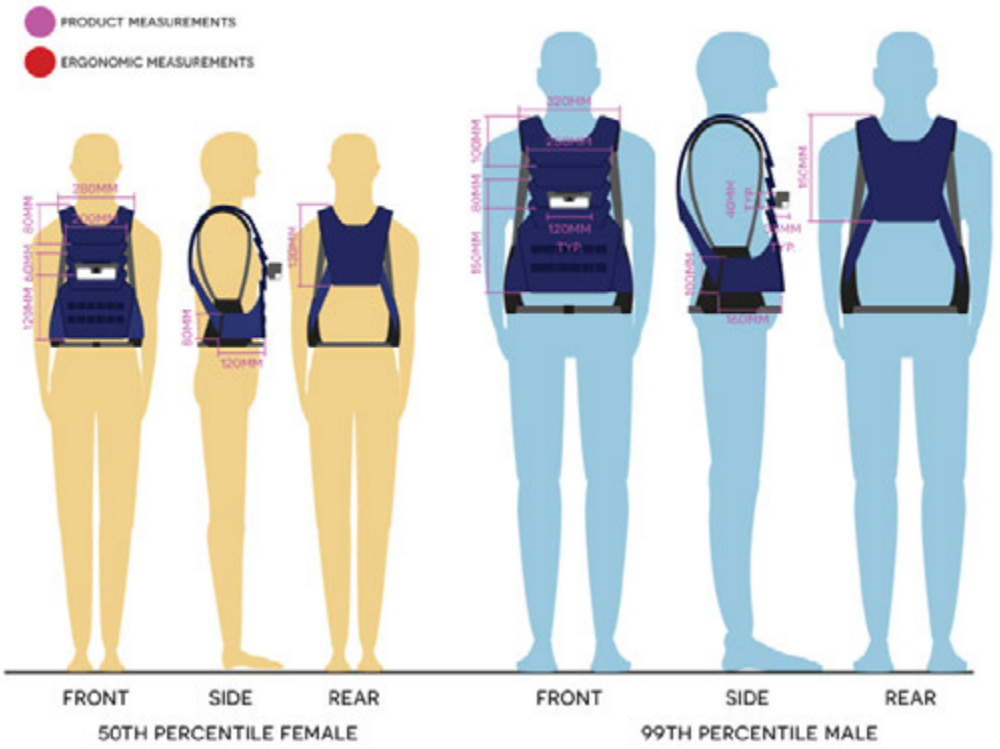


Figure 70 - Refined Schematic - 3

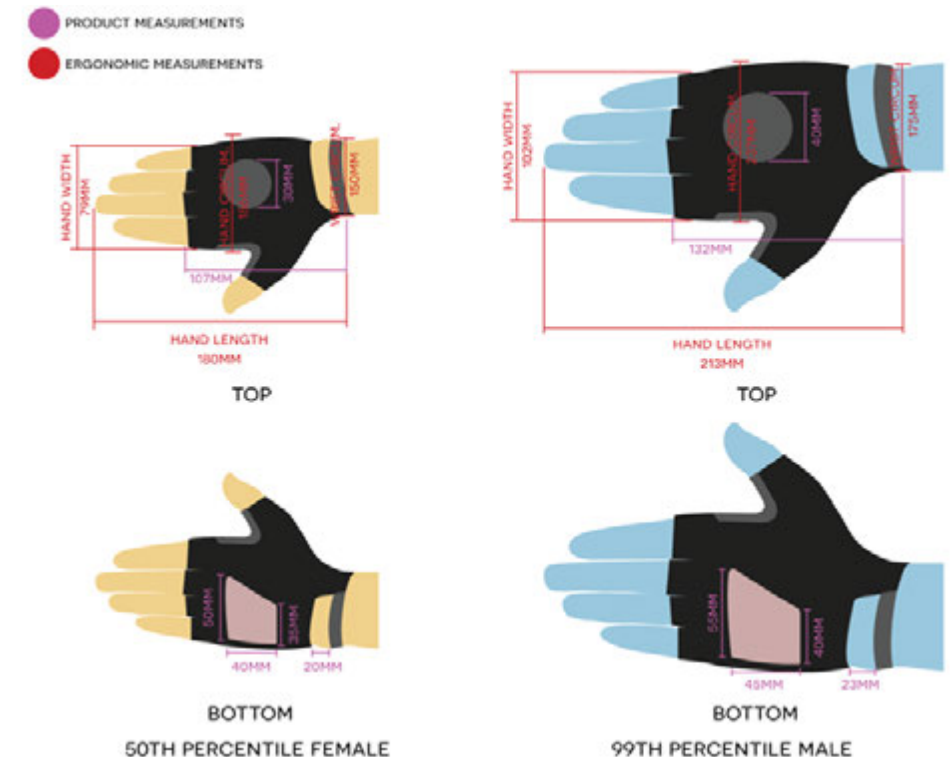


Figure 71 - Refined Schematic - 4

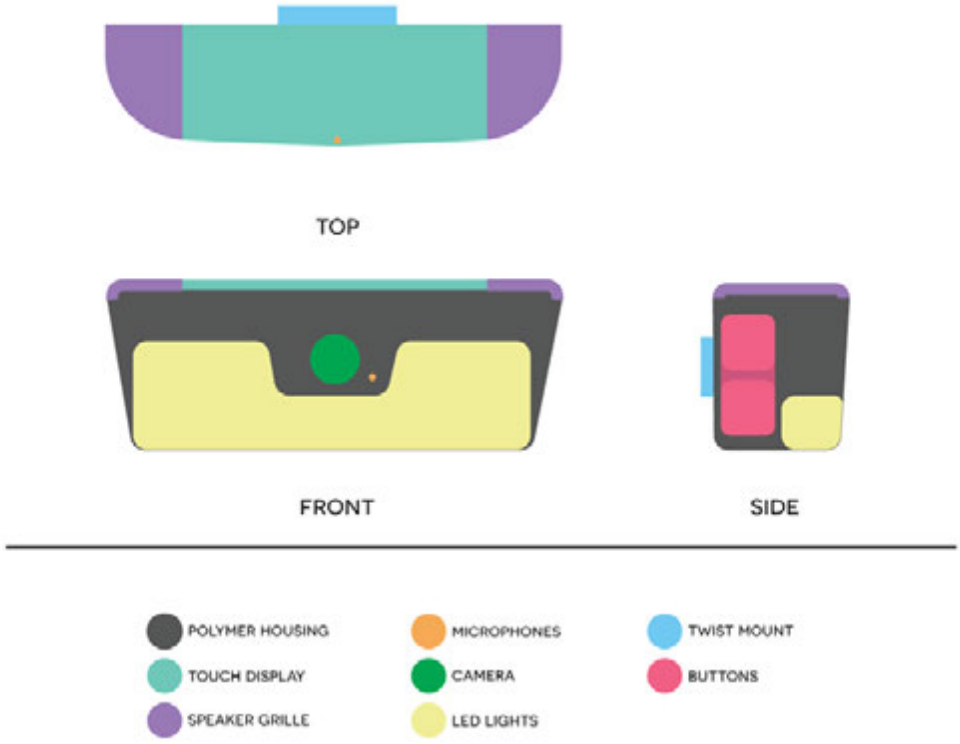


Figure 72 - Refined Schematic - 5

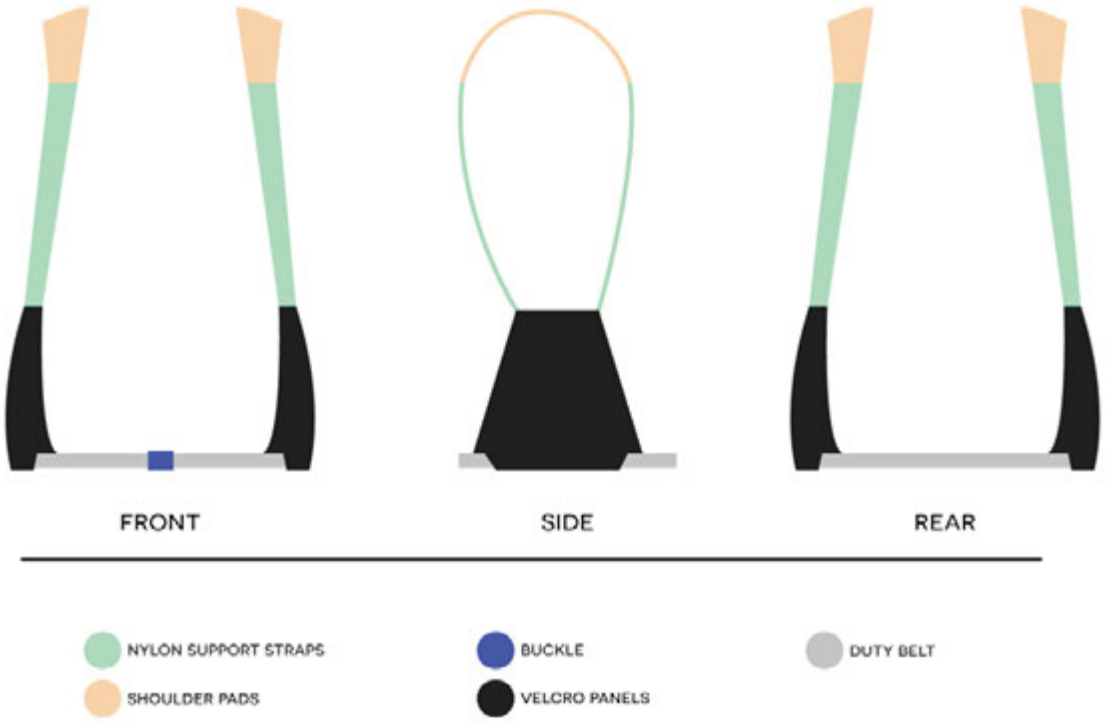


Figure 73 - Refined Schematic - 6

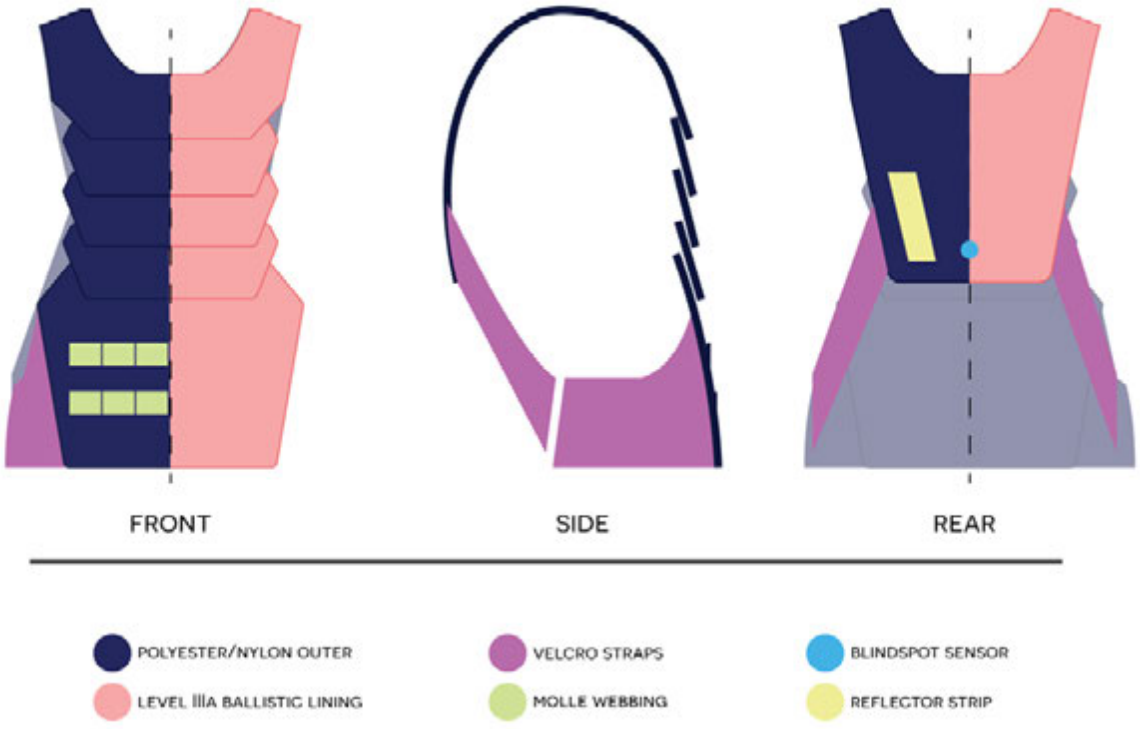


Figure 74 - Refined Schematic - 7

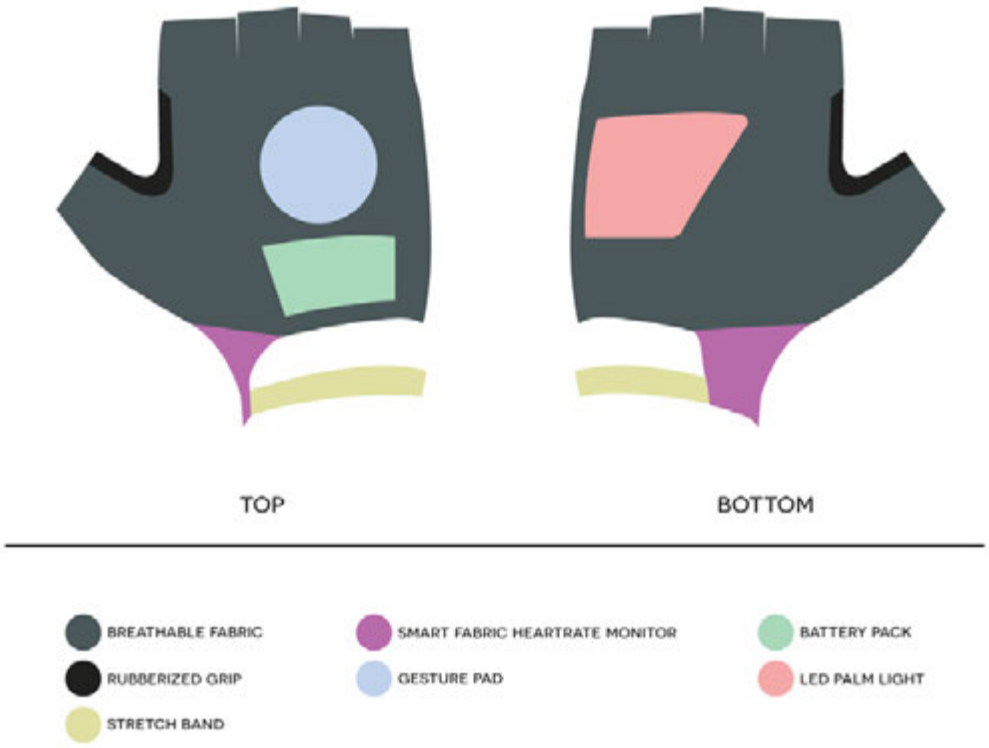


Figure 75 - Refined Schematic - 8

These refined configuration diagrams and product schematics help to further understand the size of each component to the design solution, as well as determining how each part might be arranged or assembled.

4.5 Concept Realization

During this stage of concept realization, the styling and functional details continue to be further refined and pushed forward to a final stage before preparing for a physical study model, CAD modelling, and final prototype model construction.

4.5.1 Design Finalization

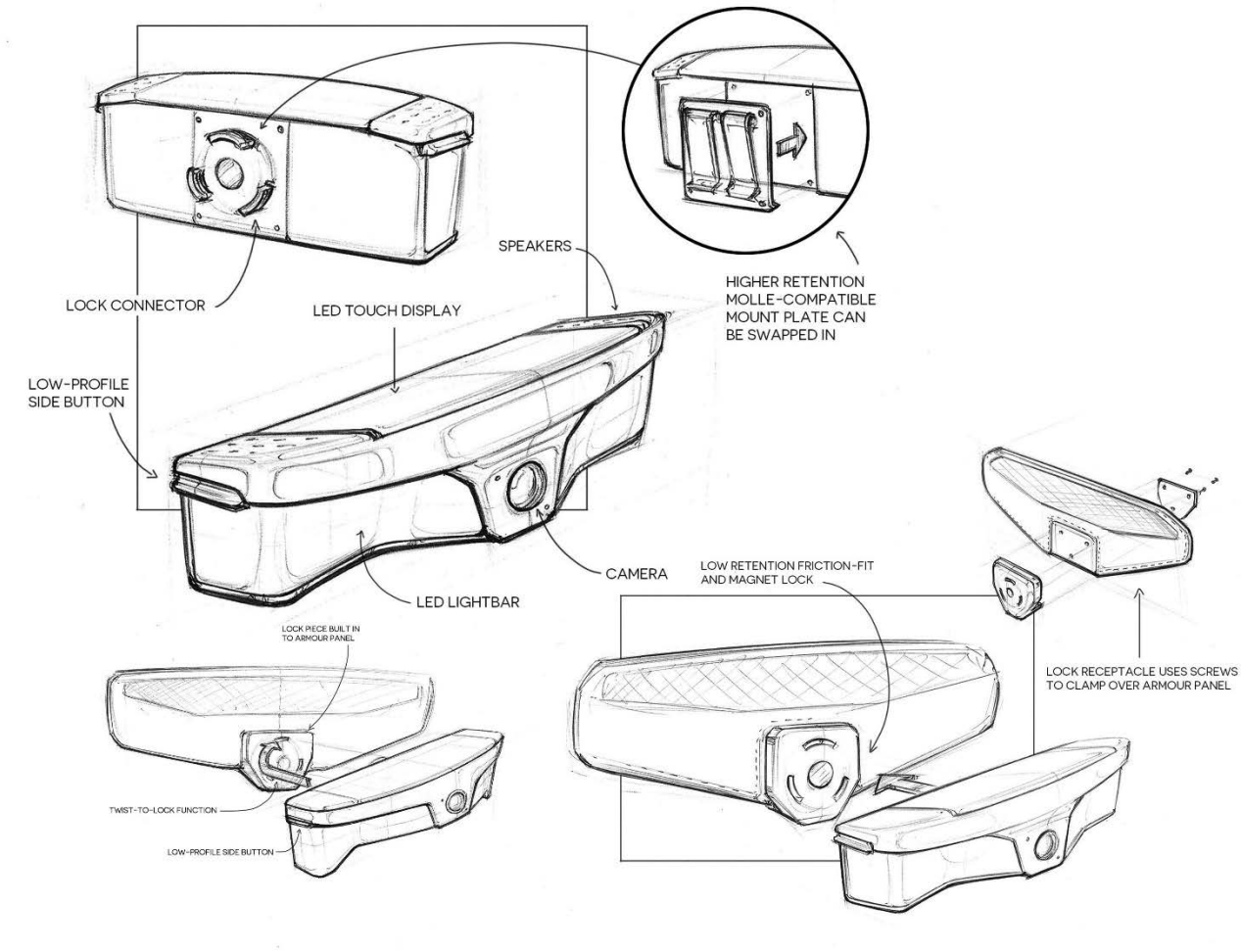


Figure 76 - Design Finalization - 1

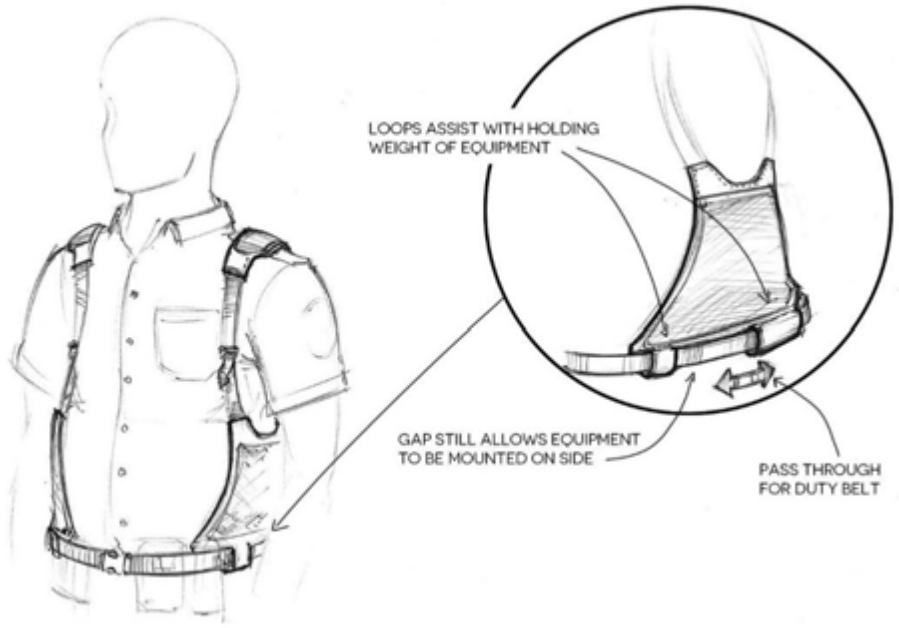


Figure 77 - Design Finalization - 2

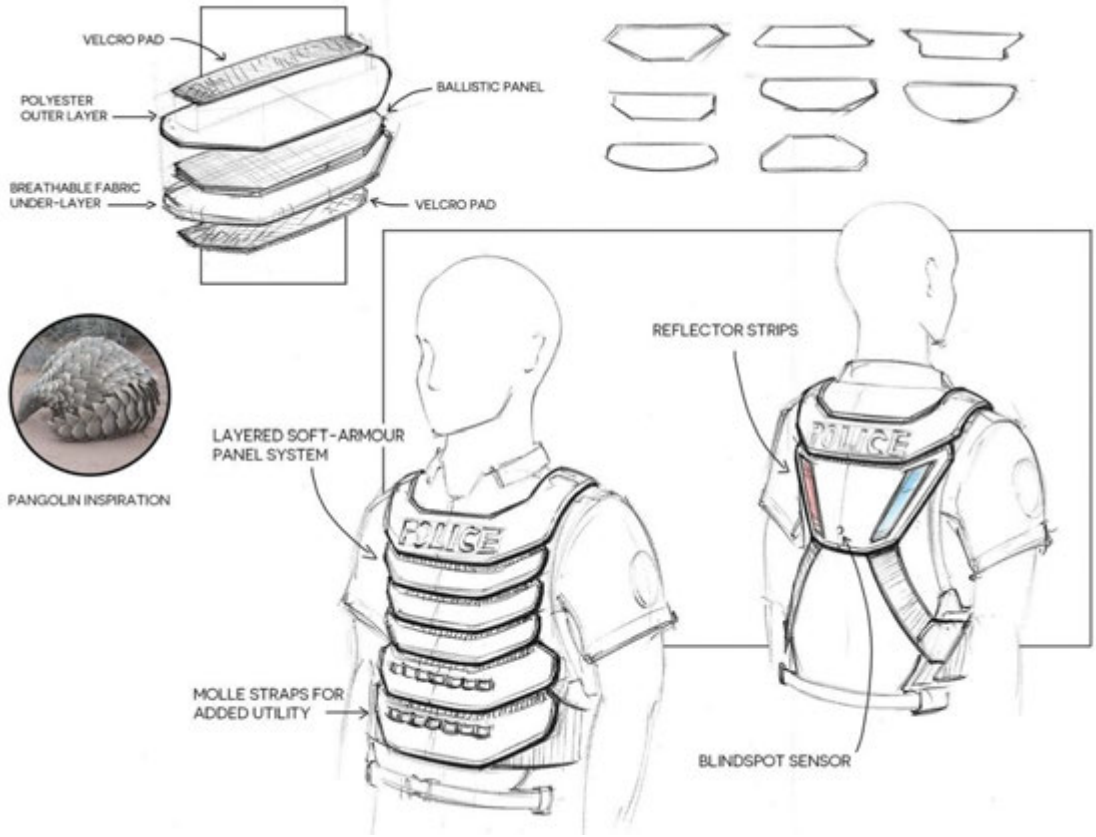


Figure 78 - Design Finalization - 3

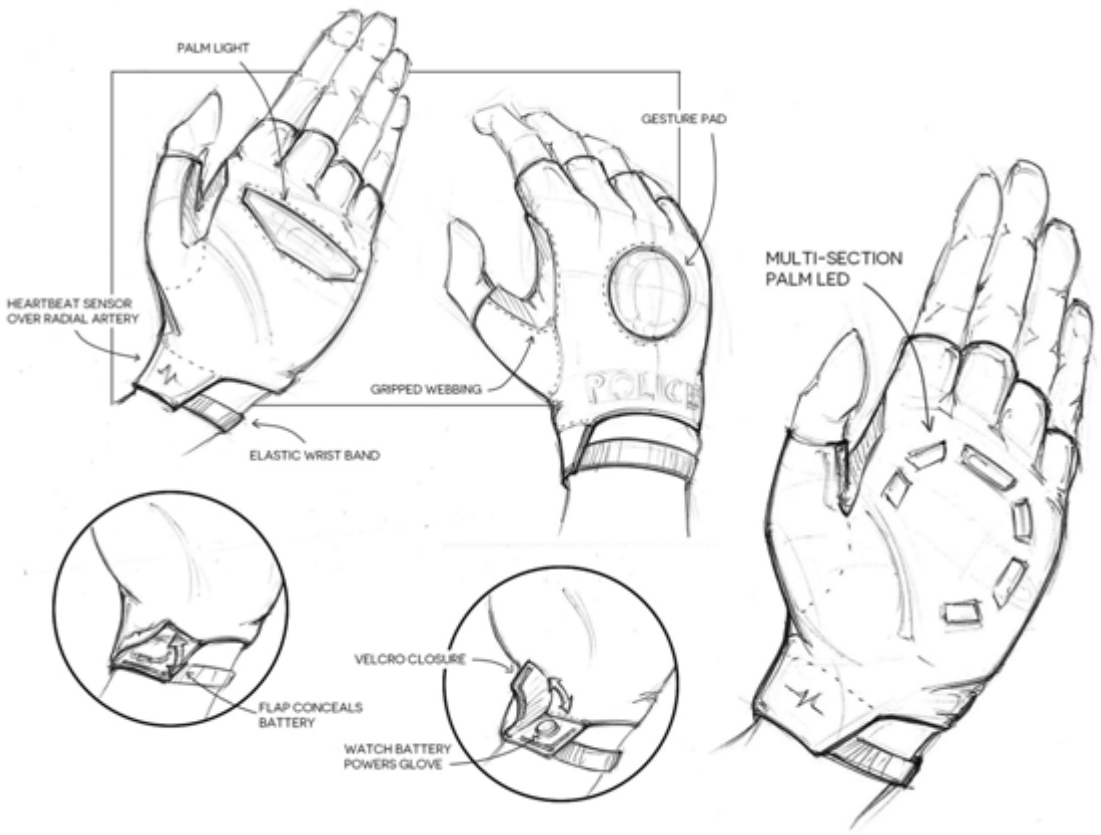


Figure 79 - Design Finalization - 4

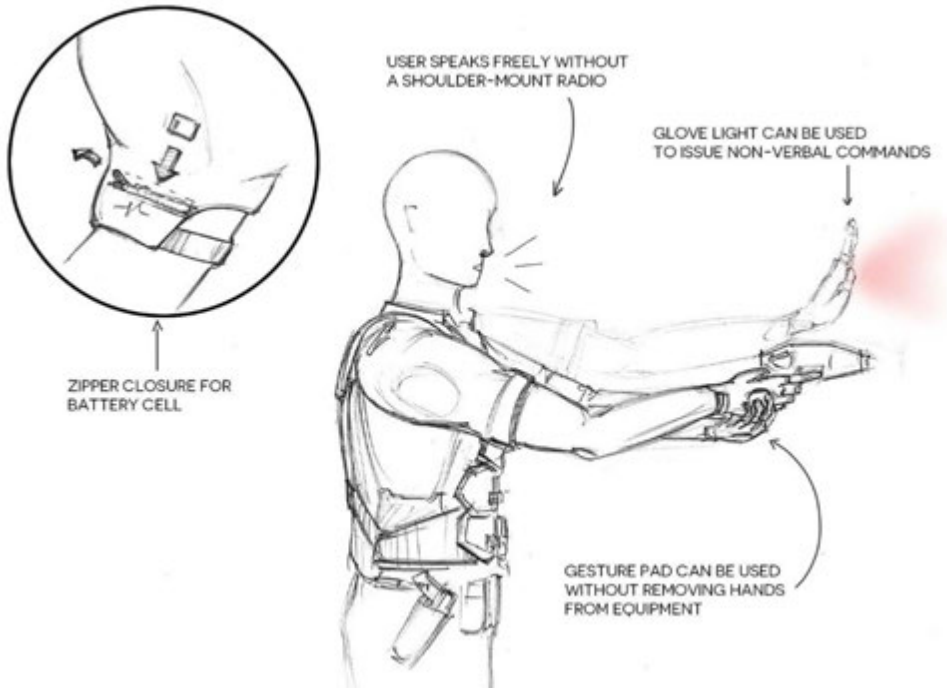


Figure 80 - Design Finalization - 5

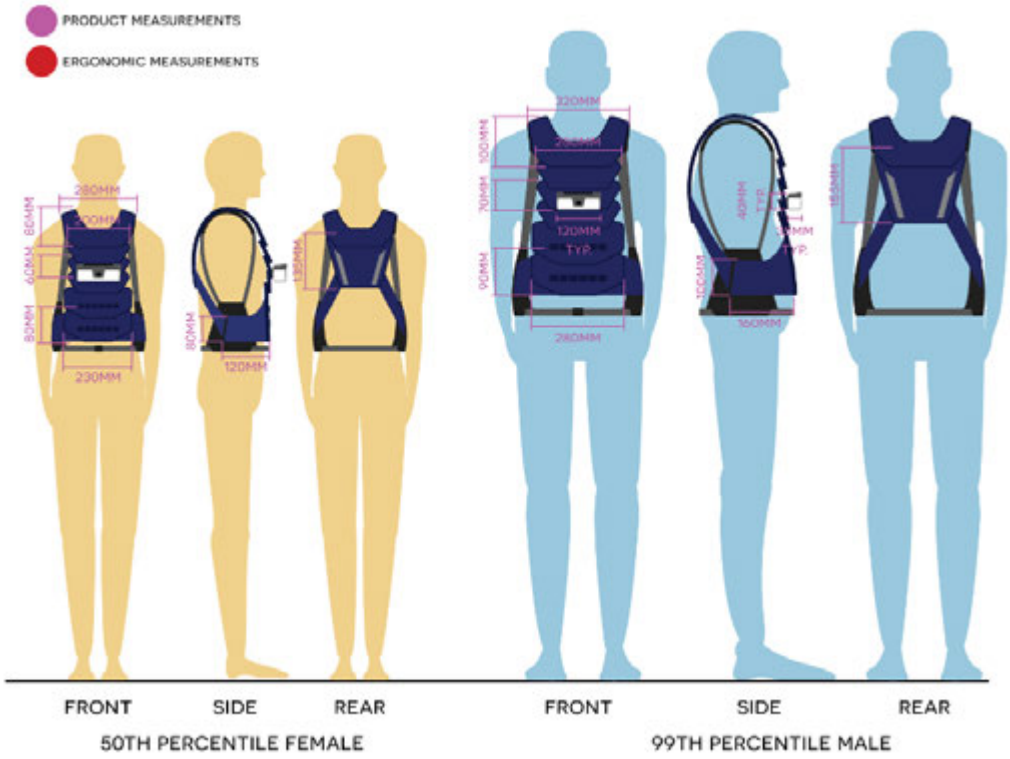


Figure 81 - Design Finalization - 6

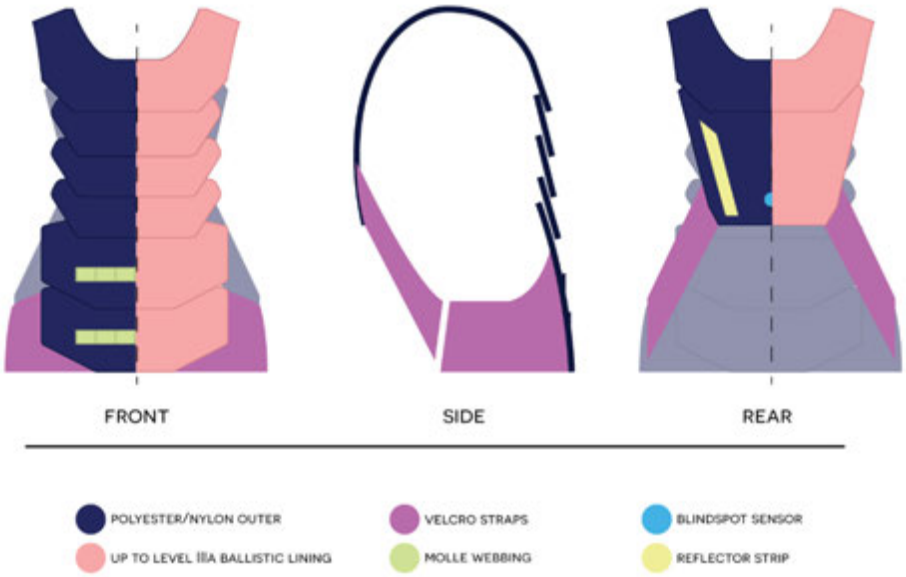


Figure 82 - Design Finalization - 7

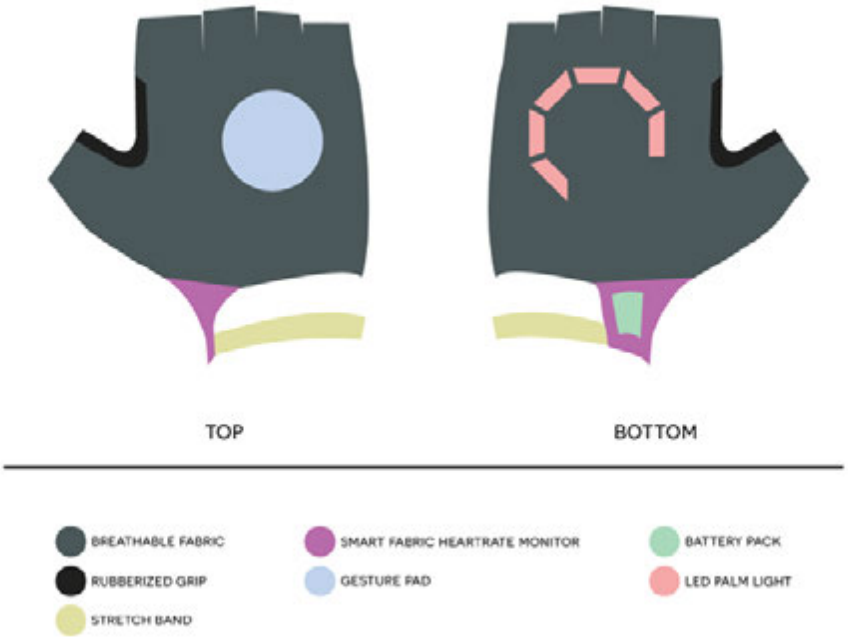


Figure 83 - Design Finalization - 8

4.5.2 Physical Study Models

A 1:1 physical study model was created based on the most up-to-date version of the design in order to understand how everything will work and fit together in 3D. The models were constructed using a mix of Bristol board, paper, tape, and staples.

Figure 84 – Initial Physical Study Model – 1

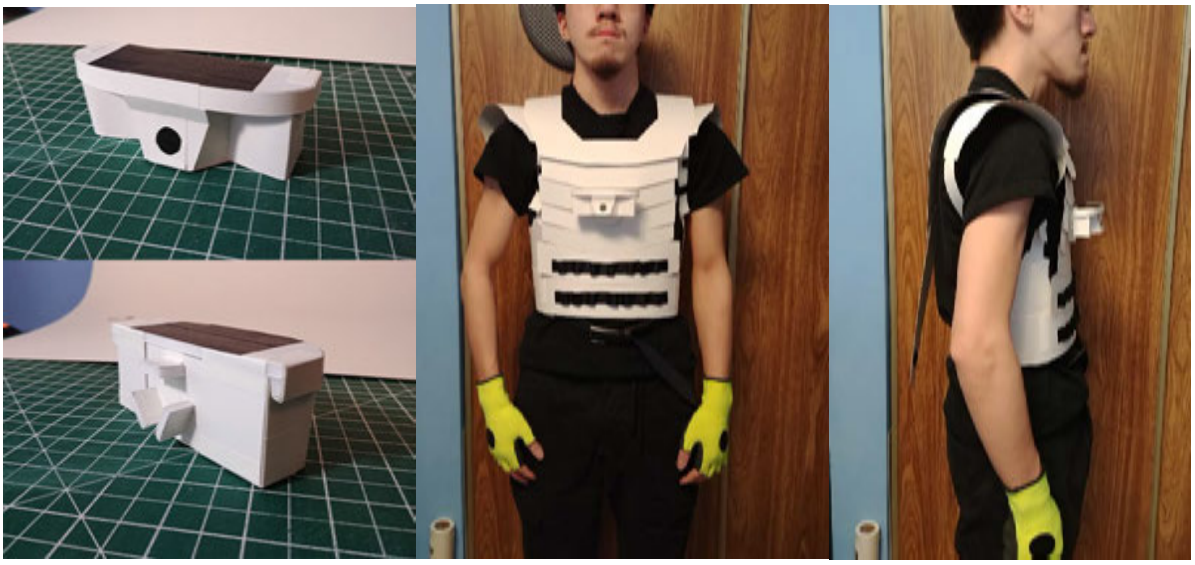


Figure 85 - Initial Physical Study Model – 2

After creating and testing the initial study model, it was found that the main panels for the armour system did not create the desired result, and the shoulder-harness required another method of keeping each side for moving out of position. Therefore, the design was modified again and another model was created.

Figure 86 - Revised Study Model – 1

Figure 87 - Revised Study Model – 2

A crosspiece was implemented to keep both straps for the shoulder-harness secured without sliding out from the user's shoulders. Additionally, the profile and measurements of the armour panels were shifted to achieve the desired design while still working with the hook and loop system. A revised diagram and schematic were created to reflect the new changes to the design.

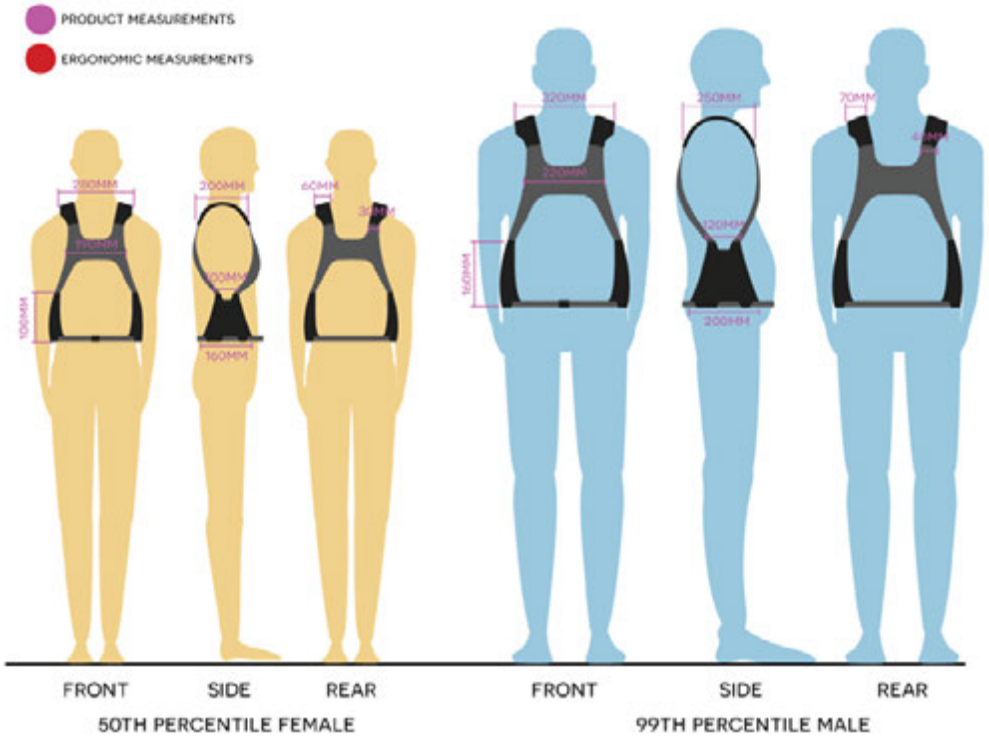


Figure 88 - Revised Configuration Diagram – 1

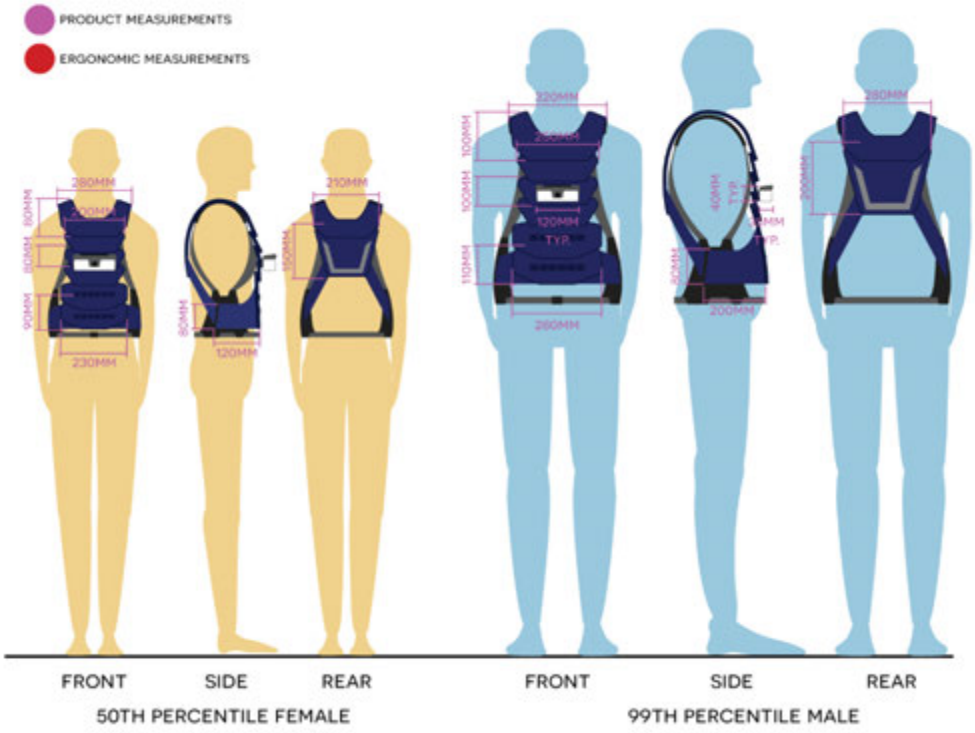


Figure 89 - Revised Configuration Diagram - 2

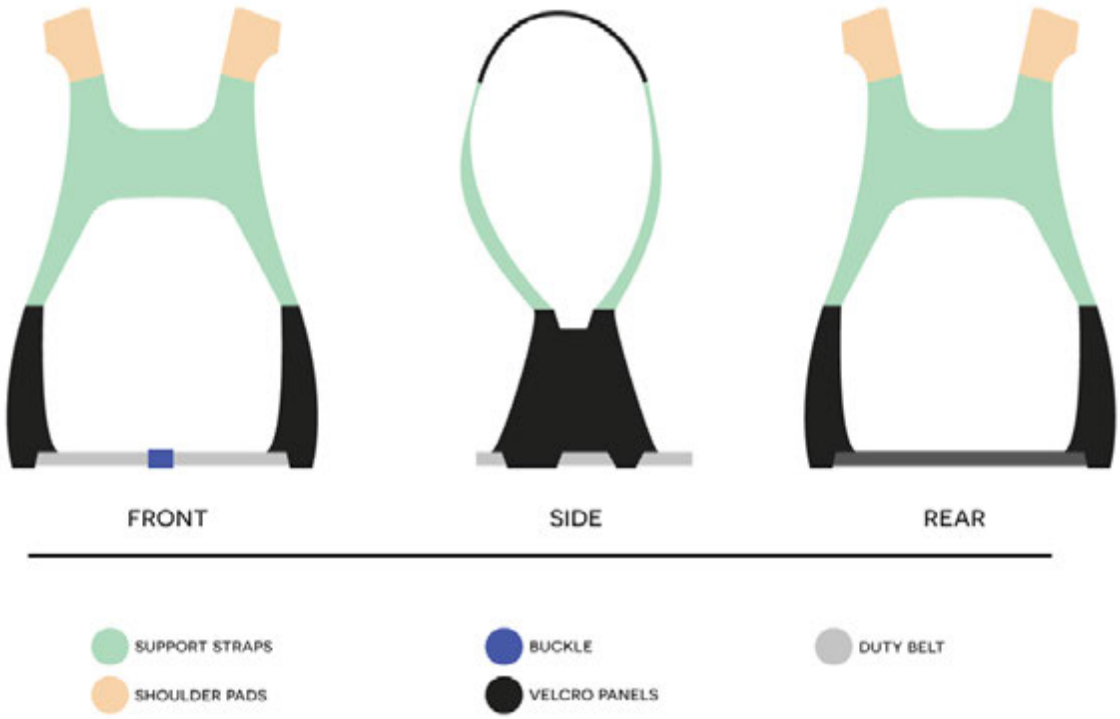


Figure 90 - Revised Product Schematic - 1

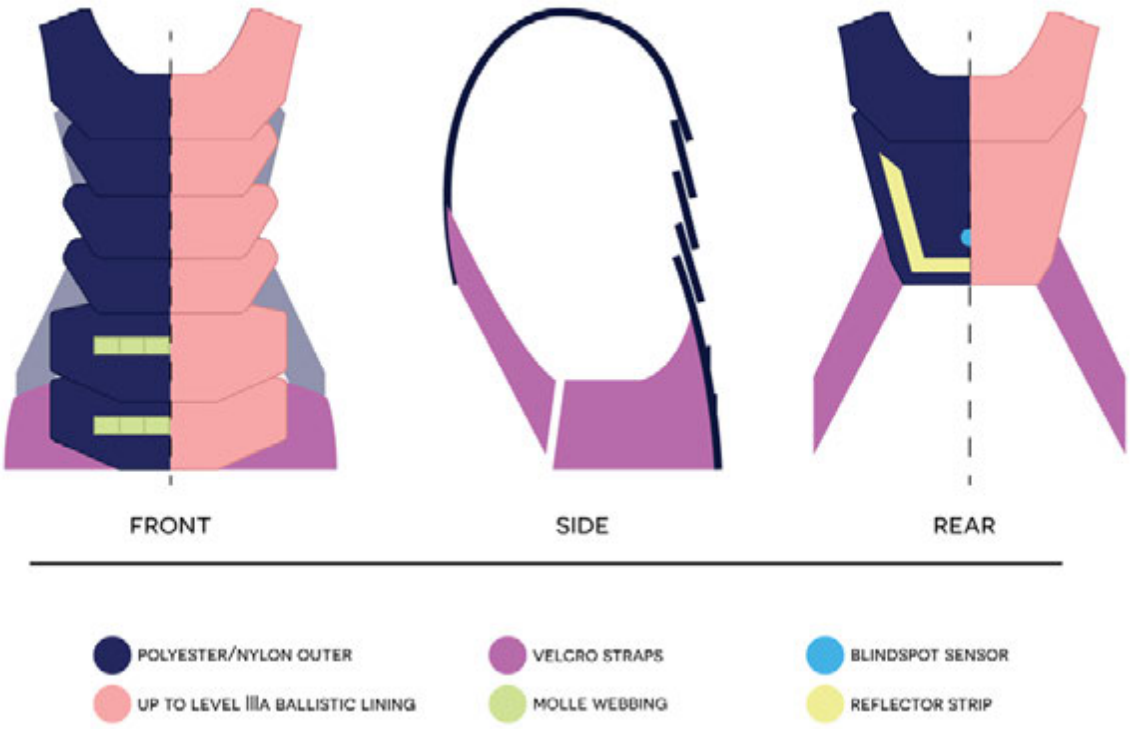


Figure 91 - Revised Product Schematic - 2

4.6 Design Resolution

With the completion of a physical study model, the last revisions and updates to the design were made to improve the aesthetics and finalise any details that were remaining. Afterwards, plans were made to move forward and begin CAD modelling the main hub device and developing the flat patterns for the duty belt harness and vest.

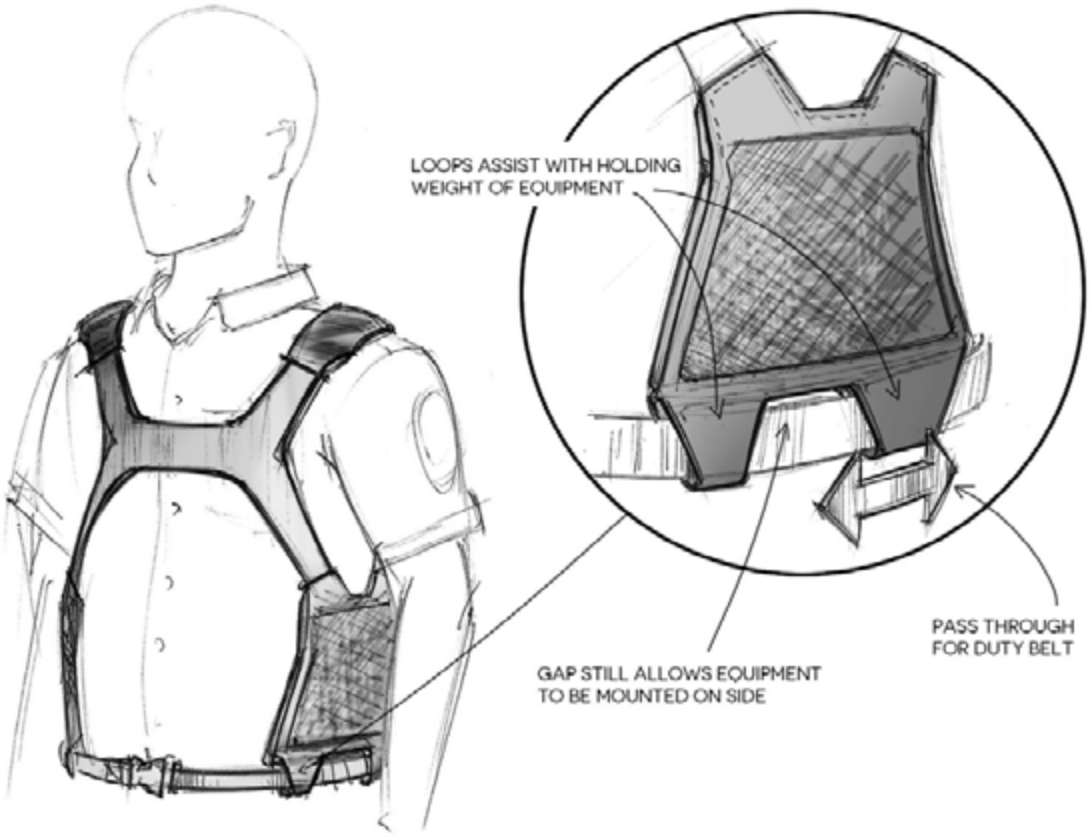


Figure 92 - Final Design – 1

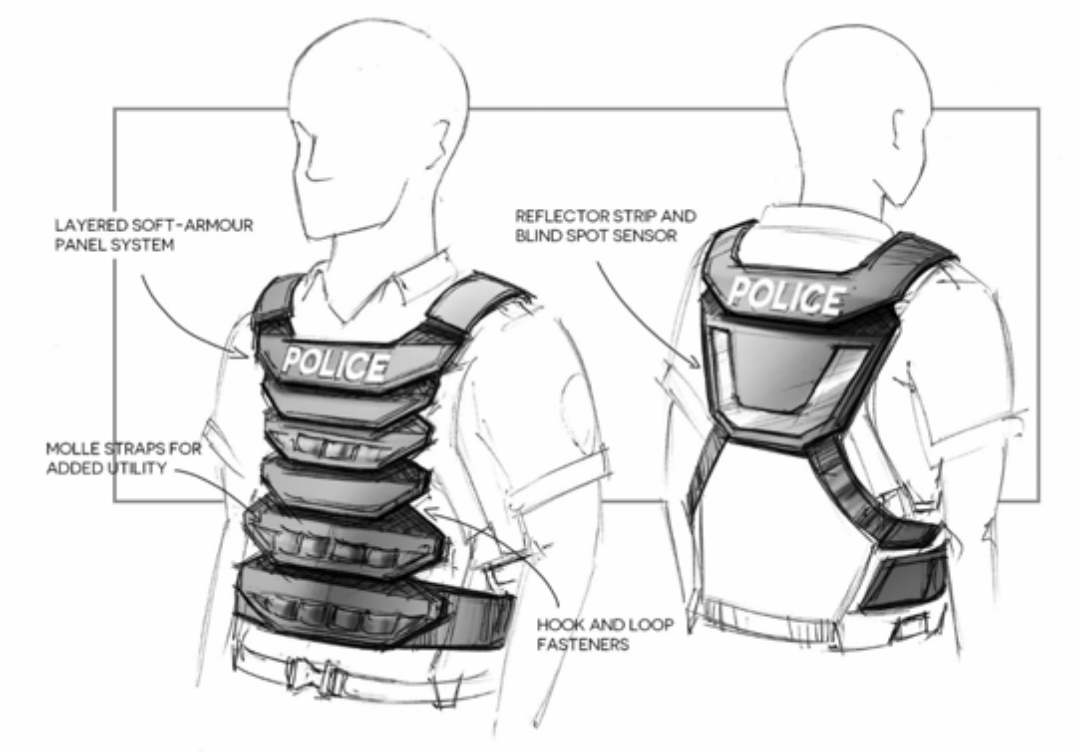


Figure 93 - Final Design – 2

Figure 94 - Final Design - 3

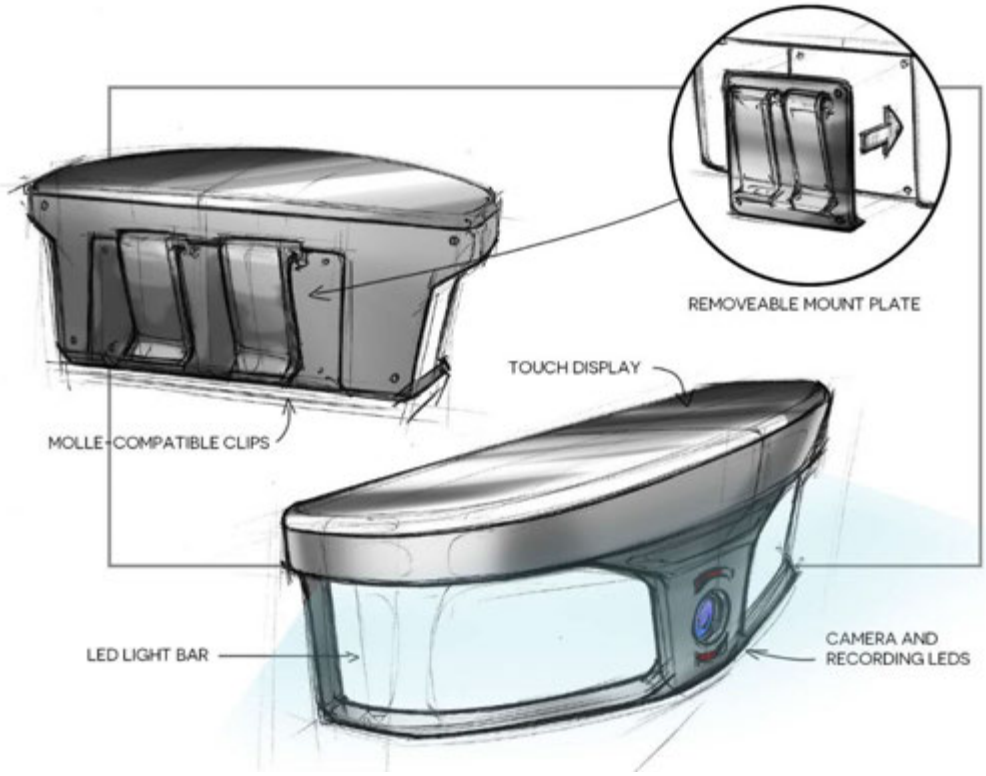


Figure 95 - Final Design – 4

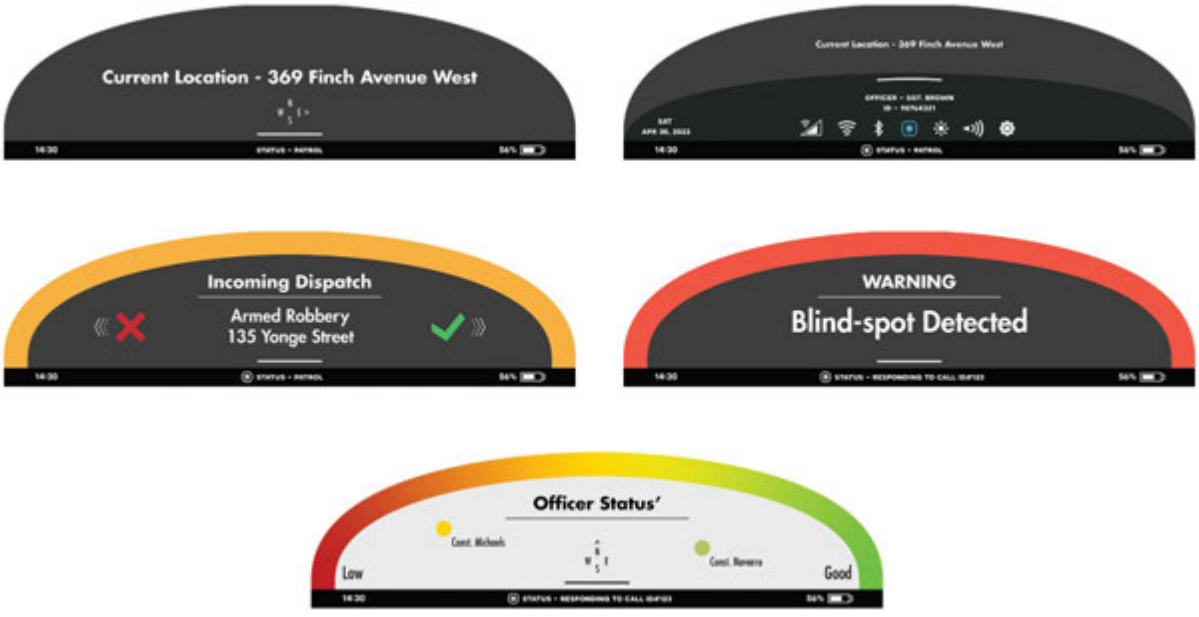


Figure 96 - Final Design - 5

4.7 CAD Development

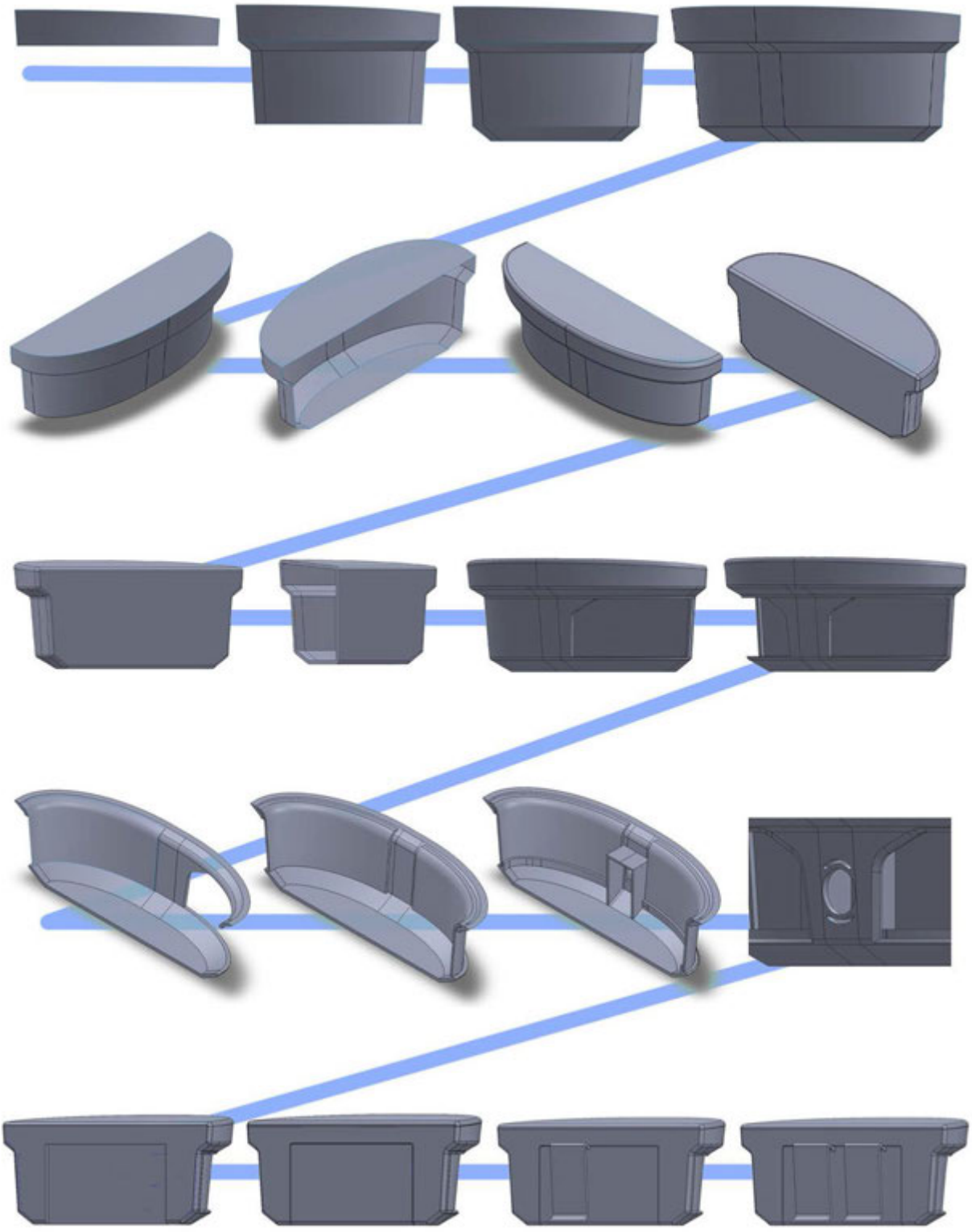


Figure 97 - Main Hub CAD - Exterior Process

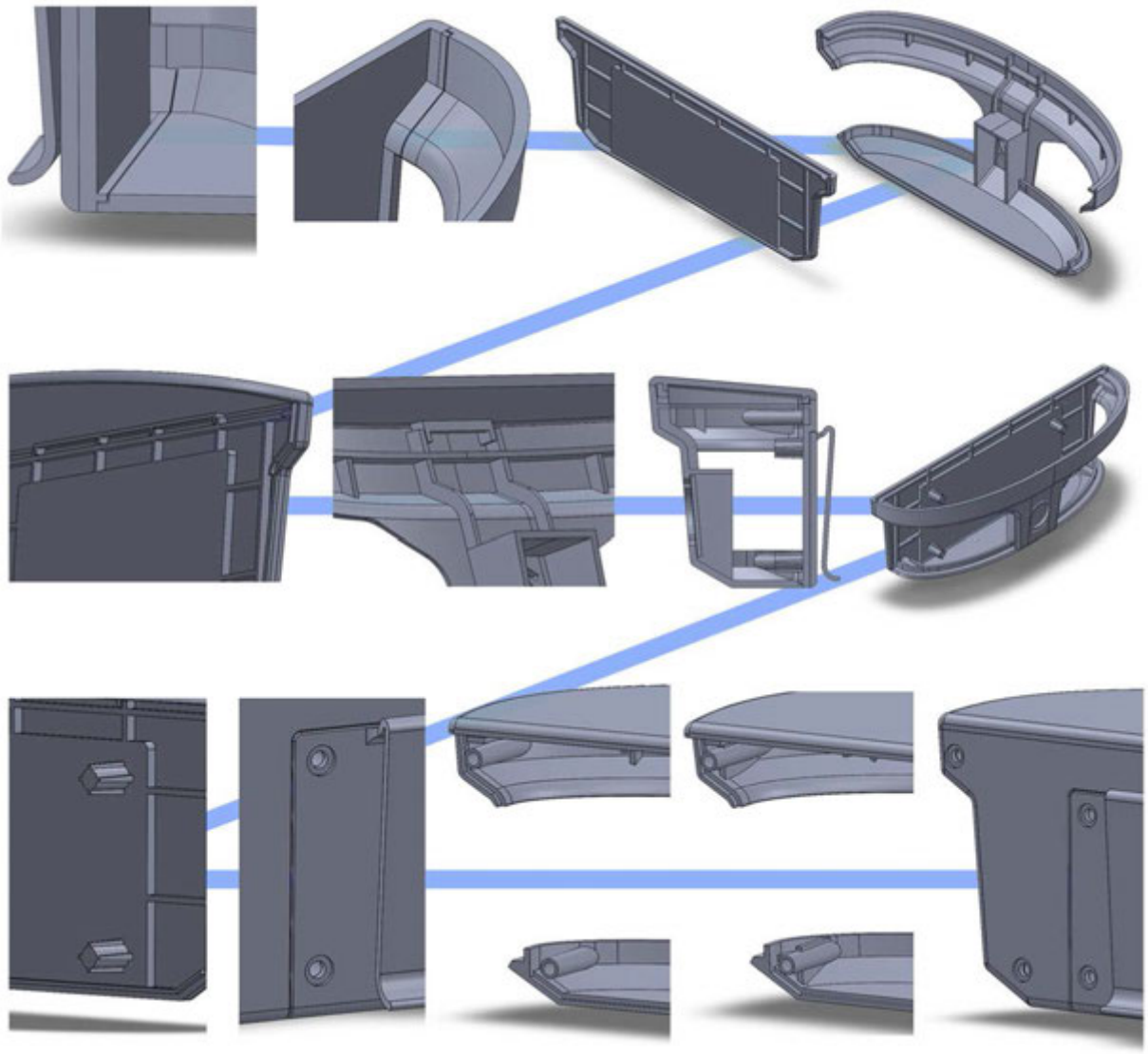


Figure 98 - Main Hub CAD - Interior Features

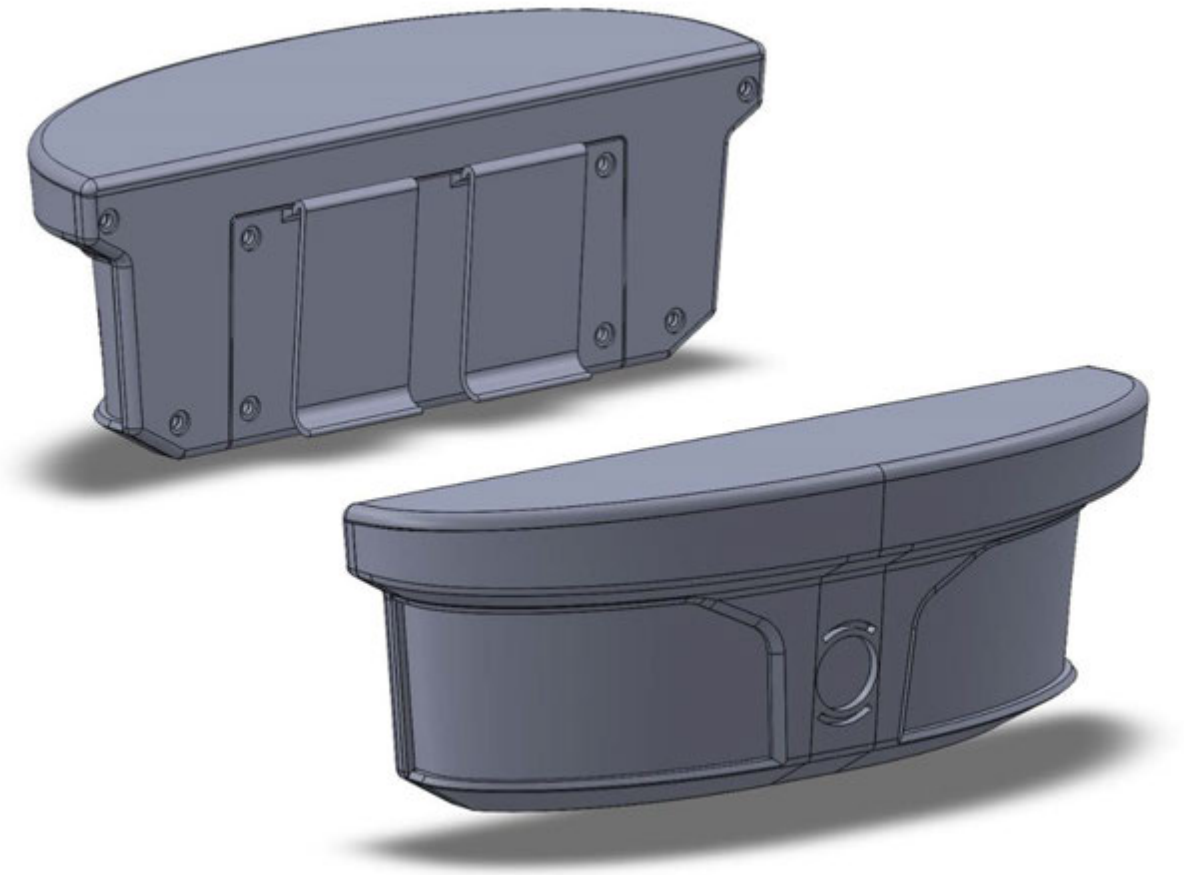


Figure 99 - Main Hub CAD - Front & Rear

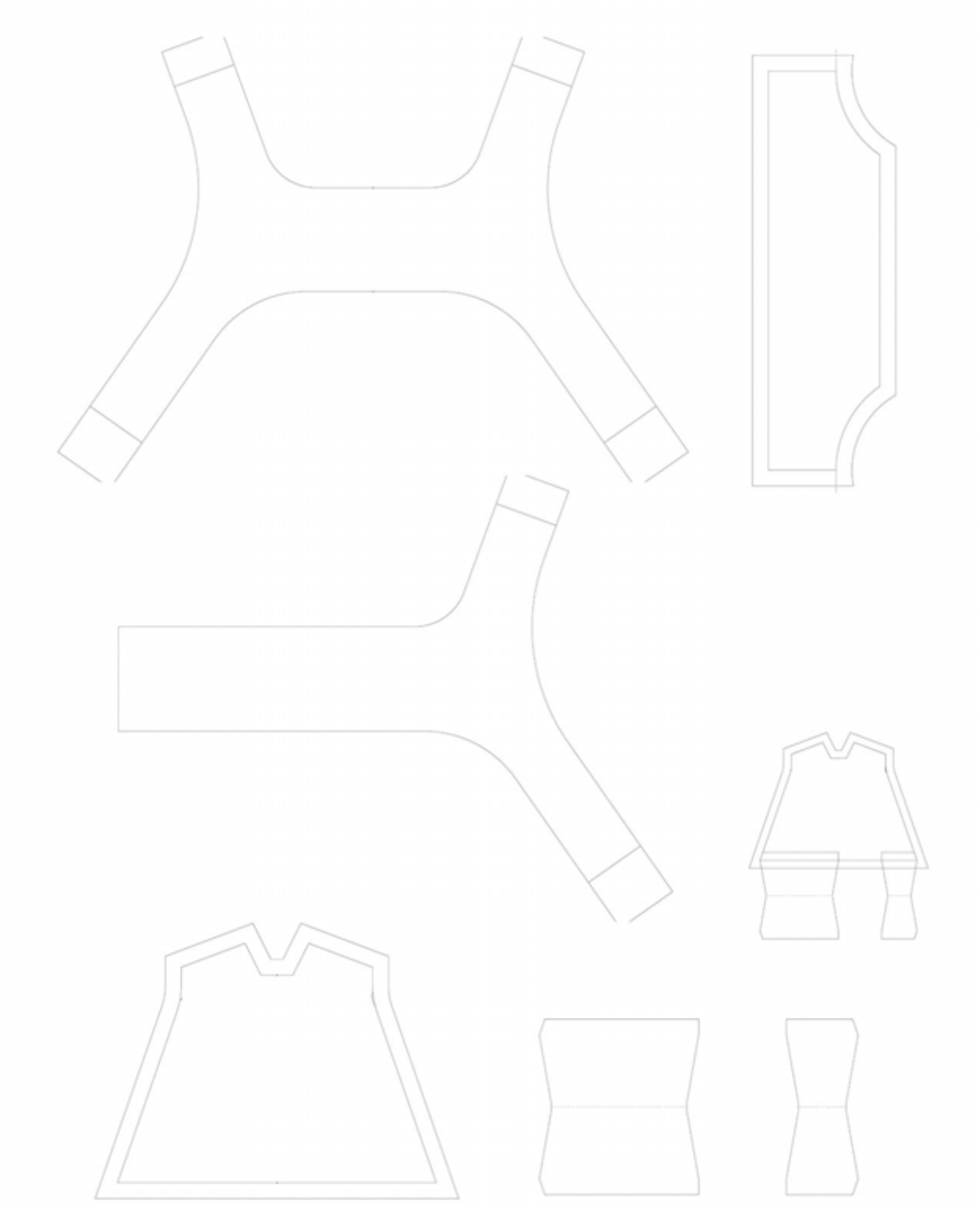


Figure 100 - Flat Patterns - Shoulder Harness

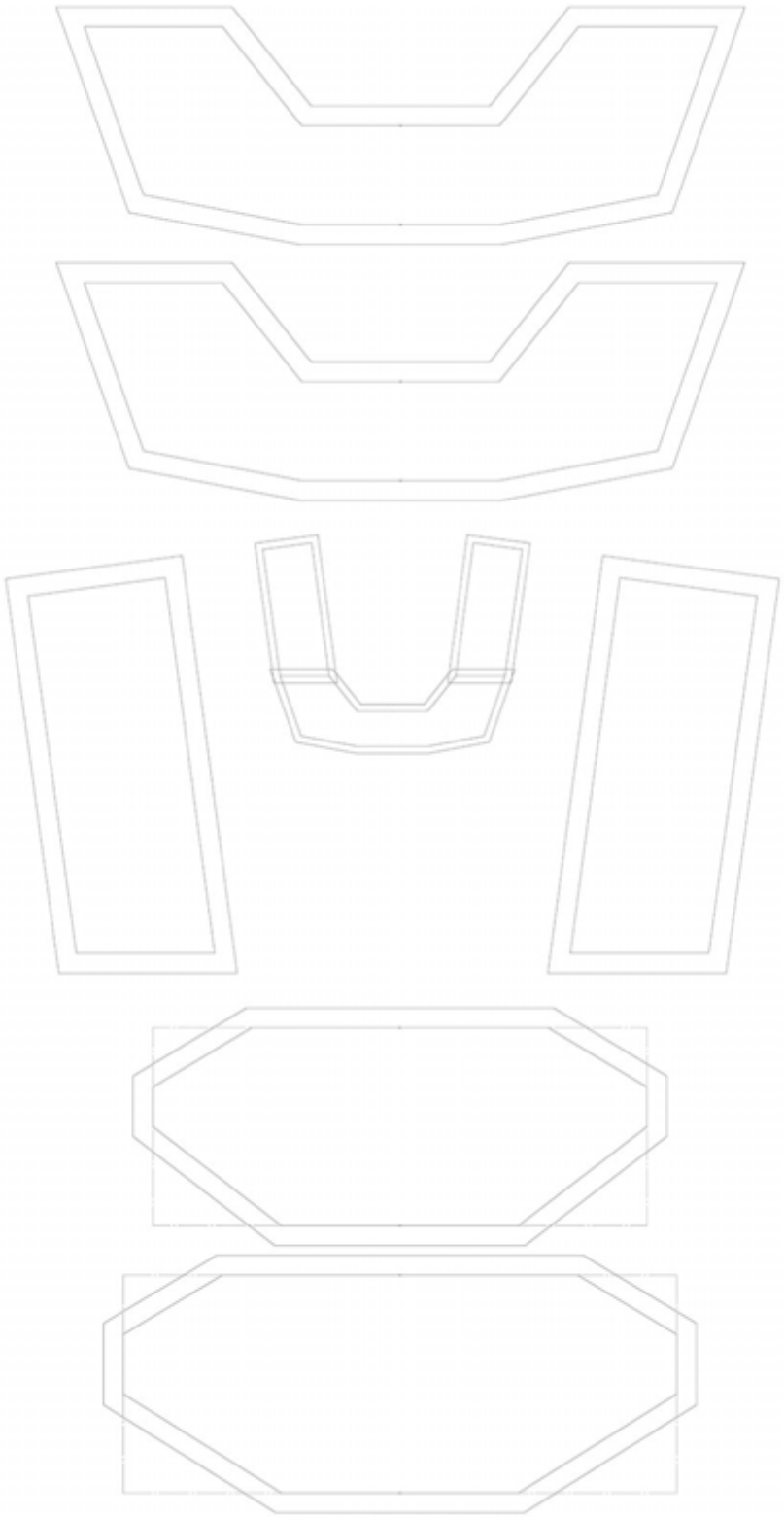


Figure 101 - Flat Patterns - Armour Panels 1

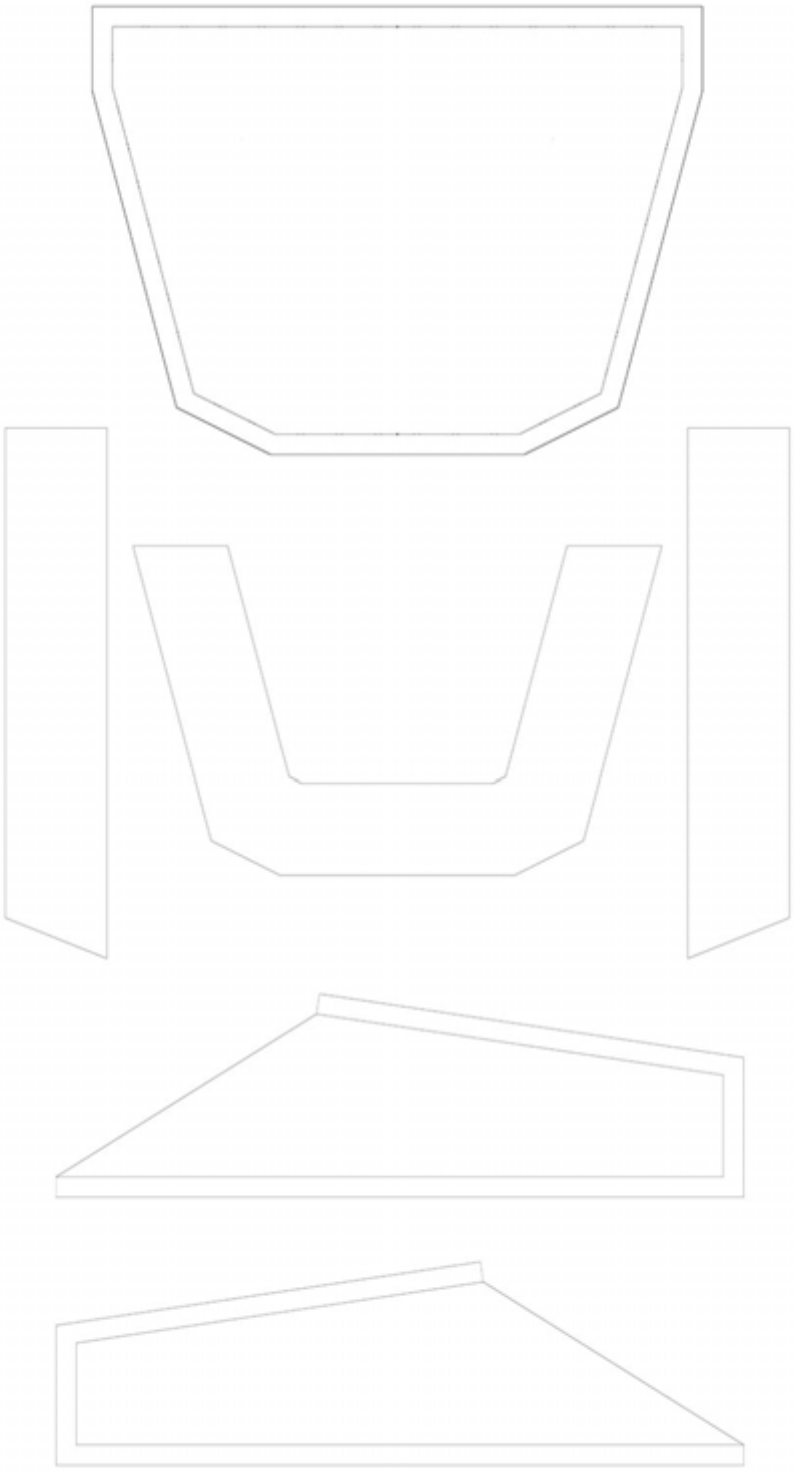


Figure 102 - Flat Patterns - Armour Panels 2

Figure 103 - Flat Patterns - Gloves

The entire CAD process took place over the course of two to three weeks. The main hub device was modelled entirely using SolidWorks. The whole housing and its locating, fastening, and reinforcement features were completed in the same starting part file, before being split into separate bodies. Due to the size and scale of the device, the CAD model was treated close to a design-for-manufacturing approach. The flat patterns were drawn in SolidWorks to achieve proper scale and measurements using dimensions derived from the physical study model, then transferred into Adobe Illustrator to clean up any lines and prepare for printing.

4.8 Physical Model Fabrication

Figure 104 - Physical Model Process 1

Figure 105 - Physical Model Process 2

Figure 106 - Physical Model Process 3

Figure 107 - Physical Model Process 4

The final model was made at a 1:1 scale in order to fully demonstrate the design concept and some of its features. All of the fabrics were sourced locally within Toronto, ON, from various shops around the Fashion District at Queen Street West and Spadina Avenue. Since the process of making the final physical model prototype involved a lot of fabric, sewing would be the primary means of construction. The flat patterns for each part of the wearable were printed to the correct size and cut out. Afterwards, they were transferred onto the fabrics by tracing using a white pencil crayon, then cut out. Many of the individual panels had separate pieces on the exterior, such as hook and loop tape or nylon webbing, so they were sewn on

first. Then a foam padding was inserted between the inner and outer faces to act as a filler and pseudo-Kevlar-like material and sewn together in one piece. A similar method was used for the rest of the pieces that required a padding or inner lining. Any small attachments were adhered using Gorilla Glue. Putting together the entire wearable consisted of attaching the panels together with the hook and loop fasteners. While it is not the first time using a sewing machine, the process was still a good learning experience filled with some growing pains, and dying motors.

The main hub device was 3D printed and outsourced to Objex Unlimited in Toronto, ON. The material used is a high-resolution resin, which allowed for the fine detail in the smaller product, and made the sanding and finishing process smoother. The plastic parts were all sanded to a smoother finish starting at 320 grit and finishing with 600 grit sandpaper. From there, the parts were primed and painted using Behr spray paint. The main housing pieces are intended to have a matted and textured finish, so not a lot of extra finishing was needed to achieve the desired result. The light bar and screen parts needed to be glossy, so they were wet sanded with 600 grit sandpaper between coats, and increased to a 2000 grit wet sand before the final coat. Assembly was completed using a combination of friction from the lip and groove features, as well as eight M.2x6mm self-tapping computer hardware screws.

Chapter 5 – Final Design

Figure 108 - Police Scene, ArtisticOperations. Retrieved from https://pixabay.com/photos/crime-scene-patrol-cars-police-6490202/

5.1 Summary

5.1.1 Description

Vigilo is a new approach to law enforcement safety that has two goals; improving the ballistic vest and redefining the officer's kit. It aims to enhance officer safety in dangerous situations by providing them with the tools to streamline their interactions and aid their awareness at any given moment.

5.1.2 Explanation

Law enforcement officers perform a critical duty in society in protecting communities and responding to crime. In order to do this, however, they need to ensure their own safety first. Much of the safety of an individual officer is dependent on their own training and experience. It is key to maintain a strong situational awareness of what is happening, who is located where, and how to act if a certain scenario unfolds. From current examples of gear that LEOs use, safety only extends as far as the ballistic vests that they wear, or other forms of hard plate shielding. This leaves an opportunity to use new technology and improve upon old technologies.

5.1.3 Benefit Statement

Vigilo builds upon the idea of a ballistic vest and transforms it into a wearable system that mitigates the physical strain on its user while providing a method to enhance their greatest skillset, situational awareness. Vigilo creates a more integrated system for law enforcement officers to connect, communicate, and co-operate.

5.2 Design Criteria Met

5.2.1 Full Bodied Interaction Design

Vigilo covers full-bodied human interaction in how each component of the final design is interactable. A combination of a wearable and a smart device target the upper body as the key points of interaction, from equipping and wearing the revised ballistic vest, to making commands with the gloves to use the main communication hub device

Figure 109 - Shoulder-Harness System

One of the key pain points for LEOs not directly related to safety, but still impactful on the user's health, is the duty belt. It is an essential piece of equipment that all officers need to have to put the majority of their gear onto. In some law enforcement agencies, an external vest carrier is not used, leaving all the equipment to be on the belt. This can cause a lot of strain and develop into worsening issues in the long-term. The shoulder-harness system used to support the duty belt can be worn over a concealed vest or under Vigilo's redesigned armour system to bear some of the weight and ease hip and back pain.

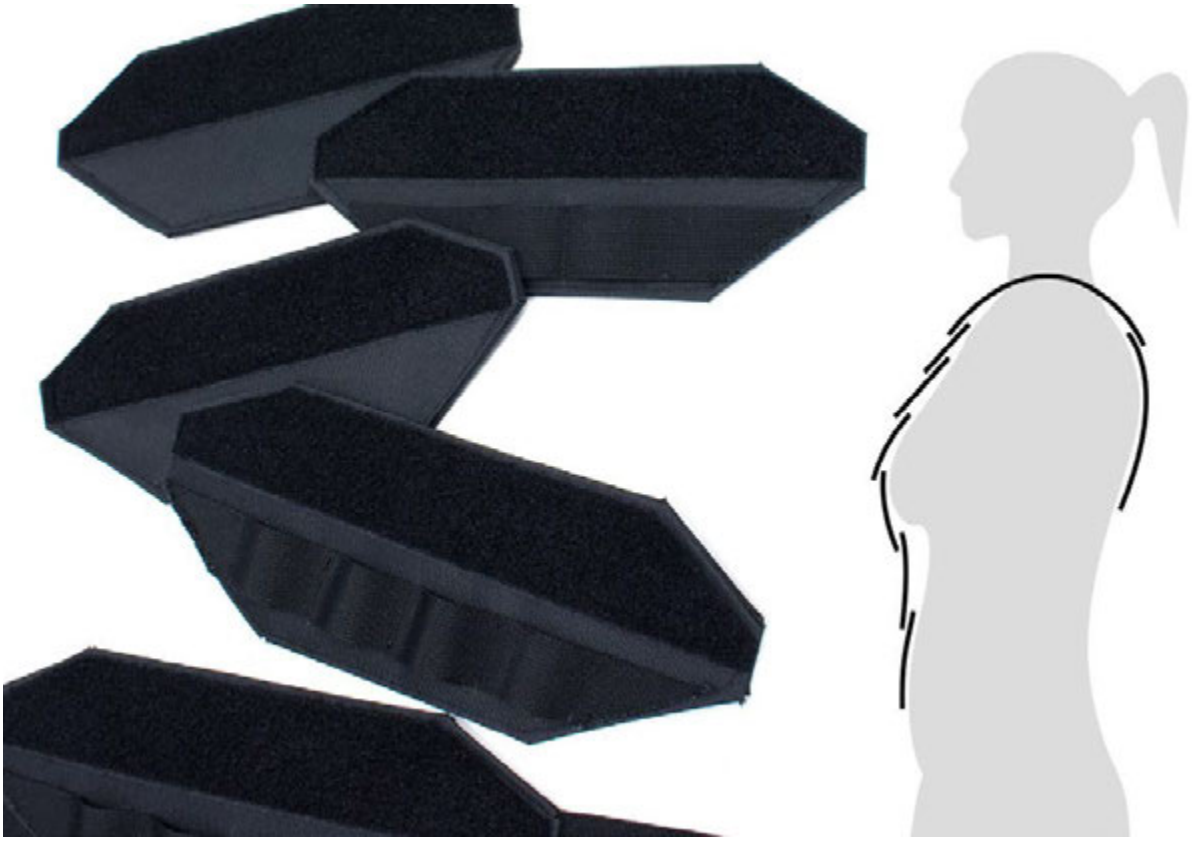


Figure 110 - Adjustable Armour Panels

Another ergonomic concern with traditional ballistic vests is fitment. It is impossible to make a one-size-fits-all, but even sizes can vary between users. The use of a hook and loop fastening system allows Vigilo to have more adjustability within a specific size group and percentile. For example, an individual user might require a size small, but have a longer torso and not be fully covered or comfortable with the pre-determined length. Likewise, most vests tend to be shaped for a male body type, making it more challenging for female users to wear comfortably in the chest area. Vigilo provides more freedom in adjustability for these users.

Figure 111 - Removeable Armour Panels

The hook and loop fastening system also addresses another potential pain point of removing the vest when the user has been hit by a bullet. Typically, treatment would have to wait until later, and it would require the whole vest to be removed. Vigilo's armour panel system makes it easier for other first responders, paramedics, or even the user themselves to quickly removed the affected panel and check for any injuries.

Figure 112 - Seamless Interaction

The use of smart gloves aims to centralise many interactions. The average LEO should have equipment such as a shoulder-mounted radio, flashlight, and body-worn camera. Interacting with either piece of utility would require the user to move their hands to different parts of their body or fumble around to reach for the right one. The gloves enable smart gestural commands that can be determined by the user to streamline their interactions and negate the split second where they have to think about their action. For example, activating the radio without having to remove one's hands from their weapon.

5.2.2 Materials, Processes and Technology

Vigilo's outer vest armour panels can utilise a polyester or nylon exterior in order to maintain a necessary degree of resilience to wear and damage due to being the most exposed and at-risk parts of the wearable. Hook and loop fasteners and nylon webbing are used for attachment points. Heavier duty elastics are used for the straps that attach the outer vest. The inside lining of the outer vest panels would utilise a ballistics lining, such as DuPont's Kevlar. The shoulder-harness system and gloves can utilise more eco-friendly alternatives to polyester and nylon, such as Lyocell or other recycled polyester fibres. The gloves also use emerging smart fabrics for vitals tracking and registering gesture inputs. Sewing would be the most effective and practical method for assembly of each part. Vigilo's main communication hub device would have to be manufactured using plastic via injection molding. A likely material would be ABS plastic since it can recycle a portion of re-used plastic into the molding process. The touch display would use a tempered glass for durability.

5.2.1 Design Implementation

Vigilo makes use of existing manufacturing methods that have been optimised to mass manufacture products. As such, design implementation of Vigilo would be quite feasible, with the biggest factor laying in the advancements of smart technology and fabrics to tie in the rest of the concept.

Bill of Materials					
No.	**Component**	**Material**	**Manufacturing**	**QTY**	**Est. Cost**
Communication Hub Device					
1	Front Housing	ABS	Injection Molding	1	$5
2	Rear Housing	ABS	Injection Molding	1	$5
3	Mount Plate	ABS	Injection Molding	1	$5
4	Display Exterior	Tempered Glass	Heat Treatment	1	$10
5	Light Bar Housing	Polycarbonate	Injection Molding	2	$10
6	Display Panel	Various	Various	1	$100
7	LED lights	Various	Various	2	$20
8	M.2x6mm Screws	Carbon Steel	Casting	8	$0.01/each
9	Camera	Various	Various	1	$75
10	Electronics	Various	Various	Varies	$600
Wearable System					
11	Vest Outer Layer	1050D Nylon	Sewing	1yd x 5ft	$20/yd
12	Shoulder Harness Crosspieces	Lyocell	Sewing	0.5yd	$35/yd
13	Gloves	Lyocell	Sewing	0.5yd	$35/yd
14	Padding	Foam Lining	Sewing	0.5	$15/yd
15	Smart Fabrics	Various	Sewing	Varies	$200

16	Fastening	Hook and Loop Tape @ 2 in.	Sewing	4yd	$5/yd
17	Duty Belt	Nylon Webbing @ 1.5 in.	Sewing	2yd	$2.50/yd
18	MOLLE loops	Nylon Webbing @ 1.25 in.	Sewing	3yd	$1.75/yd
19	Rear Vest Straps	Heavy Duty Elastic @ 2 in.	Sewing	0.5yd	$2.25/yd
20	Front Vest Straps	Heavy Duty Elastic @ 3 in.	Sewing	0.5yd	$4.40/yd
21	Ballistic Lining	DuPont Kevlar Level IIIA	Misc.	0.5yd	$350

Table 12 - Bill of Materials

5.3 Final CAD Rendering

Figure 113 - CAD Render Front

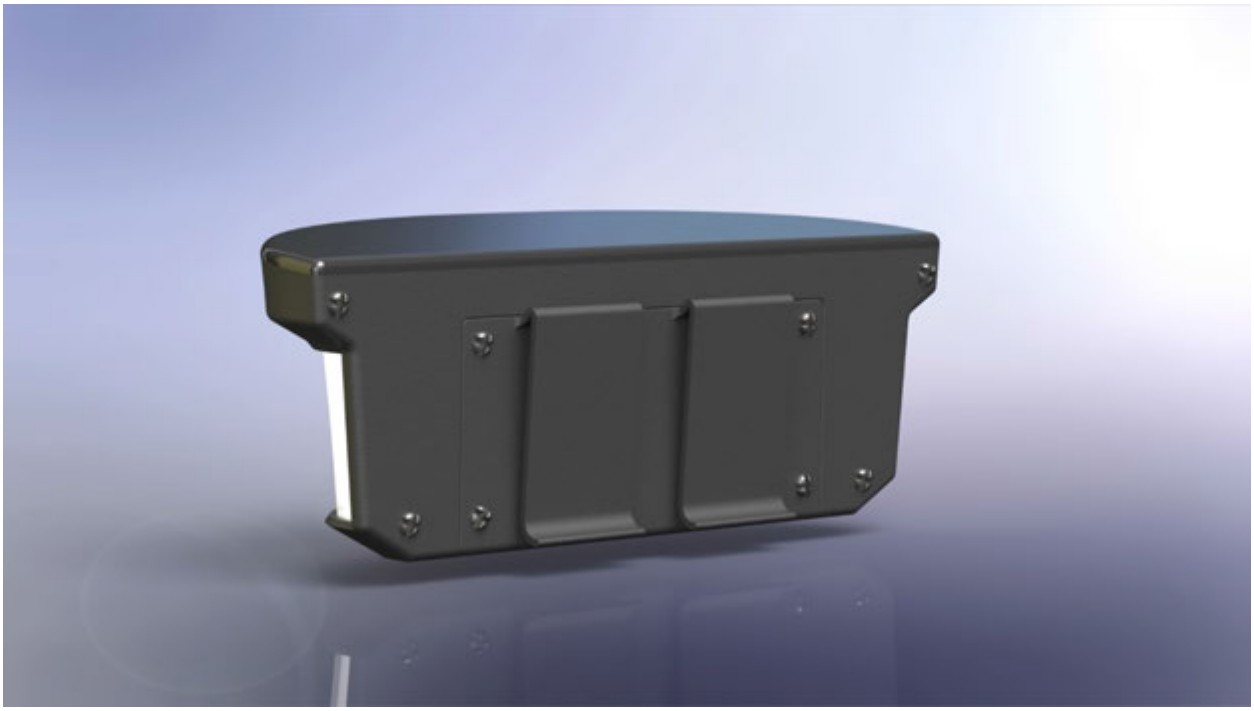


Figure 114 - CAD Render Rear

5.4 Physical Model

Figure 115 - Physical Model - Shoulder-Harness

Figure 116 - Physical Model - Outer Vest

Figure 117 - Physical Model - Gloves

Figure 118 - Physical Model - Communication Hub

5.5 Technical Drawings

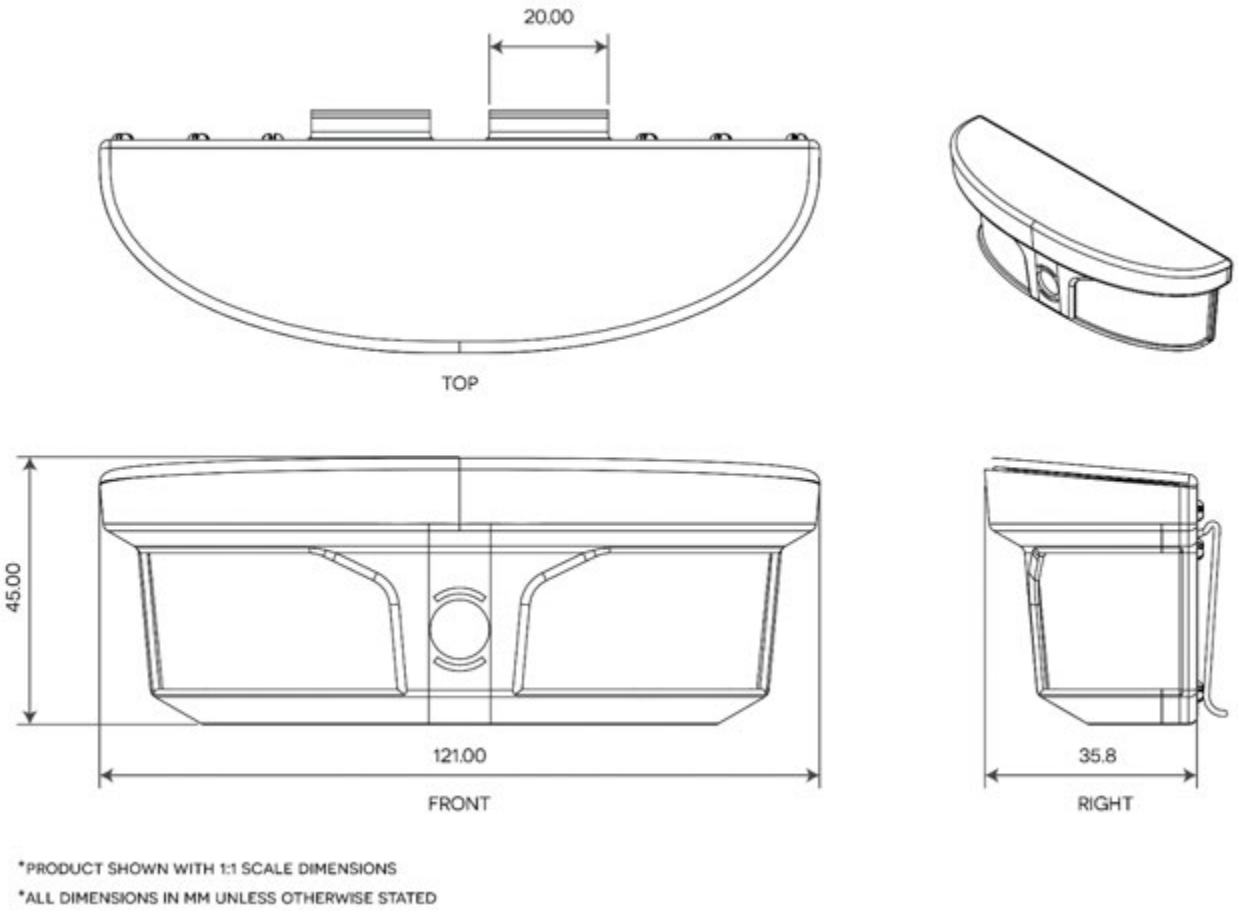


Figure 119 - Communication Hub Technical Drawing

Dimensioning on the flat patterns is variable and cannot be listed as exact measurements. The primary front armour panels and rear panel are the most reliable to measure, and have been provided assuming a small to medium size bracket.

*PRODUCT SHOWN WITH 1:1 SCALE DIMENSIONS
*ALL DIMENSIONS IN MM UNLESS OTHERWISE STATED

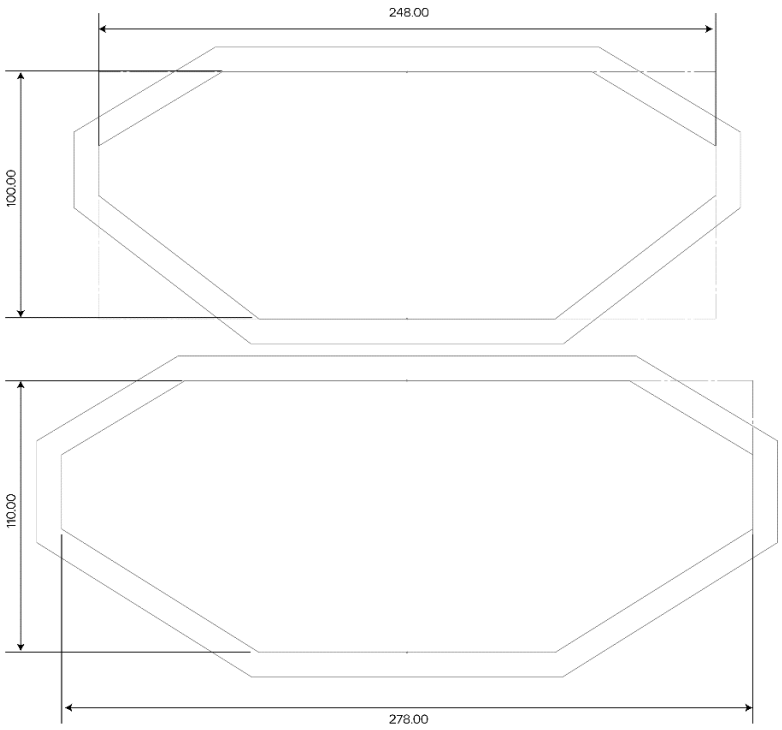


Figure 120 - Front Armour Panels Technical Drawing

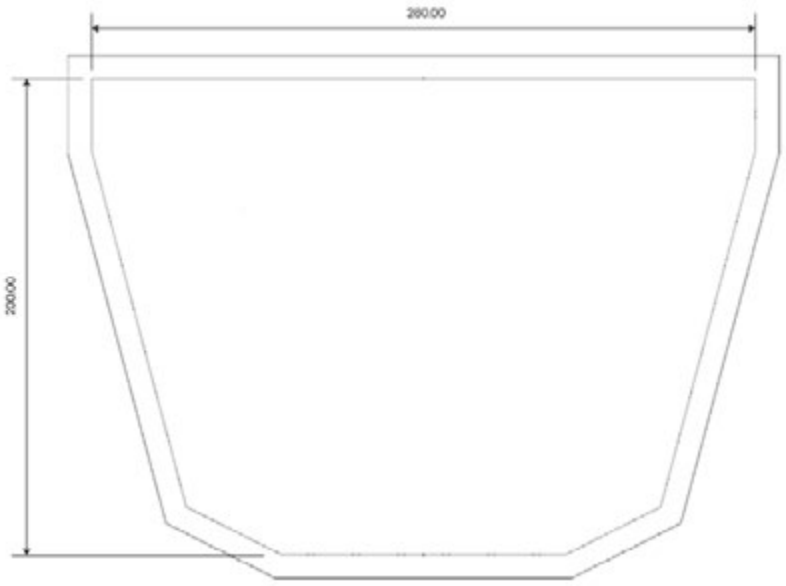


Figure 121 - Rear Armour Panel Technical Drawing

5.6 Sustainability

Vigilo tackles sustainability primarily through its removable armour panel system. With such high crime rates across North America involving assault or firearms, it is inevitable that ballistic vests will be damaged or need to be replaced to keep officers protected. If a vest is damaged, the whole thing needs to be replaced due to the entire panel being compromised. This can result in a lot of excess materials used for a new vest. When one of Vigilo's armour panels is damaged or worn-down, it can be replaced individually, rather than replacing an entire vest. In less exposed parts, such as the shoulder-harness system or underneath layers of the panels, an eco-friendlier fabric can be used as alternative to the typical polyester and nylon found in most current ballistic vests.

Chapter 6 – Conclusion

Figure 122 - In-Situ Photo

Law enforcement can be a very dangerous line of work, with over hundreds of officer injuries and fatalities each year in North America. Law enforcement officers perform a crucial role in helping to keep communities safe and respond to criminal activity, and Vigilo aims to enhance the officer's ability to perform their duty in dangerous situations. By taking a different approach to the ballistic vest, a wider range of users can be accounted for ergonomically, as well as granting first responders and paramedics quicker access to injuries. Vigilo also redefines what the officer's kit is and how they interact with their equipment in any given scenario. In doing so, it is a tertiary goal for Vigilo to push the boundaries of what kind of thinking and technologies can be applied to improving law enforcement officer safety.

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Appendix A – Discovery

Literature Review Search

The objective of this report is to perform an initial literature review and research into the chosen thesis topic using academic resources, such as the Humber Library database and Google Scholar, as well as common consumer search engines, such as Google. The findings in this report will be related to the topic of law enforcement officer (LEO) safety in the line-of-duty, including the potential for fatalities due to violent situations and crimes, as well as any accidental incidents.

Search Topic

Thesis Topic: Law enforcement officer (LEO) safety in violent situations.

Background: LEO's perform the very crucial role in helping to keep communities safe and responding to criminal activity. It can be an extremely dangerous profession, with hundreds of officer fatalities yearly in the United States. Many are firearms-related, others traffic-related, or even accidental. Most LEO's tend to be equipped with a light body armour vest, which is suitable to most general situations, however, it does still leave the rest of the officer's body exposed. Moreover, there is the potential for the officer to be in vulnerable positions or caught off-guard, such as at traffic stops or domestic calls.

Needs Statement: Law enforcement officers need a solution that improves their safety and security without becoming too over-encumbered.

Current Solutions: Most LEO's wear light body armour vests, and typically carry a taser and/or sidearm pistol. Some police departments may have access to high fire rate or higher-calibre weapons and equipment, as well as better armoured vehicles, although this not consistent across a city or state/province.

Key Article 1

Method

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

- Search Engine: Humber Libraries
- Key Words: "police safety"

Findings

Citation:

Masera, F. (2021). Police safety, killings by the police, and the militarization of US law enforcement. Journal of Urban Economics, 124, 103365. https://doi.org/10.1016/j.jue.2021.103365

Summary Statements

1. Militarization of police officers does not necessarily increase their safety. There are positive correlations between police militarization and increased officer injuries, potentially due to increased deployment of LEO's to more dangerous situations.

2. Military equipment is often used against armed and barricaded suspects, as well as drug raids. Negative effects have been reported when used in disturbance calls, stopping robberies and burglaries, and drug raids.
3. Public perception to police militarization is variable. Many view it as dangerous and a risk to increasing killings of minority groups, whereas others view it as a necessity to increase the safety of LEO's on duty due to the risks they face.
4. The use of military equipment and more heavily armed LEO's could have a positive correlation with violent criminals using higher-calibre firearms or increased aggression towards LEO's.

Key Article 2

Method

A key article for this topic was sourced and selected. Required article content (Main was copied and highlighted.

- **Search Engine:** DuckDuckGo/Google (Both yielded the same source)
- **Key Words:** "most dangerous situations for police"

Findings

Citation

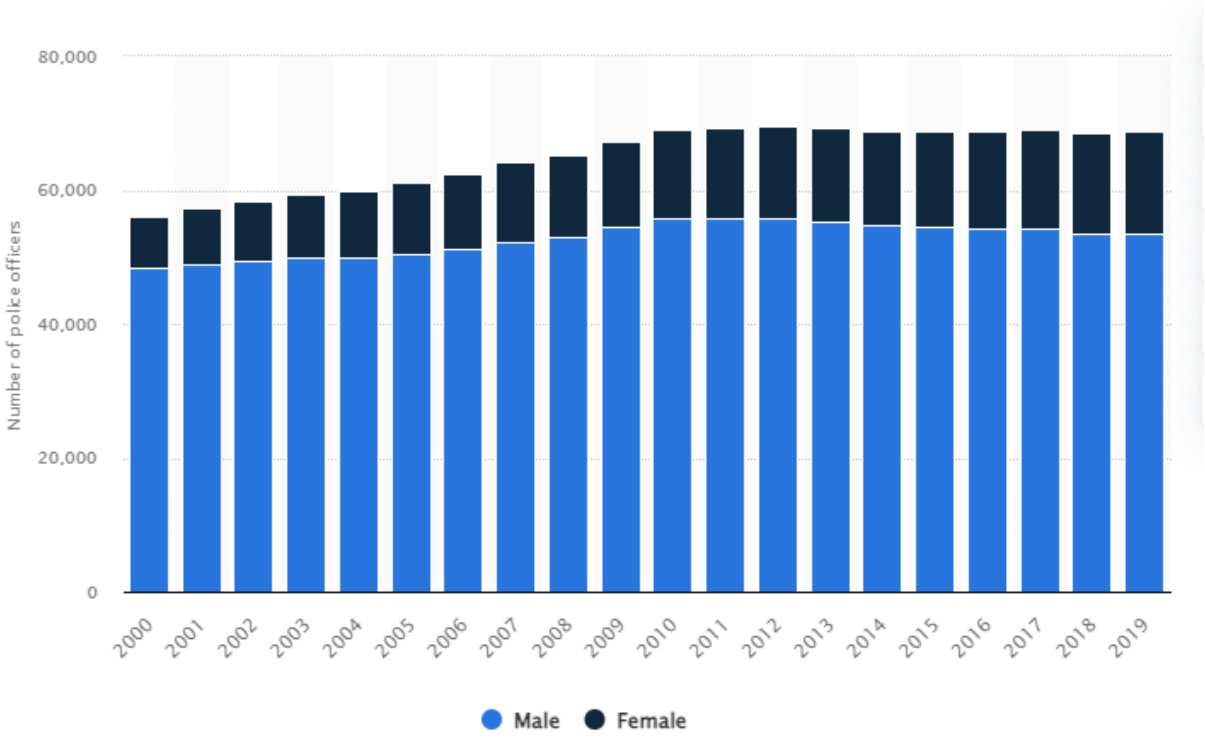
Dawns, S. (2019). The most dangerous situation police officers will face in their career. Law Enforcement Today. Retrieved from https://www.lawenforcementtoday.com/most-dangerous-situation-police-face/

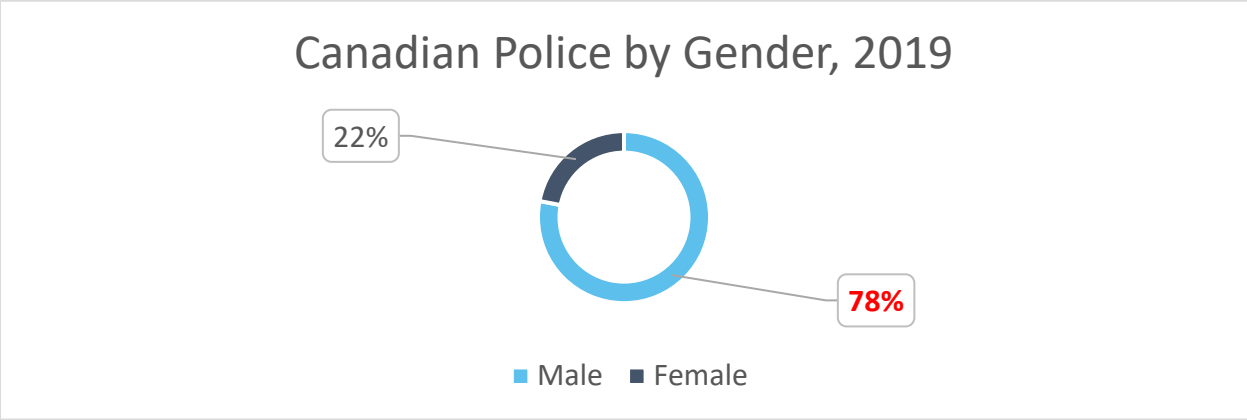
Summary Statements

1. Traffic stops and domestic violence calls are among the most dangerous situations for a LEO to be involved in. They have the potential to escalate very easily and become violent at a moment's notice.
2. Monitoring the reported suspect and victim(s) is important. Keeping individual parties separate and away from areas with potential weapons, such as the kitchen, is important to ensuring the physical safety of everyone involved.
3. Situational awareness and having enough time to react or prepare for a situation to deteriorate is key for the LEO to react and respond appropriately.
4. Children can provide valuable insight for probable cause to an investigating officer.

Appendix B – Contextual Research (User)

Gender Statistics





Jeudy, L. (2021). Number of police officers in Canada from 2000 to 2019, by gender. Statista. Retrieved from https://www.statista.com/statistics/436331/number-of-police-officers-in-canada-by-gender/

Interview Notes – Session 1

- Most common calls are public disturbances
    - Summer and Christmas are assault
    - Drunk driving
    - Minor theft (under $5000)
- Most dangerous call involves assault calls, as weapons are unknown
    - Shootings, assault with a deadly weapon
- Domestic violence calls
    - Tight spaces
    - Potential for weapons
    - Intoxicated suspects
- Gang-related crimes
    - Almost always armed
    - Volatile situation
- Really excited as recruits, dream job essentially
- Desensitized over time
- Rookie responding to fleeing suspect, had to climb a roof to chase, attempted reasoning, no taser, wanted to avoid using gun, tried baton to no effect, had to use gun as last resort
    - High intensity, high adrenaline, on edge

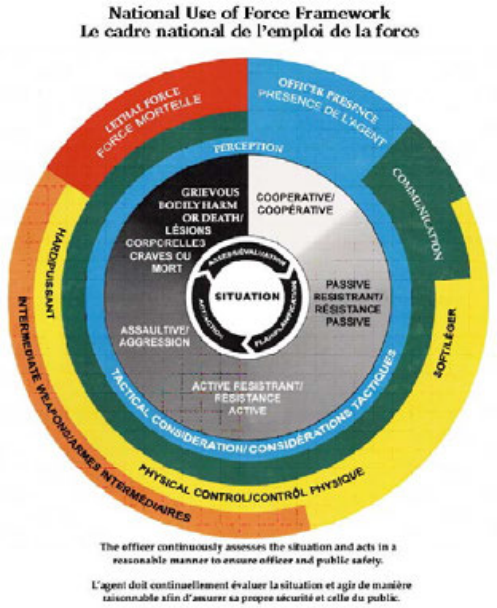
- Responding to gunshots in an apartment complex, woman feigned ignorance, find wounded man, discover rifle and suspect wife of the crime, questioned, and gained proper confession
    - Silence adds pressure to gain a confession

Interview Notes – Session 2 & 3

- Tight space, house or apt
- Only you and your partner
- Suspect has advantage
- Separating suspect from victim
- Situation can escalate quickly, especially after officers leave
    - Suspect can cause further harm or kill the victim
    - Officers in Ontario have legal ability to arrest if there is reason to believe domestic violence occurred
- Example:
    - Man waited for spouse and shot and beat her
    - Took another hostage
- Officers try to separate both parties to question and gain info
- Look for evidence of conflict at scene
    - Bodily injuries
- Direct the victim to social services or counselling
    - First contact, most that can be done is ^ after arrest

- If suspect is uncooperative and is armed or keeping hostage, lethal force is required
- Approaching dangerous situations
    - Officers must prioritise their own safety in a situation, not run blindly into a dangerous situation
    - Must still put safety of civilians above all else
    - Armed and barricaded, hostage, first responders call and wait for backup, such as EMS, negotiators, SWAT/tactical teams
    - First responders have to cordon off area and secure it
- in cases where there is a serious immediate threat, officers must intervene
    - Example: Raptors parade shooting
- First responders must go in if shots are fired before backup arrives
- As situation evolves, different officers get delegated to different tasks
    - First responder may be set to cordon off area
    - Specialists go in
- Regions can vary
    - OPP/RCMP in more remote areas are left with only themselves and their partner
- Close quarter spaces like homes are particularly treacherous
    - Limited room for movement or cover
    - Indoor spaces
- Weather can impact a foot chase
    - Rainy, snowy, dark
- Height factors in

- Can be at risk of falling over ledges



- Officer presence is enough to deter basic crime, cooperative users
- Communication, verbal is passive resistance
- Soft force, using more intent
- Must assess, plan, act
    - Are they cooperative?
    - Do they have a weapon?
    - Are they shooting?
    - Can they be restrained?
- Experience and officer training/mentality going into a situation plays the biggest role in safety
    - All officers receive similar training
    - Have to be on the ball, situational awareness must be ready at all times

- 21-foot rule
    - Keeping appropriate space between officer and avenues of attack or threats
    - Leave enough time to react and respond to a threat
    - At least enough to draw weapon and return appropriate use of force
- No height or weight restrictions, just need to be capable of passing physical tests
    - 6ft 160lbs ideal before, still generally preferred
    - PIN test https://www.youtube.com/watch?v=P3n-LJ7ETZI&ab_channel=OfficialYRP
    - PREP test https://www.youtube.com/watch?v=LZnigMxeET0&ab_channel=J.Decarie
    - Hypothetically, a 1st percentile female can become an officer if they pass all the physical tests, but more than likely, a larger candidate will be more favoured
    - http://www.torontopolice.on.ca/careers/uni_minreq.php
    - https://paladinsecurity.com/law-enforcement-careers/become-police-officer-canada/#section1
    - https://www.rcmp-grc.gc.ca/en/qualifications-and-requirements

Appendix C – Field Research (Product)

Product Benchmarking Preparation

Product 1: Axon Taser X26P

https://www.axon.com/products/taser-x26p

Non-lethal tool for subduing uncooperative/aggressive suspect.

- Compact design
- Blast doors protect cartridge from damage
- IPx2 resistance against rain and dust
- High-impact polymer housing
- Ambidextrous safety switch
- Drop tested at 4 feet

Product 2: Glock 17/22 Pistol

https://us.glock.com/en/pistols/g17-gen4

Common standard issue law enforcement sidearm.

- 9x19mm or .40 S&W options
- Modular configuration for right- and left-handed users
- Shorter length barrel
- Relatively lightweight
- Lethal stopping force

Product 3: Colt Canada C8 Carbine (Semi-automatic variant)

http://military-today.com/firearms/c8.htm

Standard issue carbine available to Toronto Police Service.

- Alternative option for emergency/dangerous situations, such as active shooters or barricaded suspects
- Farther effective range than standard pistols
- Standard NATO specifications

Product 4: Ford Police Interceptor Sedan (Out-of-production, but still in-service)

https://live.staticflickr.com/7845/46833952324_e9edf912fa_b.jpg

Standard police response vehicle.

- Available in different engine/powertrain configurations
- Reinforced cabin and driver compartment
- Secured and barricaded rear seat
- Well-rounded performance and utility

Product 5: Ford Police Interceptor Utility

https://www.ford.com/police-vehicles/hybrid-utility/

https://c2.staticflickr.com/6/5607/15443145448_d71b4a7392_b.jpg

Standard police response vehicle.

- Hybrid/AWD powertrain
- 75-MPH rear-impact crash-test rated
- Improved utility and cargo space
- Reinforced cabin and structural enhancements compared to civilian variant
-

Product 6: Horse

https://www.blogto.com/city/2019/05/why-we-still-have-mounted-police-toronto/

Horses used by the Toronto Mounted Police Unit.

- Draft horse crosses and pure Clydesdales
- Useful for navigating crowds, crowd control and dispersal, with more recent use for community support
- Makes officers appear more approachable
- Provides higher line-of-sight to spot crime

Product 7: SafariLand Shift 360 Plate Carrier

https://safariland.com/collections/tactical/products/shift-360-scalable-plate-rack-system-shift_360

Lightweight body armour plate carrier.

- Lightweight closure
- Velcro straps
- Modular webbing loops
- Easy adjustment
- Supports different levels/sizes of plates

Product 8: Axon Body 3

https://www.axon.com/products/axon-body-3

Body camera for recording officer activity.

- Automated redaction and transcription
- Four microphones for recording audio
- LTE connectivity for viewing officer location and monitoring
- Saves up to 18h of no-audio footage in event of late or forgotten activation
- IP67 rated for dust and water resistance
- Full-HD recording
- Drop tested at 6 feet

Benefits and Features Benchmarking

SafariLand Shift 360 Scalable Plate Rack System

The Shift 360 System is a sleek and innovative plate rack design that offers the operator ultimate scalability based on mission-specific requirements.

Highest speed and most dynamic situational scalable plate rack on the market.

Features design refinements for increased fit, form and function such as cummerbund upgrades, reinforced attachment system and new closure & load-bearing platform offerings.

Features

- Designed for SAPI plate system across multiple sizes ranging from small to extra-large plates
- Bottom loading front and rear plate pockets accommodate 10”x12” SAPI rifle plates covering small to extra-large body types and sizes
- Lightweight, highly durable internal lining system ensures a tight and secure fit and will support a variety of plate thicknesses
- Ergonomic shoulder support system with improved adjustability and load bearing support
- Internal flex-pouch for radio and accessory storage on external cummerbund
- AWS platform offers improved strength and reduced weight with a distinctive, cutting-edge look

Benefits Table

Product	Axon Taser X26P	Glock G17 Gen4	Colt Canada C8	Ford Police Interceptor Utility	SafariLand Shift 360 Plate Carrier	Horse	Axon Body 3
Image							
Benefits	• Small frame, easy to handle • Easy front-load system • Blast doors make cleaning maintenance easier • Dual-sided safety switch improves usability for left-handed users	• Improved useability for left-right hand operation • Customizable grip allows user to improve comfort • New recoil assembly reduces maintenance needs	• Telescopic buttstock improves useability for different users • Shorter barrel for improved handling and comfort	• Safer crash structure • Hybrid powertrain improves fuel economy • AWD provides improved traction • Improved cargo space for equipment	• Lightweight, easy to carry • Modular attachment system allows for improved protection • Improved adjustability for user fitment • More functional attachments	• Provides better viewpoint for spotting crime • Easier to manoeuvre through crowds • Faster than foot • More approachable and friendly to civilians	• Easy wireless activation, better focus on the situation rather than hitting record • Officer tracking improves safety when separated

Features Table

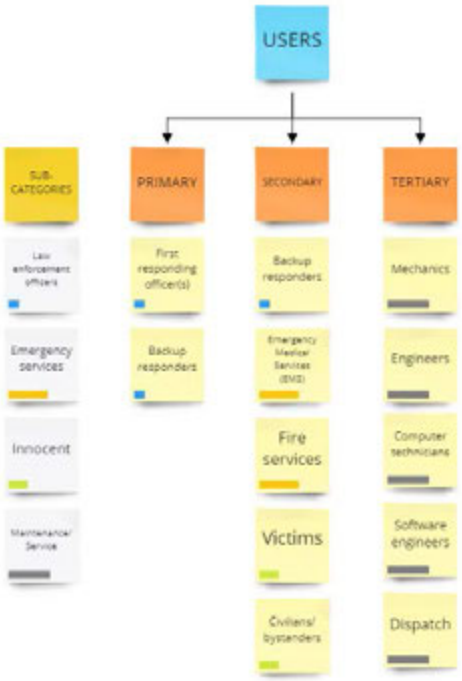
Product	Axon Taser X26P	Glock G17 Gen4	Colt Canada C8	Ford Police Interceptor Utility	SafariLand Shift 360 Plate Carrier	Horse	Axon Body 3
Image							
Features	• Compact design • Ergonomic handle • Blast doors protect cartridge • Front-facing reload system • Trilogy logs record device operation and performance	• *Modular Back Strap* design allows for customisable grip • Rough texture • *GLOCK* dual recoil spring assembly • Reversible magazine catch	• Iron sights integrated into carry handle • Picatinny rails (later models) • Telescopic 4-position stock • Standard NATO 5.56x45mm • 368mm barrel	• Hybrid/AWD powertrain • Cargo space • *75-MPH Rear-Impact Crash-Test Rated* • *Side Protection and Cabin Enhancement Architecture* • *Police Perimeter Alert* automatically secures car	• Uses SAPI plate system • Bottom loading front and rear plate pockets • Lightweight, durable internal lining system • Ergonomic shoulder support system • AWS MOLLE straps for attachments	• Higher viewpoint • Crowd control and manoeuvrability in crowded area • It is a horse	• Live alerts, tracking, and streaming through network • Secure and encrypted data • Sleek and rugged design • Video retrieval up to 18h audio-free if recording fails to activate

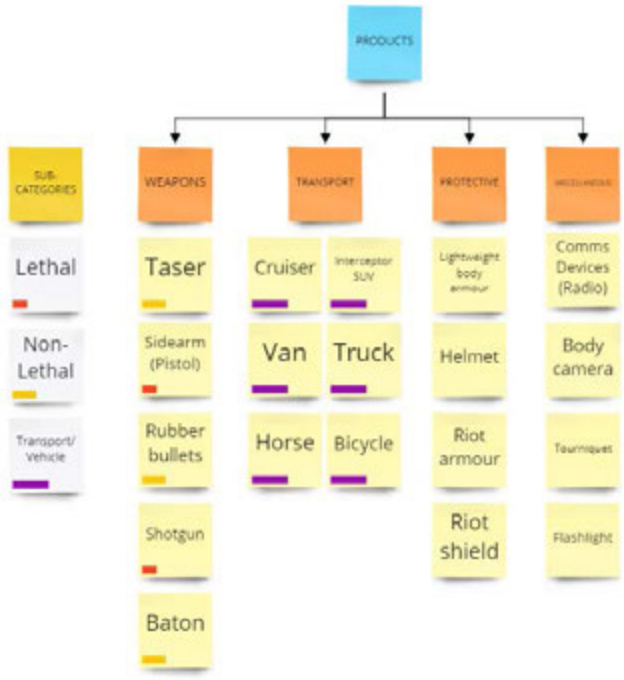
Key Takeaways from Benchmarking

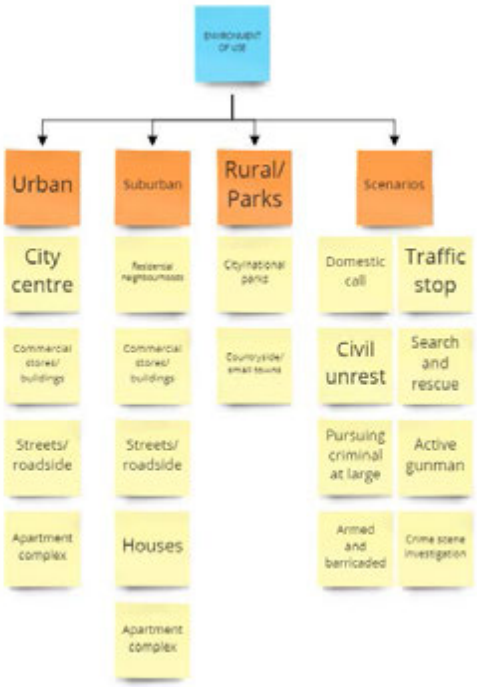
- Ergonomic considerations for both left- and right-handed users is important
- Adjustability for different positions improves user comfort or experience
- Equipment that is tight and secure mitigates chance for failure
- Equipment should be easy to use and handle
- Lightweight, more compact, shorter, etc.
- Safety is key
- Should be easy to use or fairly straightforward

Appendix D – Result Analysis

Affinity Map







WEAPONS NOTES

+ Taser is non-lethal
-- Risk of injury to recipient when falling
-- Not always reliable, and requires both prongs to connect to the person
-- Target could be unaffected

+ Pistol can stop a criminal relatively effectively
= Lethal method
-- Effective range can be too short in certain scenarios

TRANSPORT/VEHICLE NOTES

= Cruiser and interceptor SUV are fairly standard patrol and pursuit vehicles
= Cruiser is well-rounded, balance between performance and utility
+ SUV offers more utility and cargo space, as well as better suited to rougher terrain and poor weather conditions

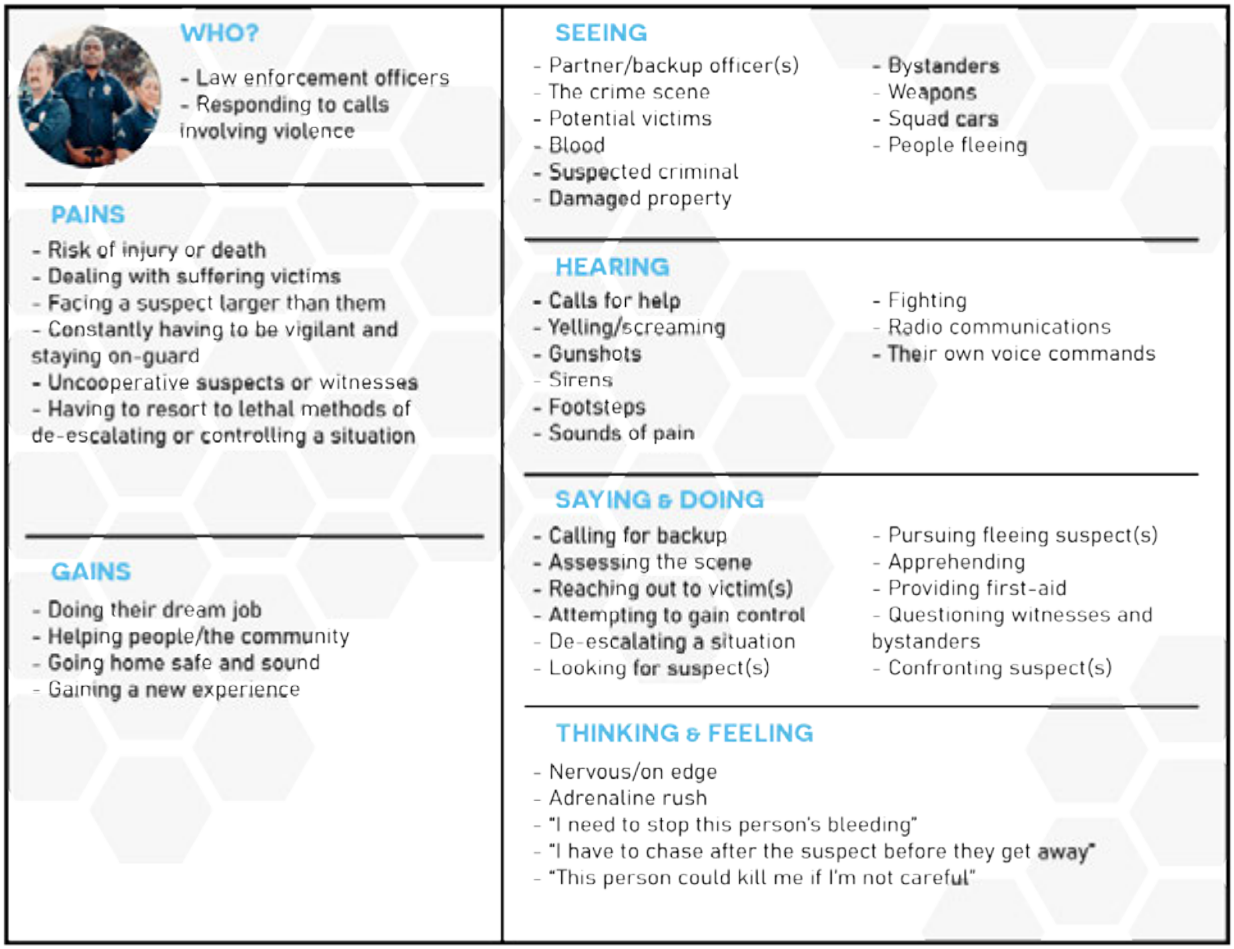
+ Bicycle allows easier movement in dense urban areas
-- Bicycle lacks protection and utility storage of other vehicles

+ Horse provides a higher view of a crowd to spot any crime
+ Suitable for navigating and dispersing crowds
-- Horseback rider is exposed

PROTECTION NOTES

+ Lightweight body armour is more easily concealed with uniforms
+ Capable of stopping or mitigating damage from light firearms
+ Less bulky
-- Cannot stop higher calibre weapons
-- Leaves rest of body exposed
-- Cannot stop blunt or sharp objects outright

Empathy Map



Preliminary Video Search

Video #1
URL: https://www.youtube.com/watch?v=zWBPodHpieQ
Title: The Physical Readiness Evaluation for Police (PREP Test)
Length: 9m 08s

Brief Description:
A run-through of an Ontario police physical training test that simulates actions that may be required by active-duty law enforcement officers when handling a call.

Relevance to Thesis Topic:
Video showcases some of the physically demanding actions demanded of officers. These scenarios can also be times when an officer may be vulnerable or at risk of harm.

Video #2
URL: https://www.youtube.com/watch?v=_UPKTekkWWQ
Title: Knife Wielding Man Nearly Takes Out Officer - Police Shooting Breakdown
Length: 4m 20s

Brief Description:
Former police officer breaks down bodycam footage of a police shooting. Officers are responding to potential domestic disturbance with a vehicle at roadside. Suspect picks up knife and charges officer, seemingly with intent to kill or cause bodily harm. Officers respond with use of deadly force. Person analysing the bodycam footage also brings up a training rule used in some police training.

Relevance to Thesis Topic:
This video highlights the speed at which a situation can become deadly for law enforcement officers when dealing with an armed suspect, and the way that officers react in that split second moment.

Video #3
URL: https://www.youtube.com/watch?v=Z1GglyfHQ5Q
Title: 100 FOOT PISTOL SHOT takes down shooting suspect - police shooting breakdown
Length: 2m 23s

Brief Description:
Former police officer breaks down bodycam footage of a traffic stop shooting. The officer in the video pulls over a driver, and upon the car stopping, the suspect exits and immediately begins shooting. The officer reacts by exiting the patrol car swiftly and using it as cover to while stopping the threat.

Relevance to Thesis Topic:
In the video, the former officer explains how in training it is told to not stay in the vehicle in a gunfight as it would essentially be a death trap or coffin, and to instead get out and use the whole vehicle as cover. This also shows that cover and protection can be makeshift or improvised as the situation calls.

Video Observation

Design Research Focus

- To provide law enforcement officers with options for protection against bodily harm
- To improve experience in a high-stress situation involving armed suspects

Goals for Preliminary User Observation

- To observe how the user enters a scene

- To observe how the user reacts to suspect hostility
- To observe what the user does to respond accordingly
- To observe any points of contact where conflict or an injury may occur

Same incident. Video 1 contains all bodycam footage. Videos 2-3 provide extra context.

"105 Precinct Officer Involved Shooting November 24, 2020" (05/03/21)

https://www.youtube.com/watch?v=i2wxAPelbIA (Graphic content)

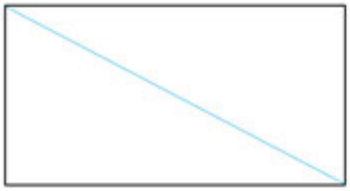
"NYPD bodycam shows domestic violence suspect ambushing officers" (05/03/21)

https://www.youtube.com/watch?v=HScaA_yXSc8

"man AMBUSHES NYPD cops during domestic violence call" (09/03/21)

https://www.youtube.com/watch?v=Slw6jv7g_lI

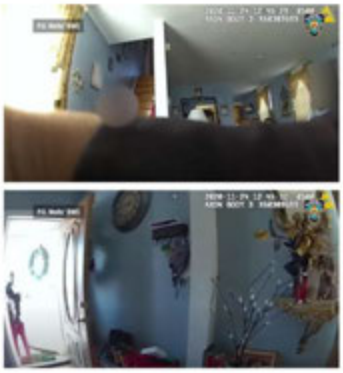
Step-by-Step Observation



Task 1: Preparation
- Victim entered precinct to report domestic violence
- Victim is afraid to enter house to retrieve her items alone and wants a police protection/escort
- Two officers performed initial interview with victim
- Officers decide to accompany the victim back to her residence

Task 2: Arrival
- Officers arrive at residence where incident occurred
- First officer informs the victim of what is going to happen and what to do
- Both officers are keeping an eye out for the suspect

Task 3: Assessing the Situation
- Officers escort the victim back into the house
- They perform a basic search of the premises
- They assess the situation by verifying the presence or absence of the suspect and any weapons
- Question the victim to gain more info on what to do moving forward



Task 4: Threat Recognition

- The victim notices the suspect returning at the door
- Officers had ~3 sec to determine if he posed a threat to their safety

Task 5: Response

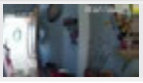
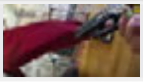
- Suspect started shooting at officers on sight
- First officer was shot in the leg and second shot in both hands before returning fire to end the threat

Task 6: Report In/Call for Aid

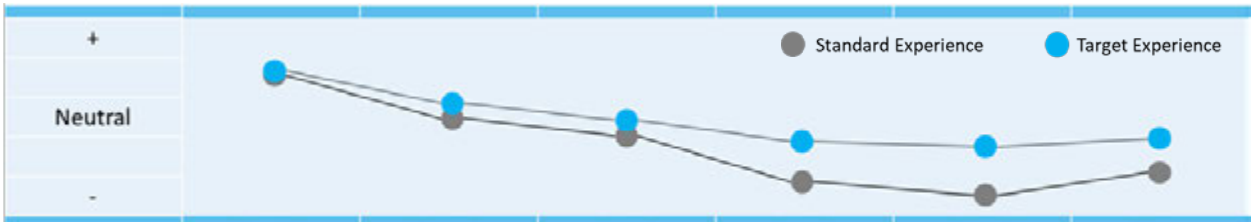
- With the immediate threat stopped, officers report the situation and call for appropriate backup to secure the area and emergency medical services to handle any injuries

Activity Mapping

User Journey Map

	Task 1	Task 2	Task 3	Task 4	Task 5	*Task *n*
User Goal	Preparation	Arrival	Assess the Situation	Threat Recognition	Response	Report In/Call for Aid
User Actions	• Receive the crime report • Listen to the victim's story • Plan to escort victim back to their home	• Drive to the residence • Survey the area • Inform the victim of what they can do to help, and social services they have access to	• Enter the house • Perform a search of the building • Ask the victim for any extra info about the incident • Heighten situational awareness	• Maintain a safe distance to react • Isolating the suspect and victim from each other • Checking for body language or aggression • Look for a weapon	• Move the victim out of the line of fire • Dodge/take cover and make it harder to be hit • Return an appropriate use of force	• Report the situation to dispatch • Request backup to secure the area • Request EMS to tend to injuries
User Thoughts	• "We need to help this victim" • "The suspect needs to be arrested"	• "Where is the house?" • "We should stay here to protect the victim"	• "Could the suspect still be here?" • "Are there any weapons here?" • "I need to be on guard in case the suspect returns" • "Should be aware of the entrance"	• "Is the suspect armed?" • "Will the suspect cooperate?" • "Will I be able to restrain them?" • "They're going to attack me or the victim"	• "The suspect is shooting at us" • "I'm hit" • "Need to protect the victim/ bystanders" • "I have to return fire to stop the threat"	• "The suspect is down" • "It hurts" • "Need backup" • "Need medical assistance" • "Check for other injuries"
Storyboard	N/A					

User Experience Map



	Task 1	Task 2	Task 3	Task 4	Task 5	Task *n*
User Goal	Preparation	Arrival	Assess the Situation	Threat Recognition	Response	Report In/Call for Aid
Problems/ Challenges		• Not all situations may not allow for safe arrival at a scene	• Close quarter environments can leave officer open • Weather conditions can affect visibility or ability to give chase	• Suspect cannot always be reasoned with peacefully • A situation can go from peaceful to deadly in seconds • Potential for hostages	• Risk of stray bullets hitting an unintended target • If lethal force is required, there is little time to do anything else but open fire	• Suspect can still be at large when call is made • Backup officers can be exposed on arrival • Negotiators need to be close to perp
Ideas/ Takeaways		• Protected vehicle/ mode of transport	• Equipment that can survey an area • Product suited to specific weather	• Worn or always in-use equipment • Shield for use by victim/bystanders	• Device that deploys rapidly or with weapon	• Device that does not distract officer or need them to fumble with hands

Takeaways

For Thesis Topic

- There are many openings where an officer may be vulnerable
- A situation can become deadly in a matter of seconds, leaving little time to react and respond
- High-stress scenarios can result in a focus on stopping a threat more than self-protection
- Victims or other innocent bystanders can be caught in a crossfire

For Further User Observation

- Proper user observation would likely put both self and advisor or participant(s) at risk
- Look for other video cases involving domestic violence for alternative users and outcomes
- Explore other scenarios where an officer is at risk of serious injury or fatality

Obtain feedback from advisor on different video observations

Root Cause Analysis

Problem

Law enforcement officers are getting injured on-the-job.

→ **Why:** Officers are responding to dangerous calls.

→ **Why:** There is a potentially aggravated suspect that could harm others.

→ **Why:** The suspect could have a weapon.

→ **Why:** It is easier to inflict harm on another with one.

→ **Why:** They may be upset or emotionally unstable.

Needs Analysis

Categorization of Needs

IMMEDIATE NEEDS	LATENT NEEDS	WANTS & WISHES
• Physical protection because their safety is at risk • Be aware of their surroundings because it allows them better control of a situation • Use their equipment quickly and easily because scenarios can become deadly in seconds	• Easy-to-use • Lightweight • Operable by many users • Durability • Range of utility usage	• Feel safe or secure because it can reduce anxiety • Comfort • Non-bulky

Needs Statements

The officer needs to. . .

- Communicate clearly because they need to interact with people regularly
- Feel safe or secure because it can reduce anxiety

- Have physical protection because their safety is at risk
- Be aware of their surroundings because it allows them better control of a situation
- Use their equipment quickly and easily because scenarios can become deadly in seconds

Insights Statements

1. Concern for individual safety
    - Risk of a suspect attacking an officer
    - Having to enter a dangerous situation when civilians are endangered
2. Trouble maintaining situational awareness in high-stress scenarios
    - Can be easily distracted or tunnel-visioned when in danger

Problem Statements

Problem Statement

Law enforcement can be very dangerous and put an officer's safety at risk.

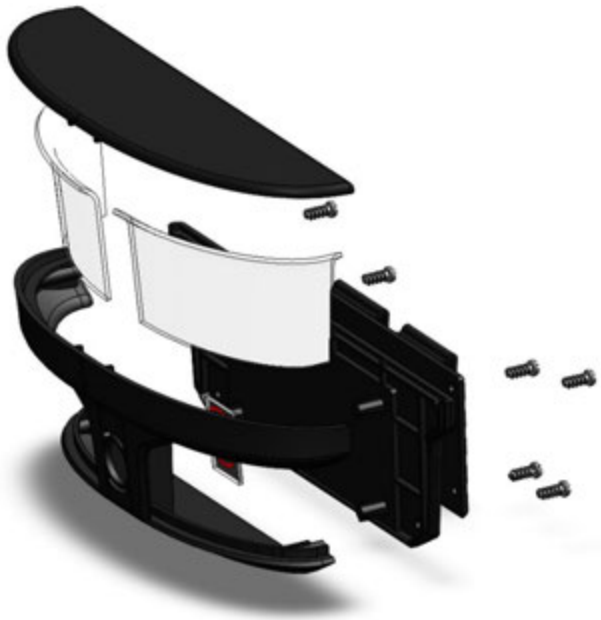
Opportunity

There is an opportunity to provide officers with more options to increase their safety and likelihood of avoiding injury.

General Solution

Easily deployable and useable device that provides an officer with more methods of communication and information gathering.

Appendix E – CAD Development

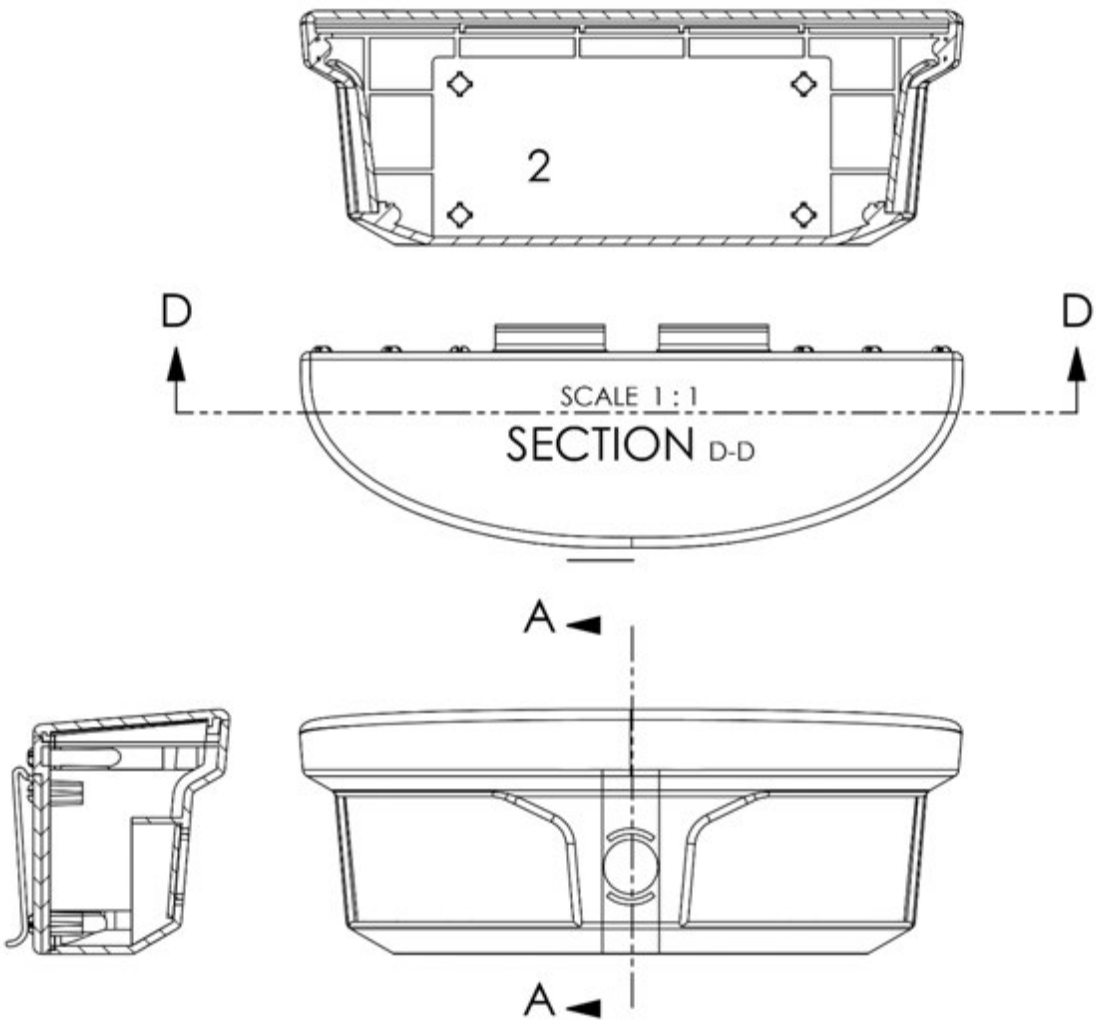


Appendix F – Physical Model Photographs


LICE


POLICE

Appendix G – Technical Drawings



Appendix H – Bill of Materials Info/Data

Referenced Items	Image	Cost
1050D Nylon Sourced locally		$19.99/yd
Neoprene (reference for Lyocell price) Sourced locally		$34.99/yd
Miscellaneous fabrics and attachments (e.g. Hook and loop) Sourced locally		See Chapter 5.2.3
Injection molding ABS (assumed mid-volume production) https://formlabs.com/blog/injection-molding-cost/		$3000/mold $2.60/part
Milwaukee Tool 100 Lumen Pen Light https://www.homedepot.ca/product/milwaukee-tool-100-lumens-aluminum-pen-light-with-clip-2-pack-/1001630143		$28
BulletSafe IIIA Bulletproof (reference for Kevlar vest) https://bulletsafe.com/products/bullet-proof-vest		USD$274.99

Smart Sleeve Wearable (reference for smart glove material) http://komodotec.com/product/aio-sleeve/		USD$159
Samsung S20 (reference for Communication Hub electronics) https://www.samsung.com/ca/smartphones/galaxy-s20/galaxy-s20-fe/		$809.99

Appendix I – Sustainability Info/Data

Everything You Need to Know About ABS Plastic

Tony Rogers on July 13, 2015

What is ABS Plastic?

Acrylonitrile Butadiene Styrene (ABS) is an opaque thermoplastic and amorphous polymer. "Thermoplastic" (as opposed to "thermoset") refers to the way the material responds to heat.

Thermoplastics become liquid (i.e. have a "glass transition") at a certain temperature (221 degrees Fahrenheit in the case of ABS plastic). They can be heated to their melting point, cooled, and re-heated again without significant degradation.

Instead of burning, thermoplastics like ABS liquefy, which allows them to be easily injection molded and then subsequently recycled.

By contrast, thermoset plastics can only be heated once (typically during the injection molding process). The first heating causes thermoset materials to set (similar to a 2-part epoxy), resulting in a chemical change that cannot be reversed. If you tried to heat a thermoset plastic to a high temperature a second time, it would simply burn. This characteristic makes thermoset materials poor candidates for recycling. ABS is also an amorphous material meaning that it does not exhibit the ordered characteristics of crystalline solids.

Lyocell properties

Fabrics qualities:

Soft
Breathable
Lightweight
Durable
Anti-bacterial
Moisture-wicking

Environmental impact:

Low impact in closed-loop processes
Eco-friendly with sustainable forest management

Drawbacks:

Complex production
Chemical-intensive
Water and energy-consuming

Environmental impact of polyester

Plastic waste, including PET bottles, is quickly becoming a global environmental and social issue.

Every year, the world produces more than 300 million tons of plastic, as reported by the United Nations. Eight million tons of plastic are dumped into the ocean annually. Less than 10% of all plastic is recycled.

If current trends continue, our oceans could contain more plastic than fish by 2050. And the plastic industry could account for 20% of the world's total oil consumption.

More than a million plastic bottles are sold around the world each minute. And the number of bottles sold yearly will increase to 583.3 billion in 2021, according to Euromonitor.

Raw material sourcing, extraction, and textile fabrication contribute massively to the disastrous environmental impact of fashion. Using recycled fibers like polyester for clothing reduces fashion's impact.

Recycled polyester water and energy savings

For each kilogram of recycled polyester fabric produced, up to 62% less energy and 99% less water are used compared to virgin polyester. Recycled polyester reduces carbon dioxide emissions by up to 20%.

To create polyester from crude oil, the oil needs to be refined first. Then, it undergoes chemical extraction.

Plastic polymers are created through polymerization. They are extruded into fibers through spinning before being spun into yarn.

The virgin polyester manufacturing process consumes a lot of energy, water, and chemicals. It also releases pollutants and greenhouse gases into the atmosphere.

On the other hand, recycled polyester removes the need for crude oil, refinery, and chemical extraction. Its fabrication requires plastic PET bottles.

Appendix J – Approval Forms & Plans

Thesis Topic Approval

IDSN 4002/4502
SENIOR LEVEL THESIS ONE AND TWO

Humber ITAL / Faculty of Applied Sciences & Technology
Bachelor of Industrial Design / FALL 2021
Catherine Chong / Sandro Zaccolo

THESIS TOPIC APPROVAL:

Student Name:	Andrew Liu
Topic / Problem Definition:	How may we improve the safety of law enforcement officers in dangerous situations?

TOPIC DESCRIPTIVE SUMMARY (Preliminary Abstract)

Law enforcement officers (LEO) face many dangerous scenarios in their line of work, leading to hundreds of officer fatalities per year in the United States alone. According to FBI statistics, many casualties and injuries are firearms- and traffic-related, with many more as the result of accidents. Some trends indicate a rise in gun violence as a cause, with other research pointing towards militarization of the police as a precursor to the rise in gun violence. From a sociological standpoint, negative sentiment towards law enforcement has also been growing due to cases of abuse of authority and civilian casualty. A literature review was completed to gain a background on police safety, while one-on-one interviews and external sources for user observation are being used for further analysis of avenues for improvement. This led to a solution for improving officer safety. Law enforcement officers perform a crucial role in helping to keep communities safe and responding to criminal activity, likewise, it is also crucial to ensure their safety as well.

Student Signature(s):	
Date:	27/09/2021

Instructor Signature(s):	
Date:	07 October 2021

Thesis Design Approval

IDSN 4502
SENIOR LEVEL THESIS TWO

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

CRITICAL MILESTONES: APPROVAL FOR CAD DEVELOPMENT & MODEL FABRICATION

Student Name:	Andrew Liu
Topic / Thesis Title:	**POLICE COMMUNICATION & SAFETY GEAR**

THESIS PROJECT – DESIGN APPROVAL FORM

Design is reviewed and approved to proceed for the following:	X	**CAD Design and Development Phase**
Comment:	- Initial CAD started reasonably as of week #7/February 22nd, continue with detailing and refinement. - Refinement and development coming along as of week #8/March 8th. - Need to get started on CAD for vest development, step-up and continue refinement and detailing. - Advised completion latest by week #9 (March 17th). - CAD completion in week #11.	

Design is reviewed and approved to proceed for the following:	X	**Model Fabrication Including Rapid Prototyping / 3D Printing and Model Building Phase**
Comment:	- Cannot approve of model fabrication until CAD development at 90% completion of all components > advised completion latest by week #9 (March 17th). - Once CAD is completed, can move forward to model fabrication from week #10 onward. - Model fabrication in progress.	

Instructor Signature(s):	Catherine Chong Sandro Zaccolo
Date:	29th March, 2022

Chong, Kappen, Thomson, Zaccolo

TCPS-2-Core Certificate

PANEL ON RESEARCH ETHICS
Navigating the ethics of human research

TCPS 2: CORE

Certificate of Completion

This document certifies that

Andrew Liu

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

N01233121

Date of Issue: **23 September, 2021**

Research Plan and Advisor Initiatives

IDSN 4002
SENIOR LEVEL THESIS ONE

Humber ITAL / Faculty of Applied Sciences & Applied Technology
Bachelor of Industrial Design / FALL 2021
Catherine Chong / Sandro Zaccolo

FTA-4 RESEARCH PLAN & ADVISOR INITIATIVES

Student Name:	Andrew Liu
Topic / Problem Definition:	How may we improve the safety of law enforcement officers in dangerous situations?

Introduction

The purpose of this research plan is to set an objective to aim for while performing literature reviews and secondary research, advisor interviews, and user observation studies. Through product benchmarking, strengths and weaknesses of existing products and solutions will be analysed to find gaps in the market. This plan will also act as the groundwork for directing further design ideation and concept development for a solution of the chosen topic relating to officer safety.

Research Plan

Elements that are being looked for in research are the kinds of products and equipment used by law enforcement officers, primarily as it applies to North America, and what common elements and key features may be important to proper and effective usage. Likewise, common scenarios that can result in bodily harm to an officer on-duty as well as the types of harm and crime committed will be determined to guide the design process to a more specific path.

This research will be performed through the internet and Humber Libraries for more academic sources related to the topic. Product pages and other review sources will be used for information regarding relevant selected products. Crime statistics made publicly available by Toronto Police Services and York Regional Police will be used for deeper analysis on violent crime and their rates based on area. User observation will primarily be conducted through available footage from officer bodycams online, and potentially through interview with an advisor on how they perceive a given scenario due to proper user observation running risk of harm to either participant or observer.

Through advisor interviews, it is planned to gain more in-depth or less common knowledge on the topic of police work and the mindset and actions done under stressful situations. Contact with an advisor will be carried out through call or email, as required.

Preliminary research analysis is planned to be finished by the **end of week 7** in order to guide the ideation and concept development stages in the following weeks. **Product research and benchmarking is complete at an initial stage**, and will be further developed as direction narrows. **Early user observation through online video** will be done by the **end of week 7** as well. A **basic introductory interview** with the first advisor has already been

1 Chong, Kappen, Thomson, Zaccolo

completed, with the aim of getting in contact with a second advisor for a more in-depth interview by the end of the month of October.

Potential interview questions listed below:

1. What is your age and gender?
2. How much experience do you have in policing?
    a. What city/region?
    b. What is/was your position/rank?
3. Can you list some common equipment that most officers have at any given moment? (e.g. weapons, protective equipment, utility)
    a. Is there anything about the equipment you just listed that you particularly like or dislike?
4. How would you describe your experience as a law enforcement officer? How does it compare to when you first became an officer as a recruit?
5. Are there any challenges that you face often while on duty?
6. What kind of crucial mistakes could an officer end up making that can cost them- or others- their lives?
    a. Are any of these mistakes common? Are they easily avoidable?
7. How do you feel about officer safety and currently available products or solutions?
8. What are some of the most common calls that police take?
9. What are some of the most dangerous calls, or have the most potential to get violent?
    a. Can you share what is going through your mind in these kinds of situations?
    b. What kinds of things are you doing in these scenarios? How are you reacting or responding?
10. Do public relation issues affect the way you carry out your job? Explain if comfortable. (e.g. negative media coverage or racial tensions)
11. Are there any experiences you have had while on-duty that stand out that you would be willing- or allowed- to share?
    a. What sort of thoughts or feelings were you having at the time?

Advisor Initiative

Currently, two advisors are planned for participation in the research portion of this thesis project. The first advisor is someone I know personally and can get in contact with when needed. The second advisor is with Toronto Police and is yet to be confirmed.

Advisor 1: Noel Brown – Police Foundation graduate, Centennial College (**CONFIRMED**)

647-822-7794 / noel_brown@hotmail.com / Availability open most days

Verbal consent given, still require signed information and consent forms as of (18/10/21), will be obtained by (22/10/21).

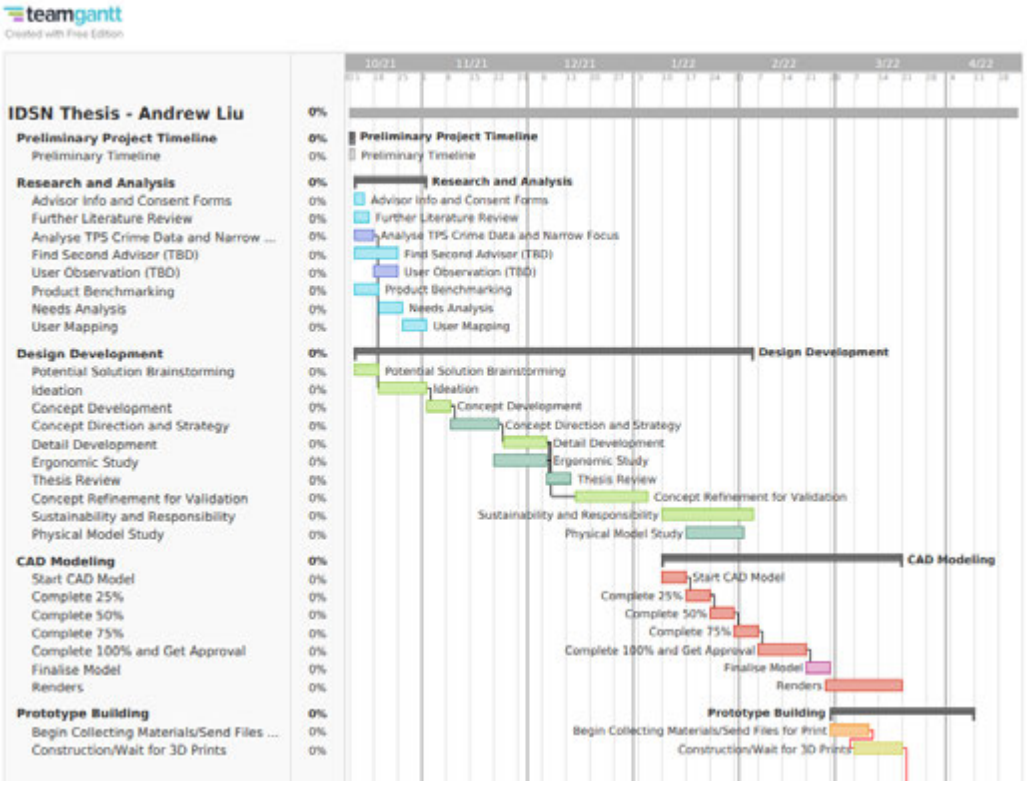
Advisor 2: Brian Moorcroft – Police Officer, Toronto Police Services / Professor, Police Foundation, Centennial College (**UNCONFIRMED**)

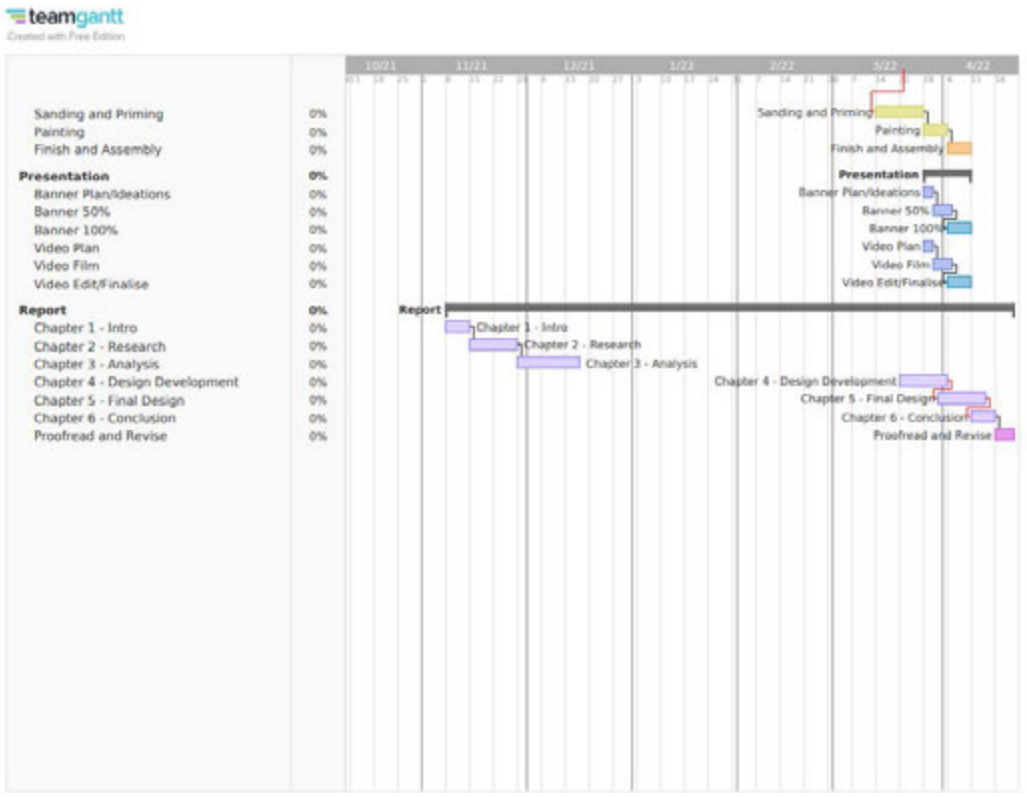
Still awaiting response and contact information via Advisor 1 as of (18/10/21). Further confirmation to be determined.

Conclusion

Through this research and advisor initiative plan, the goal is to reach a conclusion on the scenarios with a higher likelihood of officer injury or fatality, as well as potential safety risk to the public in order to direct potential design solutions down a narrower path. Furthermore, product benchmarking and user observation will be used to determine important features of products or interactions in high-stress scenarios. Advisor insights will be used to verify aspects of research or redirect attention to other important areas as needed. Together, these should aid the design process and inform a well-thought product that answers the problem definition.

Project Timeline





Appendix K – Advisor Meetings & Agreement Forms

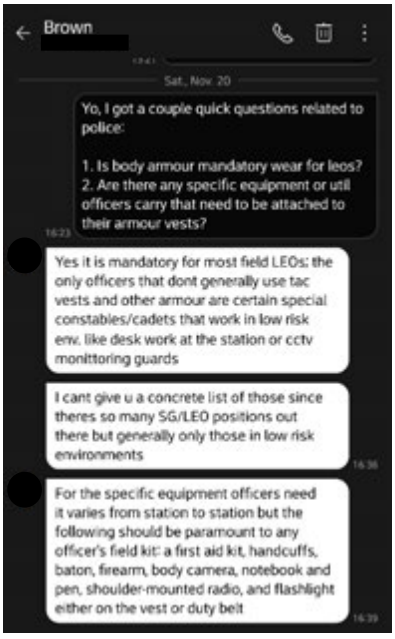
Proof of Advisor Correspondences

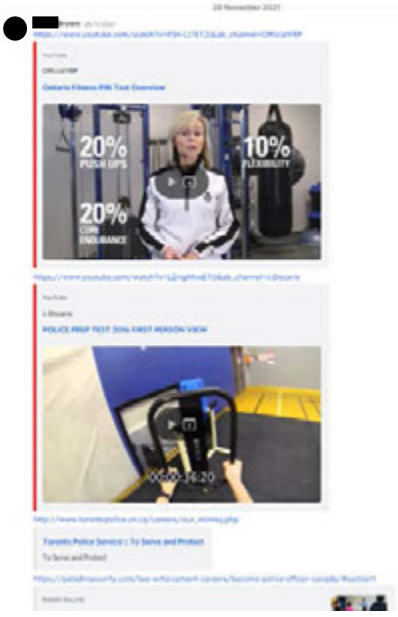
[redacted] Brown 27/09/2021
police reported crime in canada 2020 https://www150.statcan.gc.ca/n1/daily-quotidien/210727/t001a-eng.htm

[redacted] Brown 27/09/2021
summary of crime trends and changes in canada in 2020 https://www150.statcan.gc.ca/n1/daily-quotidien/210727/dq210727a-eng.htm
yrp crime report 2019-2020 https://www.yrp.ca/en/about/resources/2020_Annual_Statistics_Report.pdf
pg 38- pg 40 the breakdown of the calls that yrp gets from 2019-2020
pg 44 onwards the summary of the crimes that yrp deals with from 2019-2020

[redacted] 27/09/2021
Cool, thanks
Do you remember anything your profs told you about their mindset and thoughts during a call or when responding
stuff like that

[redacted] Brown 02/11/2021





[redacted] 02/11/2021

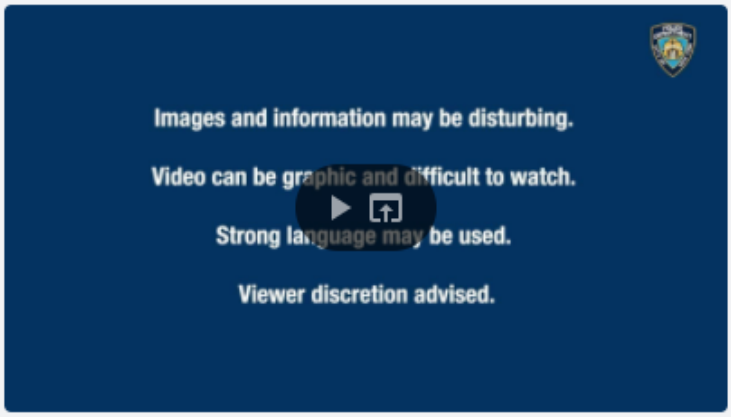
My assignment requires having an advisor or "expert" give commentary or insights based on a video user observation
In my case, bodycam footage of an incident and maybe you could comment on what the officers did right, wrong, could improve, other important notes

https://www.youtube.com/watch?v=i2wxAPelbIA

YouTube

NYPD

105 Precinct Officer Involved Shooting November 24, 2020



3:40-8:30 is bodycam from one officer and the rest is from the other pov

[redacted]Brown 02/11/2021

- officers stated that they would help clear the house with the suspect's SO (i assume) yet allow her to go upstairs on her own, unprotected

- could have had an officer maintain access control to the house at the front door so he would have been able to visually spot the suspect as he arrived

- officers responded to the shots fired as fast as they could and were able to neutralize the suspect and prevent injury to the woman, despite both being shot

- officers did not give up ground during the exchange and while the suspect was able to get close to P.O Wells, he was not able to surpass him and get close to the woman nor P.O Murphy

**before he was neutralized

- modify the previous one he was able to get past P.O Wells but he did not surpass P.O Murphy or got any closer to the woman following him getting past Wells

- im not sure how it is in new york but if it were in toronto, ideally the officers should have called for backup if there was potential for an armed suspect especially one with a gun

for toronto you call the ETF for armed shooter incidents but as the situation was still developing (and the fact that he literally pulled up guns blazing) they didnt have the time to make that call, which is the reality for a lot of police involved shootings

thats the majority of it. aside from not entirely clearing the house (i think they believed he wasnt home at the time based on what the woman was telling them), they responded to the shooting almost perfectly, since the woman wasnt shot, and they were successfully able to stop the suspect before he killed anyone

Information Letter and Informed Consent Form

IDSN 4002 / 4502
SENIOR LEVEL THESIS ONE & THESIS TWO

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

INFORMATION LETTER

Research Study Topic: Law Enforcement Officer Safety
Investigator: Andrew Liu / 416-460-8072 / andrewliu.fc@gmail.com
Sponsor: Humber ITAL, Faculty of Applied Sciences & Technology (IDSN 4002 & IDSN 4502)

Introduction
My name is Andrew Liu, I am an industrial design student at Humber ITAL, and I am inviting your participation in a research study on various problems that pertain to law enforcement officer safety. The results will be contributed to my Senior Level Thesis project.

Purpose of the Study
This study is being conducted as an aid in designing a product or other design solution that can improve law enforcement officer safety, or provide them with more options for protection. The aim is to gain a better understanding and provide insight on how an officer operates and the challenges they face to assist the design research process. This study is primarily based on understanding ergonomics, human interaction design activities, and user experience aspects of the research area.

Procedures
If you volunteer to participate in this study, you will be interviewed with questions regarding your time and experiences working as a law enforcement officer, or your experience and knowledge surrounding the topic of law enforcement. Questions will involve asking about the equipment and devices used by law enforcement, as well as the kind of work that officers take on. Your personal experience and knowledge will be a main component to this research.

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

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

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

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

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IDSN 4002 / 4502
SENIOR LEVEL THESIS ONE & THESIS TWO

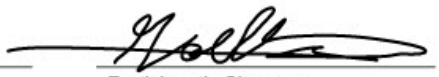
HUMBER
Faculty of Applied Sciences & Technology
Bachelor of Industrial Design / FALL 2021 & WINTER 2022

INFORMATION LETTER

Conditions of Participation

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

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

Noel Brown		2021-12-14
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: 416-460-8072

Email: andrewliu.fc@gmail.com

My supervisors are:

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

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

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IDSN 4002 / 4502
SENIOR LEVEL THESIS ONE & THESIS TWO

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

PARTICIPANT INFORMED CONSENT FORM

Research Study Topic: Law Enforcement Officer Safety
Investigator: Andrew Liu / 416-460-8072 / andrewliu.fc@gmail.com
Courses: IDSN 4002 & IDSN 4502 Senior Level Thesis One & Two

I, « insert participant's Name » Brown, Noel *(First Name/Last Name)*, have carefully read the Information Letter for the project on law enforcement officer safety, led by Andrew Liu. 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 Andrew Liu 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 principle investigator /researcher, Andrew Liu 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 Andrew Liu / 416-460-8072 / andrewliu.fc@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.

Noel Brown		2021-12-14
Participant's Name	Participant's Signature	Date

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Appendix L – Other Supportive Raw Data

Appendix M – Topic Specific Data, Papers, Publications

May 4, 2020

FBI Releases 2019 Statistics on Law Enforcement Officers Killed in the Line of Duty

According to statistics reported to the FBI, 89 law enforcement officers were killed in line-of-duty incidents in 2019. Of these, 48 officers died as a result of felonious acts, and 41 officers died in accidents. Comprehensive data tables about these incidents and brief narratives describing the fatal attacks are included in *Law Enforcement Officers Killed and Assaulted, 2019*, released today.

Felonious Deaths

The 48 felonious deaths occurred in 19 states and in Puerto Rico. The number of officers killed as a result of criminal acts in 2019 was 8 less than the 56 officers who were feloniously killed in 2018. The 5- and 10-year comparisons show an increase of 7 felonious deaths compared with the 2015 figure (41 officers) and a decrease of 7 deaths compared with 2010 data (55 officers).

Officer Profiles. The average age of the officers who were feloniously killed was 40 years old. The victim officers had served in law enforcement for an average of 13 years at the times of the fatal incidents. Of the 48 officers:

- 45 were male
- 3 were female
- 40 were white
- 7 were black/African American
- 1 was Asian.

Circumstances. Of the 48 officers feloniously killed:

- 15 died as a result of investigative or law enforcement activities
  - 6 were conducting traffic violation stops
  - 4 were performing investigative activities
  - 2 were drug-related matters
  - 2 were interacting with wanted persons
  - 1 was investigating suspicious person or circumstance
- 9 were involved in tactical situations
  - 3 were barricaded/hostage situations
  - 3 were serving, or attempting to serve, search warrants
  - 2 were serving, or attempting to serve, arrest warrants
  - 1 was reported in the category titled "other tactical situation"
- 5 were involved in unprovoked attacks
- 4 were responding to crimes in progress
  - 2 were robberies
  - 1 was larceny-theft
  - 1 was reported in the category titled "other crime against property"
- 3 were involved in arrest situations and were attempting to restrain/control/handcuff the offender(s) during the arrest situations
- 3 were assisting other law enforcement officers
  - 2 with vehicular pursuits
  - 1 with foot pursuit
- 3 were responding to disorders or disturbances

ELSEVIER

Journal of Urban Economics
Volume 124, July 2021, 103365

Police safety, killings by the police, and the militarization of US law enforcement

Federico Masera ✉

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https://doi.org/10.1016/j.jue.2021.103365

Abstract

The debate over police use of military equipment often revolves around the supposed tradeoff between increasing police safety and reducing killings by the police. In this paper, I rely on institutional features that exogenously determine the distribution of military equipment to US police departments to show that, contrary to previous evidence, there is no such tradeoff: police militarization increases killings by the police and *reduces* police safety. Each year police militarization results in 64 additional killings by the police, 12,440 police officer assaults, and 2653 police officer injuries.

NEWS

At 30 lbs., police gear more than guns, cuffs

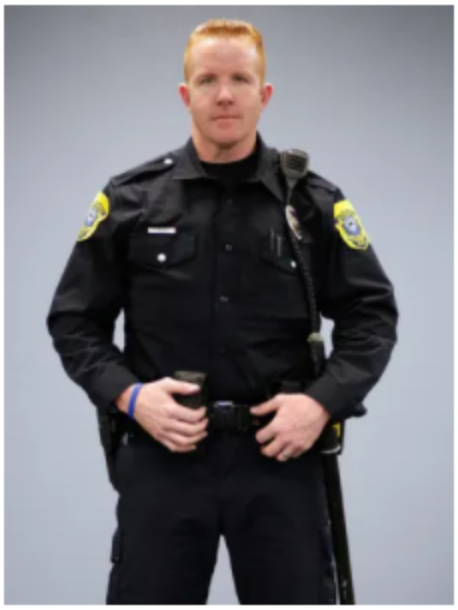
Paul Srubas USA TODAY NETWORK-Wisconsin

Published 1:34 p.m. CT Jan. 29, 2016 | Updated 1:37 p.m. CT Jan. 29, 2016

View Comments

It takes a 190-pound human to make a 220-pound police officer.

That extra weight is for all the gear a modern police officer carries.



Green Bay Police Officer Jon Nejedlo equipped with his everyday gear *Kyle Bursaw/USA TODAY NETWORK-Wi*

"It's no walk in the park," says Officer Jon Nejedlo, one of the training officers at the Green Bay Police Department. "It's probably 25 to 30 extra pounds."

Police carry a lot of gear. Police departments typically give their officers some options, but most equipment is standard. Green Bay officers carry what officers carry all around the country.

Pretty soon, Green Bay officers will also be carrying body cameras.

The extra pounds means a police officer, even a fleet-footed one, probably isn't as fast as a fleet-footed bad guy. It also handicaps an officer involved in a wrestling match with a bad guy.

It's a balancing act, Nejedlo said. You want officers to be able to catch up with bad guys, but you also want the officers to be able to do something once they get there. That means having a baton or Taser — Green Bay officers must carry one or the other or both. They also carry pepper spray, a handgun and ammunition (Green Bay police carry Glocks — either .45 caliber or 9 mm) to help subdue the crook.

There's more. A bulletproof vest. A pair of handcuffs for the crook and a spare in case he has a buddy. A flashlight. A radio with an earpiece and microphone. Keys. A recording device, in case someone wants to make a statement. Medical supplies, like rubber gloves. Business cards.

It's one of the reasons police officers are notorious for having back and hip problems, Nejedlo said.