FIREP

FIREFIGHTER COOLING SYSTEM

Kolton McConkey - April 2020

Humber College - Industrial Design

Firefighters and Heat Exhaustion

by

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Abstract

Firefighters are an essential part of the emergency service umbrella and are important members of the community. They continuously perform a dangerous and extremely strenuous job. They are subjected to the extreme heat that can lead to fatigue, muscle cramps with the possibility of losing consciousness. Heat exhaustion is prevalent in this line of work due to the heavy protective equipment worn. The purpose of this thesis is to achieve a design solution to alleviate the effects of heat exhaustion. Current protective equipment (such as turnout gear) protects firefighters from heat but is poor at dissipating it. Current solutions offer little aid in keeping the core body temperature at a controlled and comfortable level, especially for extended periods. This thesis project will provide an in-depth study of the industry of firefighting utilizing interviews, user observation, and surveys. Additionally, current training methods and skills will be analyzed to understand the entire firefighting process.

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Finally, I'd like to applaud all the brave men and women involved in fire departments, their drive to perform a job this physically demanding and dangerous is an amazing feat.

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1. Problem Definition

1.1 Problem Definition

Firefighters like many other emergency service jobs endure through tough and dangerous conditions. They are a crucial part of our emergency service teams. Inside burning houses in the heat of summer fire engulfed house can internally reach temperatures exceeding 1000°C. To keep themselves safe firefighters, wear thick, heavy turnout gear to ward off the heat. Due to these properties, the individual can become extremely susceptible to heat exhaustion, loss of consciousness or even heat stroke. These conditions are thought to be a big factor in why 45% of firefighter deaths are sudden cardiac death. Despite making up less than half of the calls in a year heat related illness account for a large portion of firefighter injuries and deaths. (Basri & Bergman, 2008) On top of that in this state firefighters are not able to perform their duty at 100% capacity.

This problem is important due to the fact that it effects almost every firefighter at some point in their careers. Heat exhaustion can be experienced due to high levels of strenuous work, this is worsened by the sheer amount of heat surrounding them. These conditions may lead to health problems further in the firefighter’s life.

1.2 Investigative Approach

To better understand the problems faced by firefighters on a daily basis the research method listed below were conducted. These approaches were undertaken to inform the design solution and follow evidence-based design development.

- Literature, Statistics and Video Reviews
- User Interviews, User Observation, User Profile
- Product Benchmarking
- Activity Mapping
- Ergonomic & Sustainability Study

Below are questions asked to Expert Users (Firefighters) to develop a better understanding of their motivations, fears and the procedures they follow on the job.

- *How would you describe the typical Firefighter demographic?*
- *What made you pursue firefighter either as a career or as a volunteer?*
- *What is the most enjoyable part of the job?*
- *Alternatively, what is the least enjoyable part of the job?*
- *What are your greatest fears while on the job?*
- *What are some of the primary equipment used in firefighting?*
- *Could you briefly describe what happens when you are called to a residential fire?*
- *Are there any points of frustration with current equipment? If so, what are they?*
- *How much of your time is spent actually fighting fire vs other calls? How much time is dedicated to searching the building and what is protocol for that task?*
- *Are there currently any needs that Firefighters have that current equipment isn't addressing?*
- *Finally, is there anything else I should know about firefighting that may not be extremely obvious?*

1.3 Background Information, History and Social Context

Firefighting is one of the major divisions in the emergency services sector. Firefighting has been around for over 2000 years. However, many of todays firefighter may contrast greatly to the firefighters of the past. With current firefighters taking on many more task outside of fire suppression, the job has become an increasingly important job within communities. Firemen currently carry out task such as fire suppression, medical aid, car extrication, search and rescue, etc. (City of Toronto, n.d)

Over the years the firefighter workforce has changed dramatically. In the past decade the more women have started to be involved within the workforce. There has also been a major change around the type of firefighters working at the stations. In its current state it is more common for small community fire stations to rely mainly on volunteers as oppose to career firefighters. (Haynes & Stein, 2016) This economic change has led many stations to only have one or two careers firemen; which are typically the Fire Chief and Deputy Fire Chief. On top of most firefighters being volunteers it is becoming increasingly difficult to retain the services of those men and women. It’s hard for people with full time job to continually give their time to the service. As much as they may want to help their community it is just not always financially viable.

Due to current technological advancements firefighting gear has become extremely durable and more lightweight. Despite this fact, most of the actions taken to rehabilitate firefighters suffering from heat exhaustion are still done post suppression.

The following chapter will examine the primary, secondary and tertiary user of the proposed design solutions as well as product benchmarking.

2. Research

2.1 User Research

User research remains at the center of the practice of Human Centered Design (HCD). The HCD methodology relies on the designer(s) to examine the product user in great detail to have a better understanding of what they do and why they do it. This will also focus on the needs of the user in relation to the use of said product. By examining the target user, the designer is ensuring that the product they are producing is useful to the user as well as purposeful. By designing products that align with users' needs we are capable of producing a product that has a meaning and purpose; a product that serves the user greatly.

The goal of this module is to:

- Determine the target demographic for this product
- Examine potential user behavior regarding this product
- Create a user profile based upon findings
- Pinpoint a primary, secondary and tertiary user for this product
- Develop a user persona to represent the average user of this product

Methods:

A Google Image Search was performed to understand what typical firefighters look like. As firefighters wear equipment that covers their faces group photos were primarily used. A literature search was also performed on the Humber Library website and Google to find statistical and behavioral data relevant to firefighters.

2.1.1 User Profile/ Persona

Gender and Age:

After conducting an image search it appears as though the majority of the firefighting workforce is of the male gender. This has largely been the norm in this industry for the last few decades. However recently more and more women have been taking up firefighting, predominantly at the volunteer level. (NFPA, 2016) Age as seen in the image research was quite diverse with some firefighter appearing to be young adults in their 20's to older men in their 50's. However similar to the images the average age hovers around the late 20's to early 40's.

Race & Ethnicity:

the predominant ethnicity among firefighters is shown in demographics as being White (Caucasian) which make up just over 80% of firefighters. With Black (African American) being the second most prominent Ethnicity.

Education and Income

For firefighters the minimum education requirement to apply for a firefighting position is to obtain at least a high school diploma. As there is not very many statistics on firefighter's career paths it is difficult to put a number on the percentage of firefighters that pursue secondary education. However, it could be deduced that due to the current job landscape that many volunteer firefighter would possess a post-secondary diploma or degree of some sorts. In terms of income Firefighters wage distribution is much more evenly spread out across the board than the average job in the US. With the majority of the earning coming in at between the $40k to

$70k bracket. Although this data is just for firefighters, Fire Chiefs can earn close to $100k (Data USA, 2017)

Based on the images search we get a general overview of who is working as a firefighter and what they look like. From this research it can be observed that the typical firefighters appear to be between the ages of approximately 21 to 45. It is also apparent that the overwhelming majority of firefighters are of Caucasian ethnicity. In these instances, the income is a harder statistic to infer as there is really no factor to base that on. An education level of at least a high school degree is required for the majority of Fire Departments applications. College education was inferred on some occasion where there seemed to be more career firefighters. It was deduced that these fire departments were predominantly staffed by volunteers with a few individuals being career firemen. With the statistical data in front of us, it's clear to see that the images portray a realistic view of the “average” firefighter.

2.1.2 Current User Practice

Activity Frequency:

Firefighters must respond to a number of different calls ranging from structural fires, medical emergencies, non-emergency calls and car crashes. They perform a lot of tasks becoming more of a jack of all trades in the past few decades. As an example, the Toronto Fire Services saw a 6.84% increase in medical calls in 2017 compared to 2016. In the same year there was also a 12.53% increase in hazardous material calls. (Toronto Fire Services, 2017)

Social and Lifestyle

Due to the cooperative nature of the job firefighters must be very vocal with their partners/ squad. In Fire Academy recruits are told that cooperation is essential to the success of their job. This skill is stressed heavily throughout the training. (South Metro Fire Rescue, 2019) Over the past couple years however the scene at fire departments has been shifting. With less and less people becoming career firefighters the force has transitioned to being primarily volunteers. With around 83% of Canadian firefighters being volunteers in 2016 there has been a big change in department dynamics. (NFPA, 2016) Firefighters are extremely active people; they spend a lot of time exercising and performing cardio while at the fire hall or during their everyday life. Even though being in good shape is a crucial requirement of being a firefighter many of them take pride in their health. To this point many have active hobbies they enjoy participating in on their time off.

Income Level:

Due to the fact that many firefighters currently working are volunteers it is difficult to determine an income level for them. As it is volunteering the people performing this job come from all different sectors of work that they perform outside of firefighting to earn a living. Despite the title of Volunteer some stations may pay a volunteer for their time spent training, performing hall duties. They will however not be paid for time spent on call which they are on 24 hours, 7 days a week. Despite this, volunteer only respond if they absolutely can commit to the time.

Location:

Most towns and cities have a fire department located within close proximity to serve the local community or communities around it. Canadian departments that consist of predominantly volunteers tend to serve communities of less than 50,000 people. Alternatively, the larger communities and cities are more often than not served by stations with a large number of career firefighters. (NFPA, 2016)

Demographics		User Behavior		Personality		Cognitive Aspect	
Age	20-50	**Frequency of Use**	On Call 10-25 times/ month	**Locus of Control**	↑	**Technical Skill**	↑
Gender	Predominantly Male (~95%)	**Duration**	Varies N/A (20 mins to x hrs)	**Self-Efficacy**	↑	**Pre-Required Knowledge**	↑
Ethnicity	Caucasian (+80%)	**Social**	High-Social	**Changeability**	-		
Income	Middle Class ($40,000 to $80,000)	**Level of Focus**	High	**Uncertainty Avoidance**	↑		
Education	High School Diploma	**Location**	Residential – Rural/ Urban				

Figure 1 - Primary User Profile Summary

Primary User	Firefighter
Secondary User	Victim of fire/ Homeowner
Tertiary User	Fire Department/ Fire Squad

Figure 2 - Primary, Secondary and Tertiary User

User Persona:

Name: Steve Malone

Age: 37

Occupation:

Income: $65,000/ year

Education: Bachelor's Degree - Marketing

Relationship Status: Married, 2 kids

Location: Innisfil, Ontario

Career/ Volunteer: Volunteer

Years of Service: 12 as a Volunteer

Social: Works with 23 other Volunteer Firefighters

Frequency of Activity: Responds to approx. 10 calls/ month

Hobbies: Strength Training, Biking, Wood working, Swimming

Figure 3 - Country Images Bodie Greiner [Image] (2016) Retrieved from https://countryimages.smugmug.com/Stock-Images/People/Temple-Fire-Portraits/Firefighter-Bodie-Greiner/i-gP76b9R/A

Profile:

Steve Malone is a 37-year-old Caucasian male. He attended university to receive his bachelor's degree in Marketing. He earns a yearly salary of $65,000 and is a 12-year volunteer at Innisfil Fire and Rescue Service. Steve began his volunteering career at 25 a few years after working a steady job. He prides himself in keeping his community safe. Steve lives an active lifestyle while trying to stay on a healthy diet.

User Behavior:

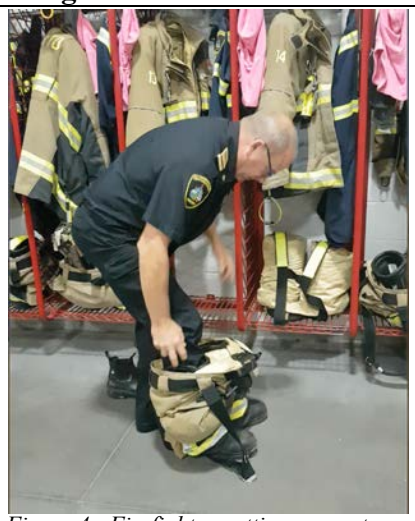
Steve responds to calls whenever he can and is fully available. Despite not needing to attend every call he tries to respond to the better part of them. He attends call roughly 10 times per month. At his department the majority of the people are volunteers, so they don't see each other very often but have built good friendships from their teamwork. Steve enjoys surrounding himself with these people as they are all in the position for the same reason, to serve their community.

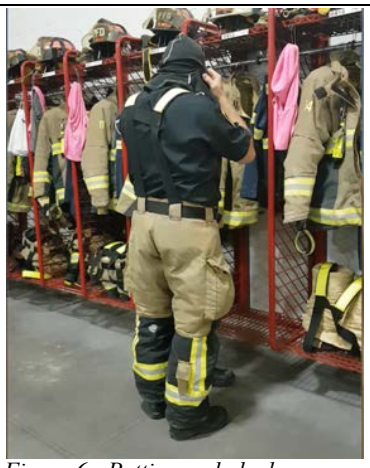
Steve's Relationship to his PPE:

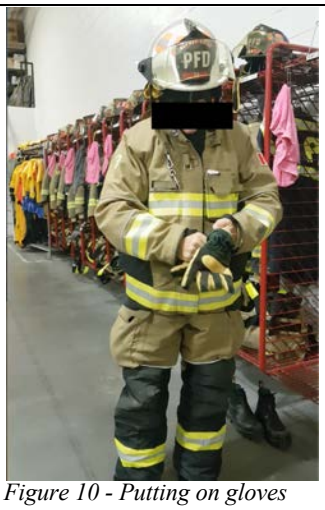
Steve received his set of PPE when he first joined the department at the time the gear was mid-grade at best. However recently his department has been updating all their gear and has gone with high end gear for all firefighters. As his department policy reads all fire gear is custom fit to the user so Steve has no trouble moving around in his turnout gear. Over the years Steve has grown accustomed to the way fire gear fits and feels. Moving around has become second nature. He is able to put it on in a moment's notice with everything securely fastened. As the town of Innisfil covers the purchase of all the PPE Steve doesn't have to spend anything out of pocket.

2.1.3 Activity Mapping

The following table below showcases a firefighter donning his turnout gear at the fire station. This is an activity that is performed for almost every type of call that comes in regardless of the severity. The firefighter can be seen putting on all his gear, without the SCBA gear in the order he would in the event of a call.

Step	Action	Description	Image
1.	Putting on Turnout Pants with boots	The firefighter starts off by putting on the pants/ boots combo. This is a fairly quick and easy action which doesn't require much effort. **Note:** Not all turnout gear has boots attached to pants	 *Figure 4 - Firefighter putting on pants*
2.	Securing Straps and clasps	Once the pants/ boots are on the firefighter must ensure the straps are correctly tightened. This is done by pulling down the straps to adjust the fit. At this point the fireman will also make sure all snaps and clasps are securely fastened. **Note:** Turnout gear is almost always fit to the firefighter. The straps adjust the fit on to a small degree.	 *Figure 5 - Securing the pant straps*

3.	Putting on balaclava	To keep the neck area safe from the fire Firemen put on a balaclava under their helmet. Similar to the pants this action is quick and simple, requiring little effort.	 *Figure 6 - Putting on balaclava*
4.	Putting on Turnout Coat	One of the most important aspects of the turnout gear is the coat. The coat is put on like any other zippered jacket and is easy to put on.	 *Figure 7 - Putting on Turnout Coat*
5.	Zipping up Coat	To make sure the body is completely sealed off from the heat the fireman zips up his jacket all the way up. This is surprisingly one of longest part of the entire process.	 *Figure 8 - Zipping up Turnout Coat*

6.	Putting on Firemen Helmet	After all the soft gear is on, one of the final steps is putting on the fire helmet.	 *Figure 9 - Securing Firemen Helmet*
7.	Putting on Gloves	The final step to the fireman's gear is to put on the gloves. It is important to note that while putting on the turnout gear is not necessarily difficult it is extremely heavy and not very breathable. At this point the firefighter is already starting to get hot without expending much energy.	 *Figure 10 - Putting on gloves*

User Experience Map + Targeted User Experience

The chart below represents the current user experience of donning of Turnout and SCBA gear. Additionally, the targeted user experience has been added to showcase the desired outcome for the User Experience the Targeted areas are predominantly contained within the SCBA actions where the task has many steps with a few awkward reaching actions. Actions such as turning on and off the cylinder valve and tightening the harness straps.

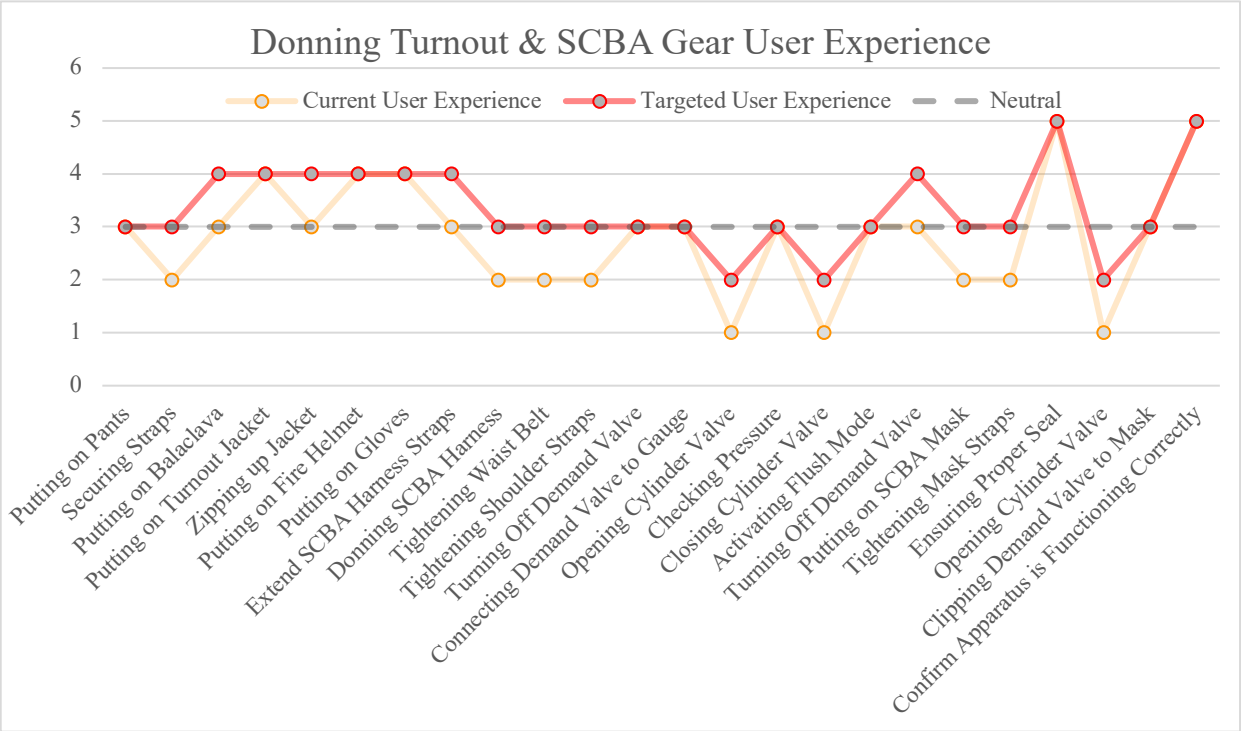


Figure 11 - Current vs. Targeted User Experience

In terms of key areas that informed design opportunities would be in the areas of wearable technology to be put on at the same time as the turnout gear. A secondary area is in the overall build of the suit. It may be possible to create a unibody suit to cut down on the response time. The third area would be within the process of donning the SCBA gear, with the specific step by step requirements.

2.1.4 Ergonomic Research

Typical firefighter equipment such as turnout gear is more often than not tailored to the specific person. If not, the gear comes in many different sizes like one would find in a traditional retail store. Seeing as there are many different people who take on firefighting the gear is offered in mens and womens sizes with a wide range of options. Existing cooling solutions such as vests offer direct body cooling but feature a large liquid cooler. Thus, making this item mainly used

post suppression. This being said firefighters face ergonomic difficulties on the job, such as small spaces and limited mobility. The image below notates ergonomic considerations with regards to two existing products.

Figure 12 - Ergonomic difficulties in existing products

As seen in the above image there are two main issues largely related to mobility and range of motion. On one hand with turnout gear due to its overall bulk it somewhat restricts the range of motion. This issue is intensified if the gear does not fit properly. This could be seen at departments where used gear is given to firefighters due to financial limitations; meaning their gear may not fit the individual perfectly well. This issue can also be seen in existing cooling rehab products. The example shown above demonstrates a cooling vest that uses an external cooler. Having this large cooler mean this cannot be used in action and is more of a post suppression product.

2.1.5 Safety & Health Research

In a field like firefighting there is an aspect of danger present on almost every call. Like many other emergency service workers, the task of firefighters is to face the dangerous environment to aid the people of the community. As firefighter are not only responsible for their own safety but the safety of everyone around them, making them an important part of the communities they serve. On the job firefighter are subjected to some of the following dangers:

- Burns and heat related illnesses (Heat Stroke and Heat Exhaustion)
- Smoke and other toxic gasses
- Physical Injuries
- Explosions
- Contact with hazardous chemicals
- Cancer Risk

Aside from dangers faced by firefighters there are associations and standards that have been put in place to help keep firefighters safe and alive while performing their jobs. All firefighters are required to attend training prior to beginning the job.

2.2 Product Research

The following chapter will focus on conducting benchmarking for product currently being used in the field of firefighting. This research will look at various areas of product benchmarking including features and benefits, functionality, aesthetics, materials, manufacturing as well as aspects of sustainability. Benchmarking will aid to understand what is already out there and determine the needs these products are trying to fulfill.

2.2.1 Benchmarking – Benefits & Features

Within the field of firefighting there are many different tools and equipment used by the department to successfully perform their job. Doing everything from responding to medical call, to handling non-emergency situations, to car crashes and structural fires. The following product XY graph was created to find a design opportunity focusing on professional gear or apparel.

Figure 13 - XY Graph comparing professional gear

The graph makes the distinction between 9 existing products used in professional practices currently. The products are placed according to their price and their performance in high heat situations. Looking at the graph it can be observed that there is a potential design opportunity within the more affordable price point, with gear offering more heat protection that regular product in that price range. After conducting features and benefits benchmarking research a frequency analysis was performed. This was done to observe the most common keywords used in promotional materials for the above products.

Key Features of Comparable Products	
Key Features	*Frequency*
Garment Accessories	132
Fabrics	56
Standards/ Regulations	18
Thermal/ Moisture Barrier	16
Stitching/ Construction	11

Key Benefits of Comparable Products	
Key Benefits	*Frequency*
Mobility/ Ease of Use	60
Protection/ Durability	37
Breathability/ Ventilation	28
Comfort	19
Heat/ Flame Resistance	16

Figure 14 - Features & Benefits Frequency Analysis Results

Above is the results of analyzing the 9 professional gear apparel products shown above. In terms of benefits the keyword appearing most often was “mobility” or some variation of that. With the thickness and weight of some EMS gear it’s easy to see why mobility would be so important, given the job they must perform. With features the top keywords mainly related to garment accessories such as pockets or handwarmers. This is an interesting discovery as pockets, and such seem to be an aspect that can be overlooked.

2.2.2 Benchmarking – Functionality

Firefighting gear is all quite different when looking at it from a functionality standpoint. SCBA gear provides the firemen with oxygen during his job to ensure he can safely enter a burning building filled with carcinogenic smoke. Other products such as the haligan and the hatchet typically are used as forcible entry tools or as a means of venting a structure. This in term allows other crew members to find trapped individuals more safely. Turnout gear is also a good example as it is mainly meant to act as a heat barrier, protecting the wearer from the extreme heat thus giving them the ability to come in close proximity to the blaze.

Looking at heat exhaustion there are numerous solutions to the problem post suppression but not very many for during a fire. A design solution for this problem could not only include a cooling module but contain other components to aid in faster and more efficient fire suppression.

2.2.3 Benchmarking – Aesthetics & Semantic Profile

Firefighting has been around for a long time and at this point their image has become iconic. Firefighters are some of the most recognizable people you will see. Every knows or has an idea what a firefighter looks like they have donned the same sort of aesthetics for ages. Refusing to abandon the tradition of the firefighter look, things like firemen helmets have not had many changes stylistically. With the classic firefighter colours of red, yellow, black, beige and white there is not many objects within this sector that do not make use of these colours. Current gear specifically the turnout gear and helmets still appear quite traditional. However, in recent years a few manufacturers have begun to produce helmet with a more modern and streamlined aesthetic.

Due to these tendencies it is perhaps beneficial to avoid any styling that strays too far away from the current or traditional look.

2.2.4 Benchmarking – Materials & Manufacturing

With the rapid advancement of technology many areas of the firefighting field have dramatically improved. Switching from steel oxygen tanks to carbon fiber has made a drastic different in not only the performance of the gear but the performance of the user. Designing gear to be lighter than ever to aid in keeping firefighters physically healthier and safer. Many of the products used today are very much just material improvements on design that have proven to be successful. An example of this can be seen with turnout gear, the style hasn’t changed very much but there have been significant changes in regard to material. In a field like firefighting with the extreme heat many of the products used must be able to withstand the high temperature. Due to this the most common materials being used in the field consist of:

- Engineering Plastics
- Carbon Fiber
- Steel and aluminum
- Kevlar and Nomex and 3M Scotchlite
- Glass

With this in mind it is important to remember the dangers of making use of materials that aren't suitable for this dangerous environment. Despite the fact that these materials are used extensively, there is also the possibility of making use of new material technology. So long as the new technology makes sense within the realm of the intended design solution.

2.2.5 Benchmarking – Sustainability

Of all the product shown above only a select few have shown to have sustainable manufacturing in mind. These products also correlate to the product that aren't related to firefighting. In terms of the turnout gear, looking at the offerings from brands like MSA and Globe, the number one priority is protection. Given the environment of use of firefighter gear things such as turnout gear, boots, helmet and accessories need to withstand the heat first and foremost. Many of these product use materials such as Kevlar and carbon fiber which technically can be recycled however the process is much more labour intensive. That being said if we look into manufacturing the majority of turnout gear is sewn or welded together meaning it isn't creating large amounts of CO2 emissions. The problem comes from the sourcing and production of these high-performance fabrics which are much more harmful.

2.2.6 Interview Results

The following sub-section contains results from Expert User interviews. These users we're interview given their vast amount of knowledge in the field of firefighting. The questions asked we're to understand how the users what they do, how they do it and why they do it. The objective of these interviews was to gain a better understanding of the people that engage in this profession.

The expert interviews were conducted online via the social forum of Reddit. This platform was chosen as it has a wide range of users from many different backgrounds. A general message was posted on the r/Firefighting subreddits to find user with experience specifically in firefighting. Two users were private messaged to conduct short text-based interviews. The following key points were derived from the two interviews.

Key Points:

a. The fact of incorporating technology when it is not needed is quite interesting. This point seems to be very important as if technology is added to something it's just one more thing that can go wrong. It would also require a specialized technician to repair.

b. Thinking about the way people live is a good point, not everyone's house is spotless. In some instances, residents may have items in their house that create a great danger to the firefighters if exposed to fire. This could also greatly increase the time it takes to search a house due to these obstacles.

c. Realizing that volunteers are doing this job out of the goodness of their heart is quite an important distinction. These people are not being paid to do this and seems that in some cases are paying their way through it. Due to it being professional gear fire fighters gear is not cheap and quite a large sum of money to pay for individuals.

d. Realizing that firefighters are not entirely sure of the situation they are going to be put in seems quite significant. They have to worry if something may happen due to the situation being much worse than they might have anticipated. Although this plays more to the emotional side of things, there may be a way for design to aid in mitigating the fear and anxiety of facing the unexpected.

e. It's interesting to note just how much analysis is done before the crew even attempts to enter the building. Realizing that there is not a "one size fits all" approach to firefighting. That different situations require the crew to adapt their process.

f. There is an entire crew of people working to extinguish a fire and it's not just the ones doing the house search and rescue. There are areas beyond the primary and secondary rescue firefighters that could also experience difficulties in design could aid and improve the process overall.

3. Analysis

3.1 Needs Analysis

The following chapter takes a look into the primary users' needs and how to best meet them through an improved design solution. This chapter will make use of the data collected in the previous chapter of user and product research. To build upon a solid foundation for creating a successful design solution.

3.1.1 Needs/ Benefits Not met by Current Products

Current products in the field of firefighting perform the job well and serve their purpose. It goes without saying that there is always room for improvement within this product category. Firefighter PPE is rather heavy and thick, resulting in the lower garment breathability. This results in the user exerting far more energy while elevating their core body temperature. The following table showcases the four most important category of needs in terms of fireman PPE. This table list under the categories areas of improvement to be considered when further developing the proposed design solution.

Needs	Benefits
Safety	• Monitor firefighters' vitals to allow for maximum crew accountability • Reduce amount of physical exertion needed to perform tasks • Provide superior protection to carcinogenic exposure
Comfort	• Allow for body temperature regulation • Create a good body fit to ensure proper • Allow for maximum range of motion as to not limit or impede movement
Efficiency	• Smoothly integrate into current turnout gear donning process • Utilize reliable technologies to minimize repair/ down time • Integrate communication to allow seamless line of contact between crew
Style	• Embracing a more modern aesthetic, while honoring traditional aspects • Ensuring proper and strategic use of high visibility material

Table 3.1 – Needs/ Benefits Identified

3.1.2 Latent Needs

Needs	Fundamental Human Need(s)	Relationship to Benefit
Health/ Safety	Physiological, Safety, Esteem	Strong
Comfortable/ Ergonomic	Physiological, Safety, Esteem	Strong
Efficiency	Safety, Esteem	Strong
Appearance	Esteem, Love/ Being	Moderate

Table 3.2 – Benefits Evaluation

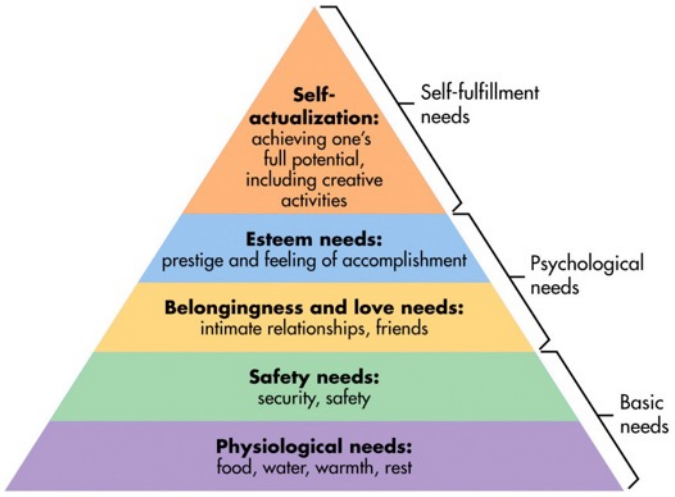


Figure 15 - Maslow's Hierarchy of Needs. [Image] (2018) Retrieved from https://www.simplypsychology.org/maslow.html

Health & Safety

Health and safety are of utmost importance in the field of firefighting. Ensuring that all the member of the crew make it out of the fire unharmed is a top priority. Firefighters face plenty of dangers within a fire not limited to collapsing structures, carcinogens, cardiac trauma. A user's sense of safety is essential to them completing the task at hand. Although it is hard to always

ensure safety within the environment of use, especially a structural fire. There are many ways to keep firefighters safe through use of products.

Comfort

A firefighter's comfort will enable them to comfortable move around the fireground freely. Most of the gear a firefighter wears are close to a custom fit making it easier for them to wear. Seeing as they wear their PPE to almost all calls requires them to have something that does not impede movement or restrict them in any way.

Efficiency

In situation like structure fires, timing is crucial. Responding to emergency calls within a moment's notice could be the difference between life or death. By seamlessly integrating a new product into the donning process the firefighter's ability to respond to calls would not be impeded. By including features necessary for the job, firefighters could more efficiently tackle fire suppression and search and rescues.

Appearance

Although appearance isn't as high a priority it still deserves attention in the design solution. Creating a product that resonates with firemen and that they are proud to wear is essential to it become a staple product within their process. Firefighters are very present figures within a community and a good appearance appeals to the crew's self-esteem.

3.1.3 Categorization of Needs

This thesis project is concerned with aiding firefighters on the fireground by alleviating problems faced in actions. To do so the areas of focus are based on the physical safety, comfort and overall efficiency of a firemen. These areas have been determined from the research

conducted in chapter 2 of this report. The list below places the users' needs into three categories of immediate needs, wishes/ wants and latent needs.

Immediate Needs

- Efficient Heat Protection
- Easy donning & doffing
- Effective body temperature regulation
- Improved visibility in smoke and other low visibility situations

Wishes/ Wants

- Lightweight
- Comfortable fit
- Sufficient tool storage
- Highly durable

Latent Needs

- Simple procedures, no added unneeded complexities
- Easy to clean/ sterilize
- High Visibility elements
- Aesthetically appealing

3.1.4 Needs Analysis Diagram

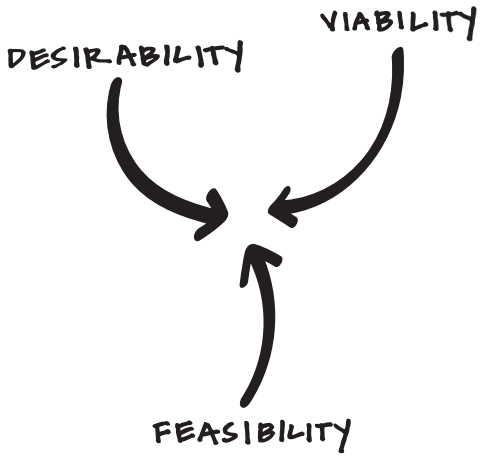


Figure 16 – IDEO Design Thinking. [Image] Retrieved from https://designthinking.ideo.com/

Desirability

Many organizations (such as the NFPA) within the firefighting community have been searching for the best protocol surrounding mitigation of heat stress/ heat exhaustion. Year after year there have been changes and suggestions made to improve upon the protocols. As of yet the only such solutions exist post-suppression. A solution for heat exhaustion mitigation mid-suppression would be of great value to aid in alleviating symptoms associated with heat related issues.

Viability

Due to the fact that fire departments are constantly trying to improve their suppression process it seems like a step in the right direction to implement new tech into PPE. Ensuring that crew members are performing their job in a safe manner is one of the most important aspects in a job such as firefighting. Although the design solution of this thesis is mainly concerned with structural firefighting the same solution could also be viable in the field of wildland firefighting.

By giving the crew more tools to keep them safe and comfortable they will be able to complete their task more efficiently and successfully.

Feasibility

Firefighter PPE has gone through a fair amount of evolution and changes over the years. New materials and technologies have been implemented to create better and more efficient products for the job. Given that the materials and technologies implemented into this thesis project are suitable for the time being. Meaning the product is not too high tech to the point where it becomes unreliable and inconsistent. It seems perfectly feasible to move the product segment forward.

3.2 Functionality

3.2.1 Activity/ Workflow Mapping

To gain a better understanding of the process of firefighting, videos sourced from YouTube were used. The videos have been compiled; the list below is a summary of the structural fire suppression process. The steps highlight areas of actions into bigger portions. Depending on the situation action order may be different.

Steps	Key Points
1. Donning Turnout Gear/ SCBA gear	- This activity is to be performed in a time efficient manner. (Roughly 2 minutes for Turnout gear + SCBA) - Depending on the station protocol/ equipment SCBA gear may be donned at the same time - This action must be completed properly to ensure complete protection from heat
2. Entering Fire Tanker	- This step is fairly simple however uses a little bit of physical exertion - At this point the firefighter is already beginning to heat up - Turnout gear may slightly impede movement

3. Driving to Fire Call	- Driving to the call is usually and easy task - With all their gear on body temperature may begin to rise - Certain fire tankers may have A/C
4. Exiting Tanker	- As with entering the tanker there is not a lot of physical exertion required - Movement slightly impeded by turnout gear
5. Putting on SCBA Gear	- SCBA gear takes roughly 60 secs to don - Must follow correct steps to ensure proper seal and connection - Turning demand on and off requires awkward reaches behind the back
6. Gathering Tools	- Most tools are organized on the side of the tanker in their own compartment - At this point the firefighter gathers what they believe they will need - Attack lines are also deployed at this time from the side of the tanker
7. Entering Structure	- Depending on the situation this process can be easy or difficult. If forcible entry is required, more energy is exerted - Firefighters may also use chainsaws and other power tools to enter to expend less energy
8. Search & Rescue	- This process is extremely important looking for anyone that could be trapped inside - Due to smoke, it may be hard to see - Firefighters depend on their sense of touch and hearing in time of low visibility
9. Fire Ventilation	- Ventilation allows smoke to clear out of the structure to increase visibility and reduce concentrated heat - This is done with manual tools or power tools depending on the materials and area
10. Fire Suppression	- Using the attack lines firemen drag the hoses to the most efficient positions - Using a line typically requires more than one person to handle the pressure of the hose
11. Rehabilitation	- A crucial step in ensuring the firefighters are safe, cooling them down and addressing medical concerns - This is typically done via external products such as rehab stations or cooling gear

Table 3.3 - Activity Mapping

3.2.2 Activity Experience Mapping

Firefighter PPE currently aids firefighters by shielding them from the dangers of a fire. Keeping them safe from the heat and falling objects. As seen with turnout gear there is the limitations to its breathability; this in terms causes the users body temperature to rise dramatically in a short period of time. Combine this temperature rise with extreme physical exertion and the firefighters are in danger of suffering from heat stress/ heat exhaustion.

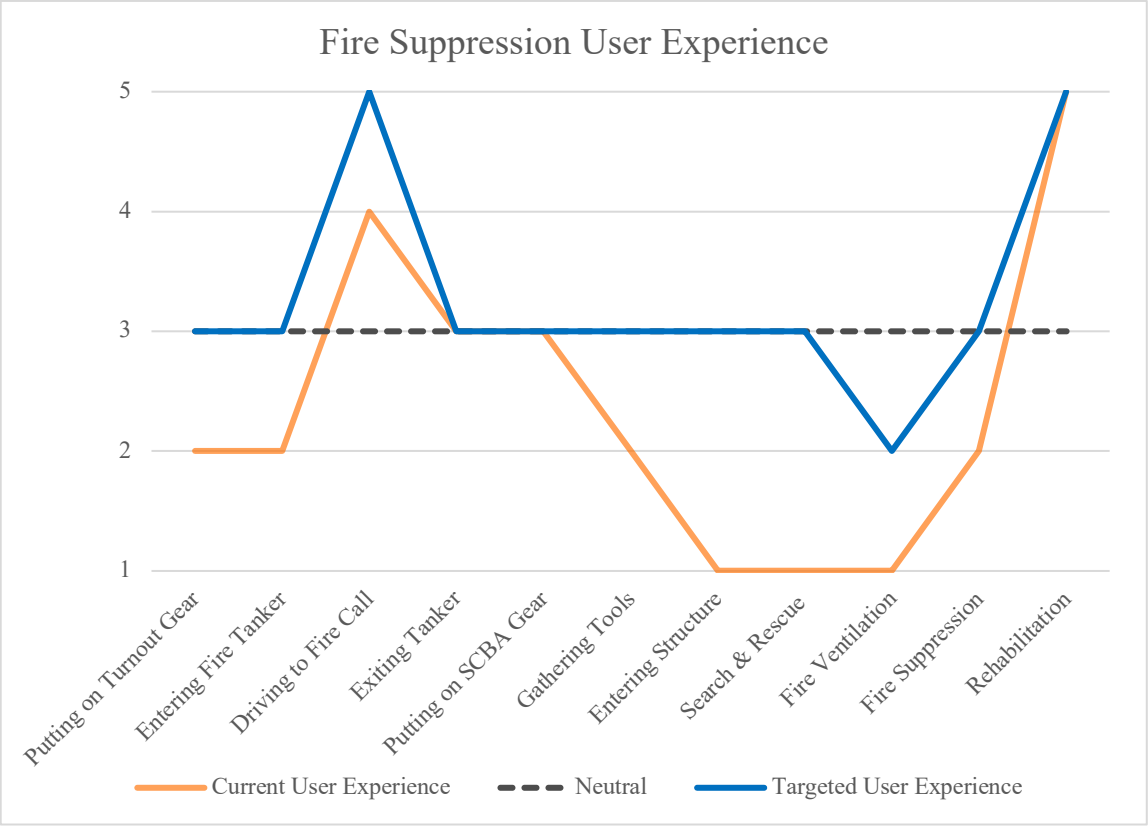


Figure 17 - Current User Experience vs. Targeted User Experience

As demonstrated by the graph above the key areas where improvements are targeted fall within the fire suppression and search/ rescue activities. These areas are significant as they are where the firefighters are exposed to the extreme heat and physical exertion. The second area of

importance would be in the lead up to an emergency call. Allowing the firefighter to stay cool during donning their gear and driving to the fire.

3.3 Usability

3.3.1 Introduction

The following report evaluates the selected design configuration based on an ergonomic observation using an ergonomic buck. The report focusses mainly upon the interactions of the firefighter entering a structure fire (Primary User). The most important aspect was determining an appropriate size to accommodate for proper user movement and full range of motion. The interaction, experienced with the following configuration focuses on the head, upper body and legs. Thus, ensuring three touch points for full body human interaction.

3.3.2 Literature Review

For this report the book: The measure of man and women by Henry Dreyfuss was utilized. This book was referenced in terms of the critical dimensions regarding a user's torso, head and legs. The measurements referenced were taken from the 5th percentile and 90th percentile males. Other references were observed, such as a study undertaken to obtain anthropometric data from US firefighters for apparatus design.

3.3.3 Methodology

The configuration used for this assessment took the form of a family of products. Making use of three touch points: the head, torso/ back and the legs. The configuration features a helmet,

a pad located on the chest and back; both are attached to the firefighter's pant suspenders. This was done to allow the product to be removed if needed. As well as a pad located on the front of the thigh. These components are used to regulate the firefighters body temperature; keeping them at a safe and comfortable temperature. To mimic the use of turnout pants the users wore snow pants. This allowed for positioning of the suspender straps to be determined.

3.3.4 Objectives

The goal of this ergonomic report/ exercise is to determine a suitable experience for users of the 5th percentile and the 90th percentile. The experience observed two users wearing a cooling system made up of three different parts.

3.3.5 Projected Target User

The targeted users in this report are the primary users outlined in section 1 of the Thesis report. Meaning this report is mainly looking at ergonomic considerations for structural firefighters. These are the people that would be entering into a building. They would be performing a search and rescue while also aiding in fire suppression tasks. However, this device may also be used by firefighters, outside of the structure. Due to there being little difference between the two aside from the tasks they are performing. It was noted during an earlier interview with a local fire chief that all gear provided to firefighters is near custom fit. Due to this the gear they wear comes in a variety of sizes instead of a one-size fits all.

3.3.6 User Environment

The user environment in which this configuration was tested occurred indoors. However, the environment in which this product would actually be used would be hard to replicate due to the extreme heat and damaged surroundings. The users were photographed in the front and side/ three quarter views. To mimic the apparel of a firefighter both users wore snow pants to simulate the thickness and suspender position of turnout pants.

3.3.7 Results

3.3.8 Ergonomic Drawings

The drawings below demonstrate the dimensions used for the components of the cooling "suit". These dimensions were obtained by referencing the measure of man and women as well as a study on firefighter anthropometric data. The goal was to cover the largest body area to cool firefighters at a more effective pace. It was also important for the solution to not completely interfere within the gear donning process. This is important as firefighter are currently used to the typical routine. Adding any complex steps would add time to respond to calls.

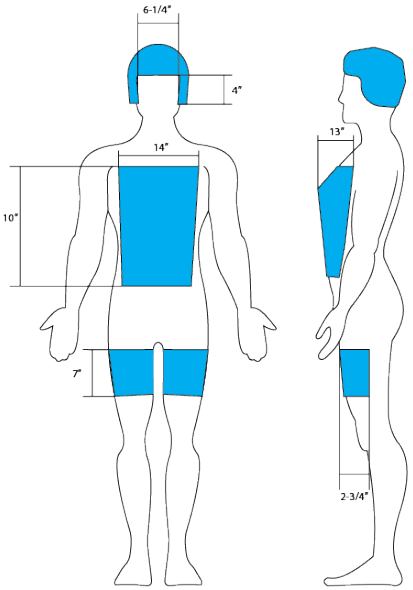


Figure 18 - 95th Percentile Male with component dimensions

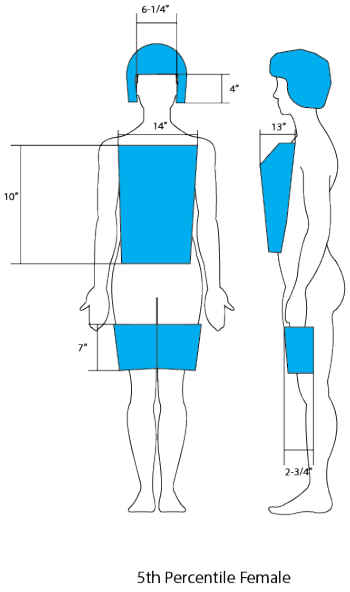


Figure 19 - 5th Percentile Female with component dimensions

3.3.9 Ergonomic Observation

For this observation foam core was used to designate the upper body and leg cooling system components. A snowboard helmet was used to mimic the proposed design intent. This helmet was also used as it closely resembles the desired style of the design concept. Tape was applied to the helmet to demonstrate the cooling lines running throughout. The two users wore ski pants to simulate firefighter turnout pants. Due to the size difference between the users two different models of ski pants were used. The components were created using foam core, however the true concept material will be more of a fabric or foam to better form to the users body.

Figure 20 - User representing the 2.5-5th percentile

With the 2.5-5th percentile user most of the components fit well and allowed for moderate range of motion. Despite using the smaller dimensions some of the components were still a little big and restrictive on the smaller user.

Figure 21 - User representing 90th percentile

With the 90th percentile user the parts fit a little on the smaller side however still covered a decent area; which would be the goal of effectively cooling firefighters. Range of motion was not impeded as much as the smaller user with the downside of covering less body area.

3.3.10 Limitations and Conclusion

At the conclusion of the observation there are a few key points that can be outlined. One of the most obvious is the environment of use; due to the dangerous conditions the typical environment could not be simulated. To visually show how the legs components would be located and fit they were positioned on the outside of the pants. This in term adds a discrepancy in the actual dimensions for the leg cuff component; this will need to be further evaluated moving forward. Due to the fact that there would be either tubing or cooling lines running through the “suit” the correct length of tubing will need to be determined. While the chest and back pieces were cut to cover the largest possible area for most effective cooling. They may need

to be slimmed down to increase range of motion for the upper body. The helmet fit both users fairly well. An added feature that may aid to accommodate the smaller user better is the presence of a micro adjustment dial on the back of the helmet. A mechanism similar to the BOA lacing often seen in the footwear industry. With this the overall size of the helmet remains the same. The only change is the interior which could provide a more secure hold on a range of head sizes.

3.4 Aesthetics

3.4.1 Introduction

Due to its nature firefighter PPE is often designed to protect the users first and foremost. Appearance is usually not at the top of the list in terms of priorities for this type of product. This means the PPE in this product segment is mainly focused on function over form. Over the years products within this category have started to adopt a more modern aesthetics however this is limited to a handful of manufacturers. This modernization can be seen in a few new helmet designs yet the options for helmets of this style are quite narrow. Examples of this can be seen below with the Cairns XF-1 (Left) and the Bullard Magma (Right).

Figure 22 - Cairns XF-1 Fire Helmet. [Image] Retrieved from https://ca.msasafety.com/Fire-Helmets/Jet-Style-Helmets/Cairns%C2%AE-XF1-Fire-Helmet/p/000360008000001010

Figure 23 - Bullard Magma Fire Helmet. [Image] Retrieved from https://www.bullard.com/product/magma

Aside from this the one important styling consideration within the industry is the use of reflective materials. Using materials such as 3M® Reflective banding is paramount to ensure user visibility. This material is often used on turnout gear, helmets and gloves to aid with fire victim or other firemen to identify each other. Within this sector the colours red, white, orange, black are often used. In terms of helmets the colours are used to distinguish between the different ranks or position. For example, in Canada Fire Chief often wear white, captains wear red and all crew below that wear yellow or black. The colour usage isn't a standard so it often differs from place to place.

3.4.2 Form Language

Firefighters PPE should present itself in a safe and protective fashion. Instilling trust within the user that this product will perform its job and keep them safe from danger. It is important for the product to appear tough and durable through the use of durable looking materials. This can be seen in the use of materials in turnout gear, making use of a strong, heavyweight fabric such as Kevlar or Nomex.

3.4.3 Conclusion

Firefighters have a very distinguishable appearance, one that has remained vastly unchanged for many years. Within this environment there is definitely a fair share of individuals who are more old school or traditional. These people are less welcoming to change especially within a field with such a rich history. Despite these long-time traditions, it should be possible to move fire PPE to a more modern aesthetics while still embracing traditional aspects. Nonetheless ensuring the products maintains a level of trust with the users.

3.5 Sustainability – Safety, Health & Environment

3.5.1 Introduction

Firefighters PPE are products designed to withstand environments of tremendous heat. The number one priority when designing and manufacturing these products is safety. Meaning the manufacturer will use the best performing materials and processes; ensuring their products provide the highest degree of safety to its users. Not only do the products firemen use not focus on sustainability; the fire suppression process makes use of lots of water. On top of this the burning of a house or building releases a number of dangerous carcinogens into the air. With this in mind at the current point it is well within reason to believe more environmentally friendly options exist. However, this is only possible if those materials and processes carry the same or superior performance of their competitors.

With the rise of new sustainable materials becoming more prevalent in modern homes firefighters are facing issues with fires burning differently. This is something the NFPA is trying to address and make organizations aware of.

3.5.2 Current Materials and Methods

As stated above the focus on performance is the number one priority. The current materials used for firefighter PPE includes Kevlar (polyparaphenylene terephthalamide), Fiberglass, Engineering Plastics, Leather, Carbon Fiber and Steel. Many of these materials are not the greatest environmentally speaking. Materials such as fiberglass which is commonly used in firemen helmets is incredibly difficult to recycle even if it can be easily separated from other components. The same can be said for carbon fiber which is used for almost all oxygen tanks nowadays. The material is hard to recycle, and in the process can damage the fibers resulting in a poorer outcome. New processes for recycling these two materials have been discovered but are

still in their infancy. Kevlar on the other hand is 100% recyclable given it can be separated from other components. All in all, the material selection within this product segment aren't the greatest in term of being environmentally friendly. However, with new materials being invented constantly there is hope. This thesis project will aim to include sustainable materials and processes wherever possible, given it doesn't sacrifice performance.

3.5.3 Manufacturing

In terms of manufacturing, many of the products used by fire stations are manufactured in Asia. Similar to many retail products this is done to save on labour cost. This does come with the cost of being harsher on the environment due to international transport. The manufacturing processes chosen for these products must ensure that their product quality is quite high. Seeing as any sort of mishap within the manufacturing could cause a fatal accident. It is entirely possible to see North American manufacturers transition to domestic manufacturing. Given the current push towards greener practices; there is a chance of sustainability becoming a bigger issue within this field.

3.5.4 End of Life and Beyond

As mentioned above many of the materials used within the firefighting sector are not fantastic products when observing from a sustainability point of view. A good portion of them cannot be recycled easily and if they can the product quality is hampered. Despite the advancements with recycling technology it may be a few more years before we see these materials successfully recycled. In the meantime, it is possible to see manufacturers experiment with new materials and processes as the technology evolves.

3.6 Commercial Viability

3.6.1 Materials and Manufacturing Selection

As mentioned throughout this report material selection for firefighting gear is extremely important not only for safety but to meet NFPA standards. The current cooling solutions on the market exist mainly in the form of a vest with common fabrics. Due to the proposition of using this cooling system in a fire the materials may need to be slightly more durable. However, these still need to provide the wearer with lightweight and breathable properties.

In terms of manufacturing seeing as the proposed design will most likely contain a soft goods component this will be manufactured similar to other professional clothing. Using machine sewing on all soft goods and traditional manufacturing for any hard goods. Seeing as most apparel and soft goods are produced overseas it would make sense to focus that way. However, given a focus on sustainability it may be more environmentally conscious to manufacture domestically. Thus, avoiding shipping assembled goods overseas. That being said it would be entirely dependent on the most economical choice as either option would have environmental effects.

Figure 24 - Cairns 360R Low Profile Helmet, Globe Classix Coat, Lion Super Deluxe Pants

3.6.2 Cost

The cost to fully equip a firefighter with all the gear they need comes out to around $2000-$3000 per person meaning it is a significant investment for most townships or cities to take on. As seen above these current products we're found on the website The Fire Store. The listed price of each of these items is as follows: Cairns 360R Low Profile Helmet ($255.59-$320.59), Globe Classix Coat ($999.00) and Lion Super Deluxe Pants ($869.99). These prices show the substantial cost of these professional equipment. Given this information it would be foreseen that the proposed design solution be within the range of $500-$900. Due to the necessary components of cooling systems and electronics making up the bulk of the final product cost. Due to the mass manufacturing the price per plastic component may be on the cheaper side without taking into account the original investment for the moulds.

3.7 Design Brief

The overall goal of this thesis is to alleviate the problems centered around heat and physical exhaustion throughout the structural fire suppression process. The list below is goals or objective that are important in order to reach the desired outcome.

1. Ensure maximum physical safety for firefighters
2. Improved control over firefighters' core body temperature
3. Alleviate the effects of heat exhaustion/ heat stress
4. Reduce the amount of physical exertion
5. Ensure a comfortable and secure fit
6. Allow for quick and easy donning and doffing
7. Create an easy way for Fire Chief to maintain crew accountability

8. Promote appearance of safety and rigidity
9. Aim to create a modern aesthetic while maintaining traditional elements
10. Allow for increased visibility in low visibility situations

4. Design Development

4.1 Ideation

During ideation the original ideas were hard to come by personally the focus was predominantly in regard to keeping firefighters cool. This original focus lead to a lack of broad ideas and depth. The research was there it was just a matter of applying it to a concept or idea. Ultimately two scenarios where achieved: one being a wearable internal cooling system to manage and control core body temperature with line of communication to the fire chief, the second a device located adjacent to the oxygen tank to provide burst of mist to the user to keep them cool.

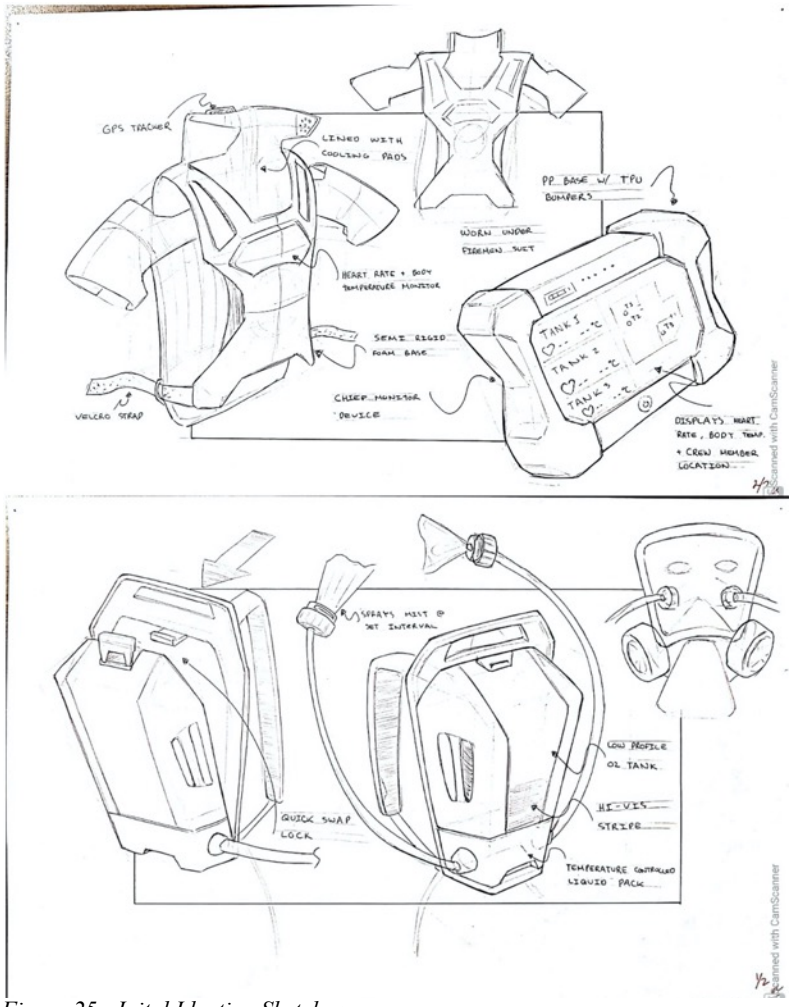


Figure 25 - Inital Ideation Sketches

4.2 Preliminary Concept Exploration

Once a general concept direction was chosen work began on broadening the focus and pushing the idea further. The wearable/ mobile device idea was chosen to pursue further. The intent was to have a suit worn by the firefighter containing cooling gel/material. It would also include internal communication and GPS to track the location within the building. A second product within that family was a mobile device used by the Fire Chief, this would be used to maximize crew accountability and provide critical info to the Chief.

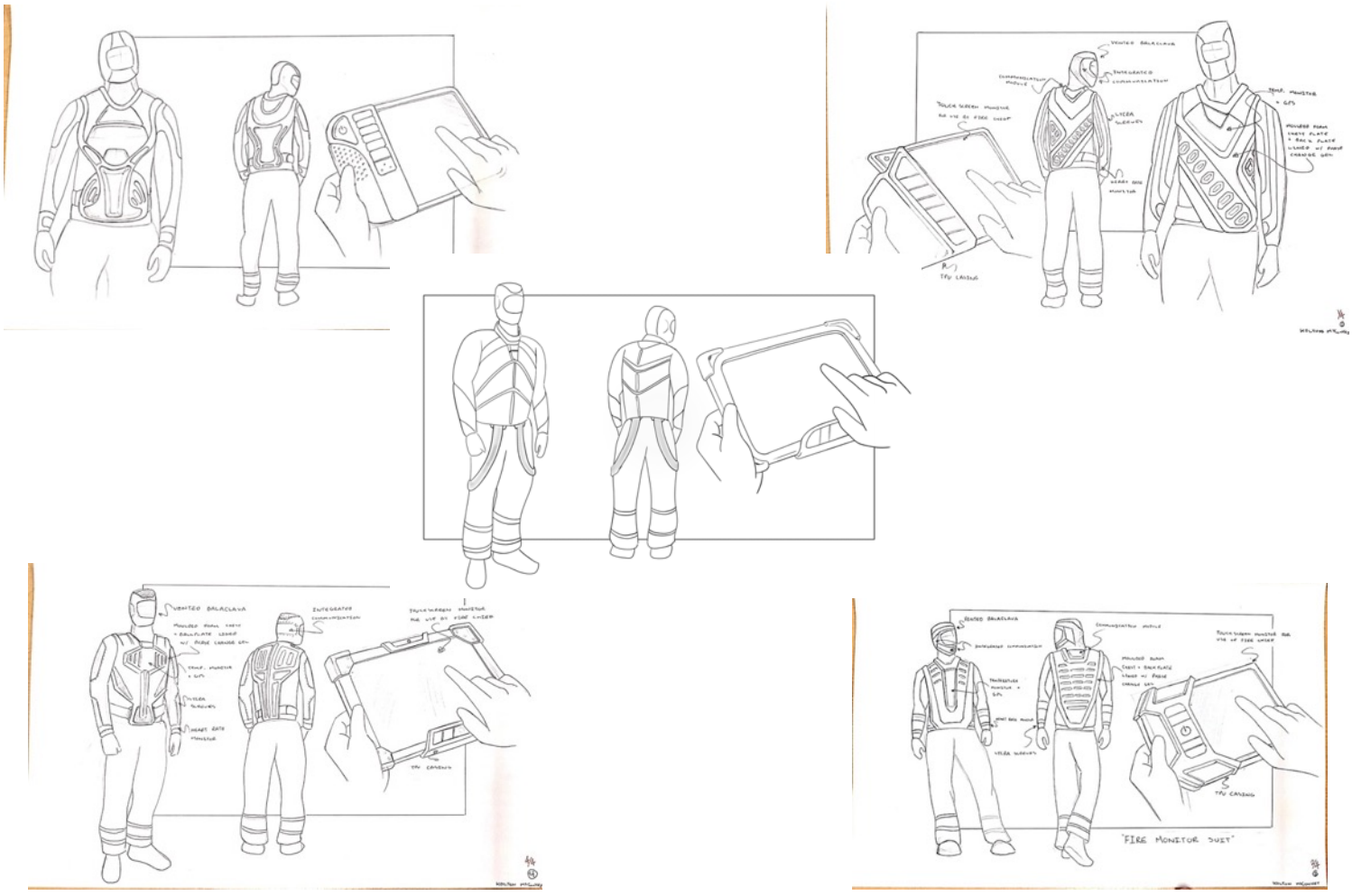


Figure 26 - Sketches of concept development

4.3 Concept Refinement

After this stage it was apparent that the suit was trending to the bulkier side, which didn't help when it comes to putting on firefighter gear quickly. This would also add more weight and layer than necessary. Thus, the upper body portion was shrunk down to focus just on the upper shoulder region. The idea of a helmet was also used, providing cooling to the head would cool the body down quite effectively as it is one of the key areas. The Fire Chief tablet was also dropped in favour of a personal armband for the firefighters.

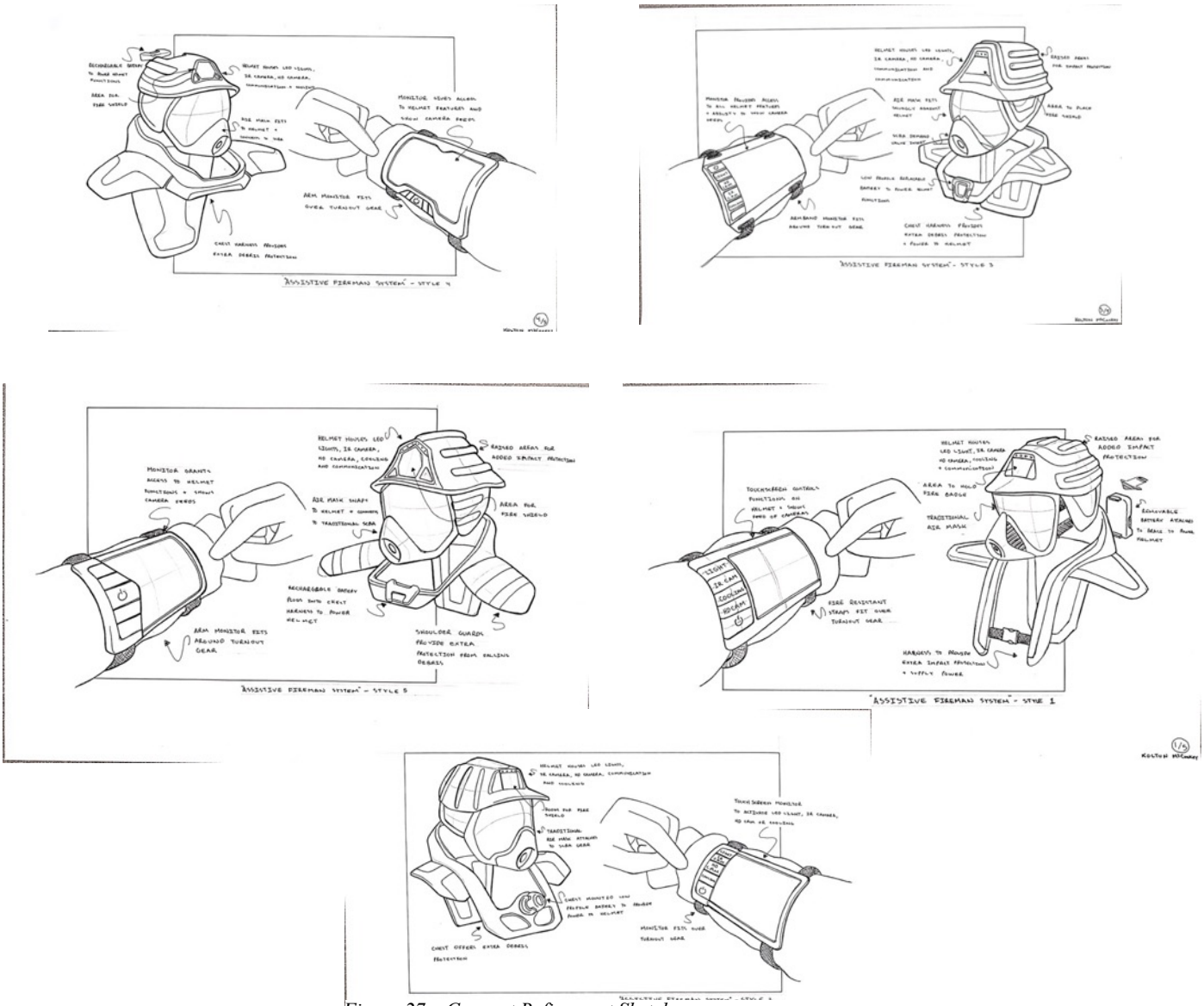


Figure 27 – Concept Refinement Sketches

4.4 Detail Resolution

After this stage it was decided that the upper body shoulder suit was still a little too bulky for the environment of use the focus then shifted to using a shirt like construction and attach a small water pump to the front of the shirt. At this point many details we're still quite difficult to iron out as I was unsure of the actual direction I wanted to pursue. The original intent was to have a helmet, chest and leg cooling system. The leg portion was dropped as it felt like it would impede the firefighter with cables and restrict their movement.

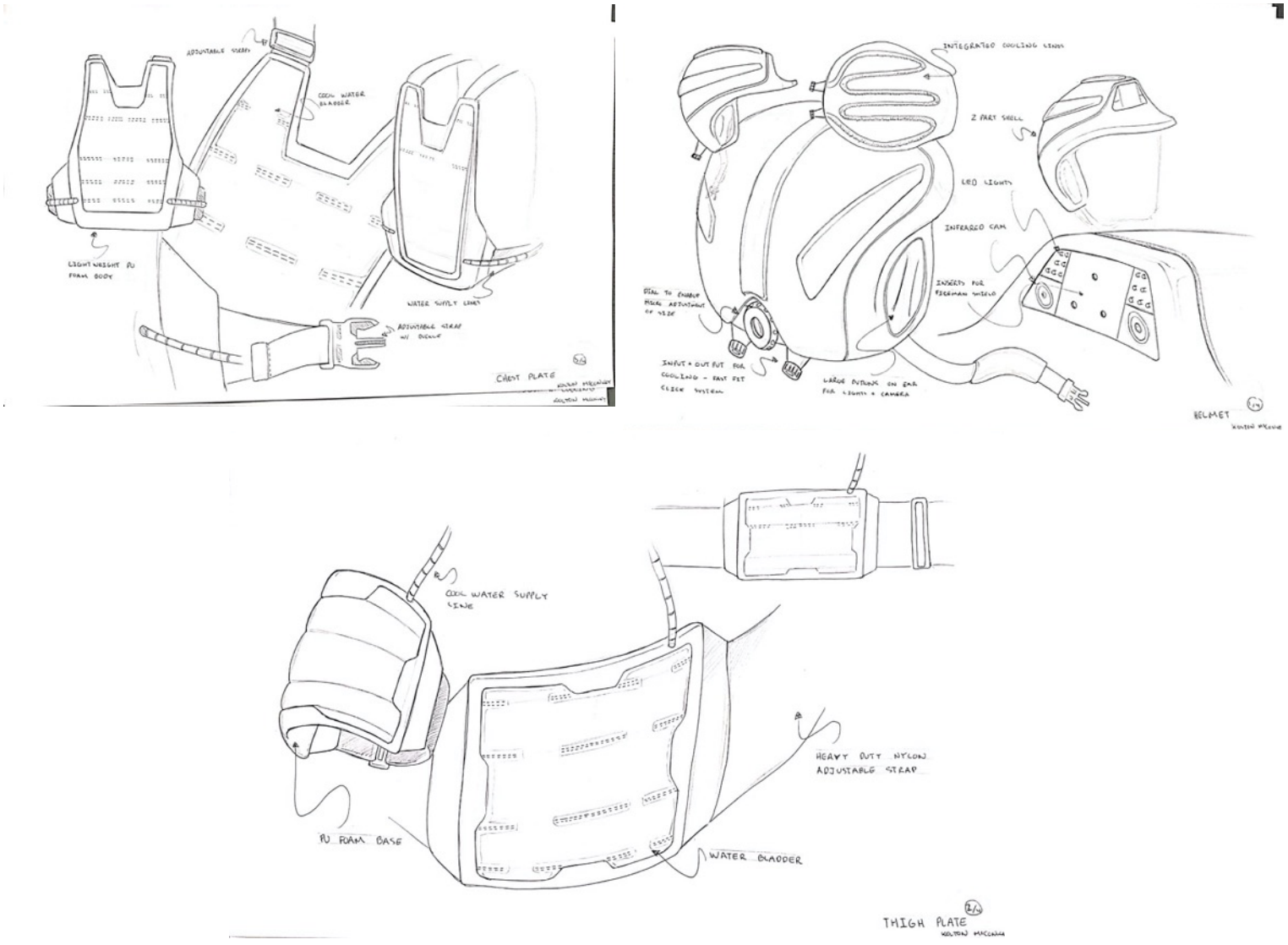


Figure 28 - Detail Resolution Sketches

4.5 Sketch Models

To get a better understanding of form, a sketch model was made using an athletic top and EVA foam. The foam was used for its great forming qualities and ease of use. A pattern was made to construct a shell for the helmet form. Initially the plan was to use and paint EVA for the final models such was the reason as to why I decided to use it. After finishing the sketch model, it was clear it would be faster and easier to model the parts in CAD for 3D printing. From the sketch model it was decided a full sleeve approach with a smaller water pump system would work best. Along with a modern style helmet with integrated cooling and Bluetooth communication. The sketches below show the modified shirt direction along with the general styling direction for the family of products.

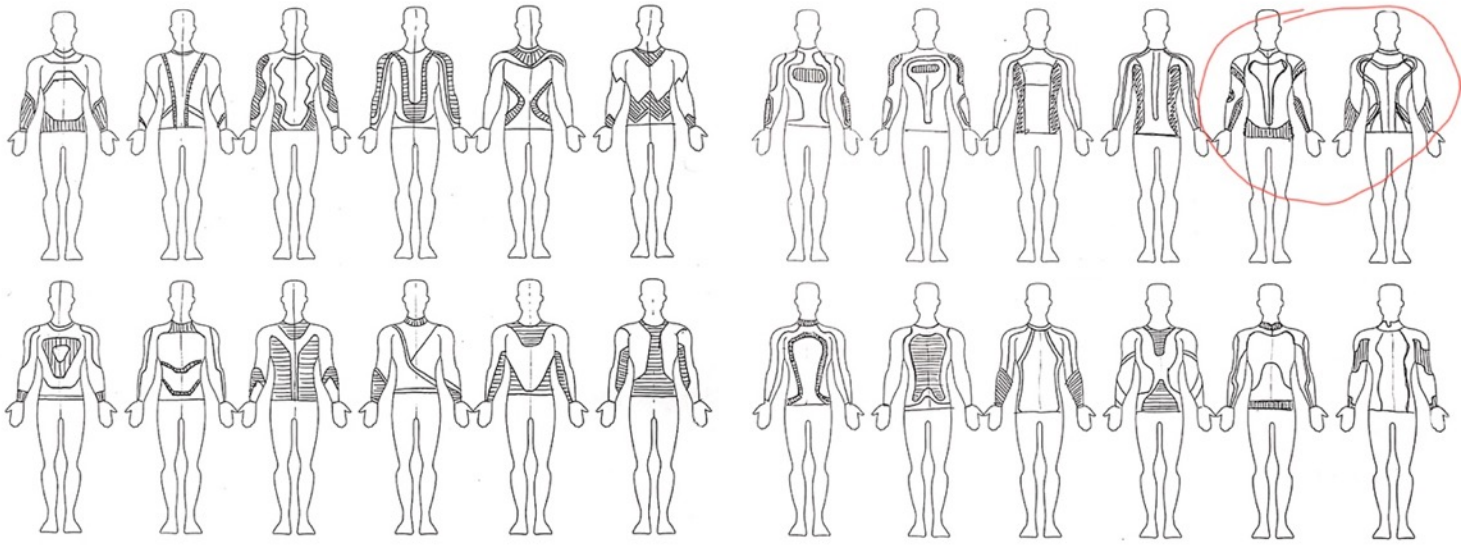


Figure 29 - Styling Direction

4.6 Final Design

Figure 32 - Final Helmet Design

Figure 30 - Final "Suit" Design

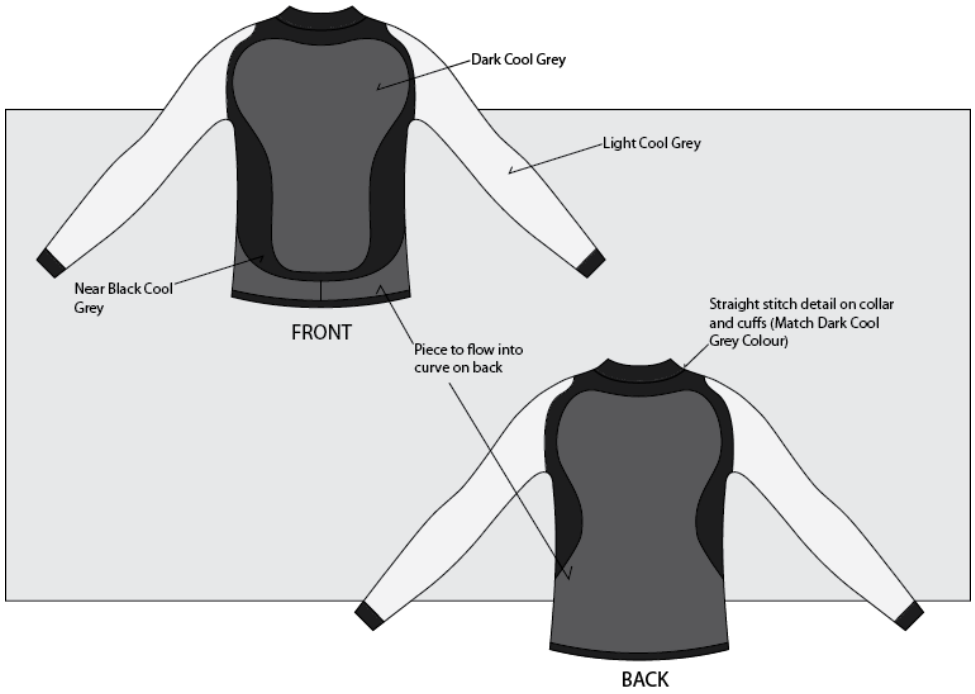


Figure 31 - Final Shirt Design

The final design was chosen to provide a more modern looking helmet with feature to aid firefighters to stay cool but also improve workflow and squad communication. By improving crew communication suppression becomes much more coordinated and focused. As every member can give direct feedback through clear communication lines via headphone style devices. Firep also provides users with maximum area upper body cooling.

4.7 CAD Models

For the CAD portion of this project a combination of software was used given the mix of hard and soft goods. CLO3D was used to develop the look and pattern for the final “suit” portion of the design. To model the hard goods Fusion 360, Rhino 6 and Solidworks were used. Making use of Fusions Sculpt environment it was possible to push and pull the form of the helmet around a 3D head model. Once the overall shape was flushed out in Fusion a .STEP file was made to export to Solidworks. Additionally, Rhino 6 was used to extract surface data for the front and rear cooling systems. This was done to make sure the devices fit as close to the avatar body as possible. Once in Solidworks final details were added to then be sent to Agile Manufacturing for printing.

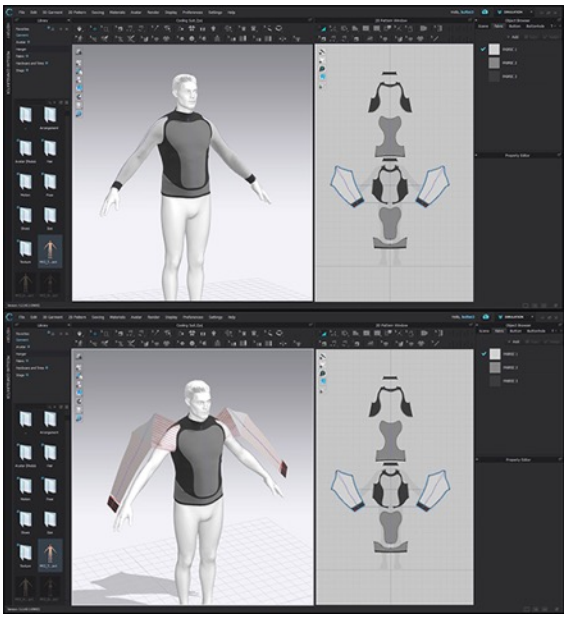


Figure 36 - CLO3D Soft Model Visualization

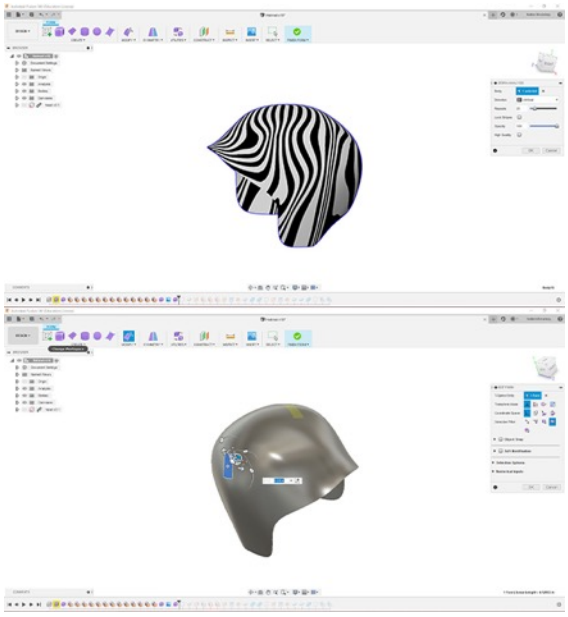


Figure 35 - Fusion 360 Sculpting

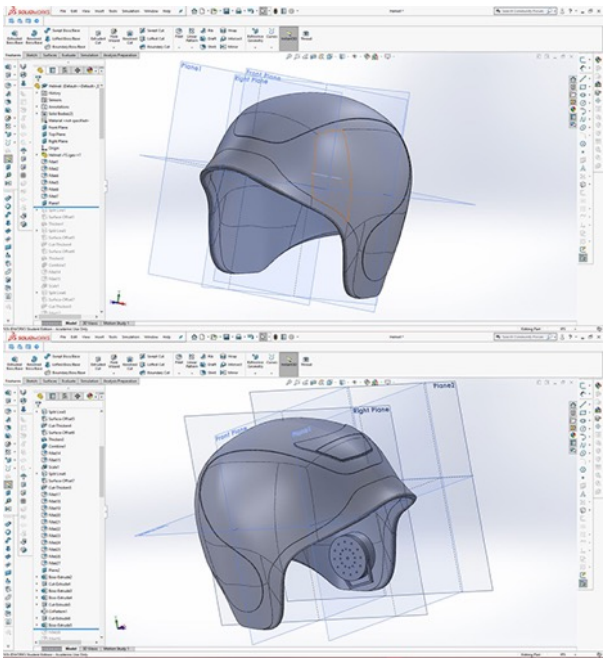


Figure 34 - Solidworks, Adding details Helmet

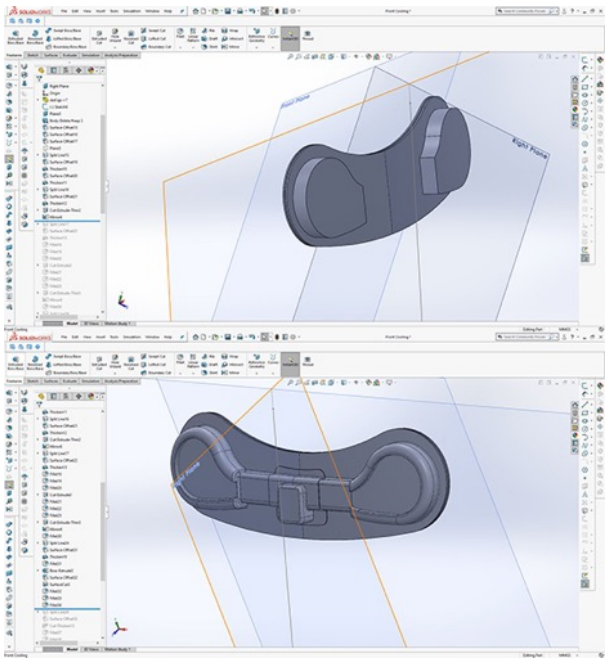
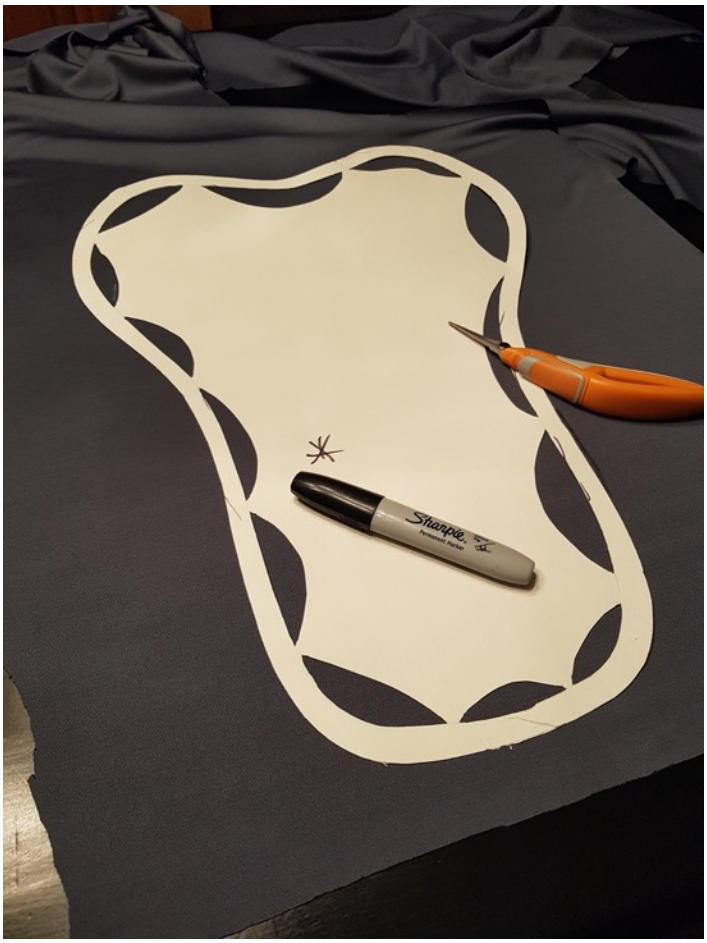
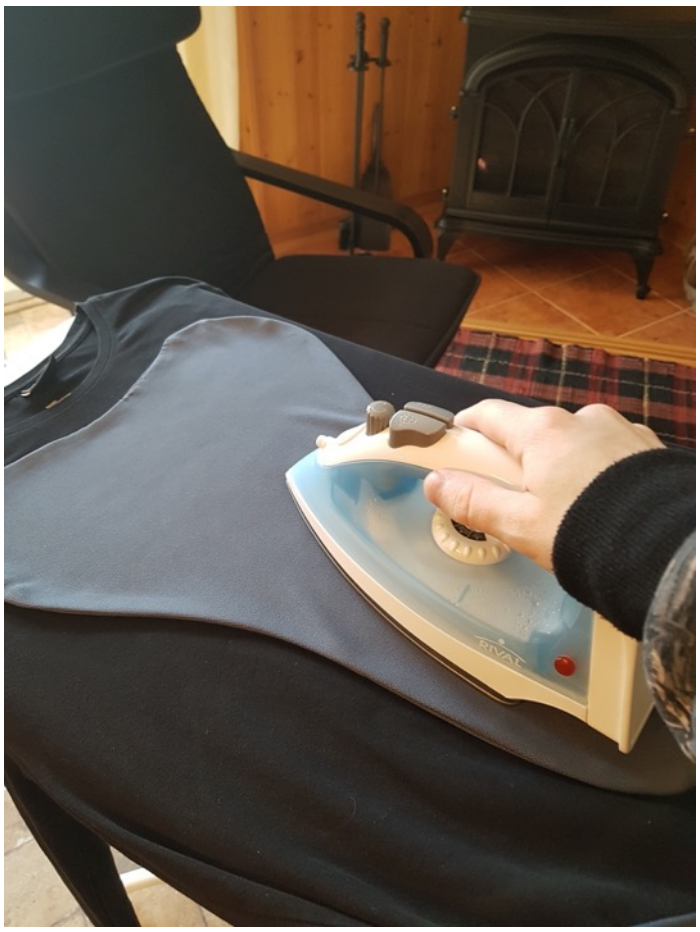


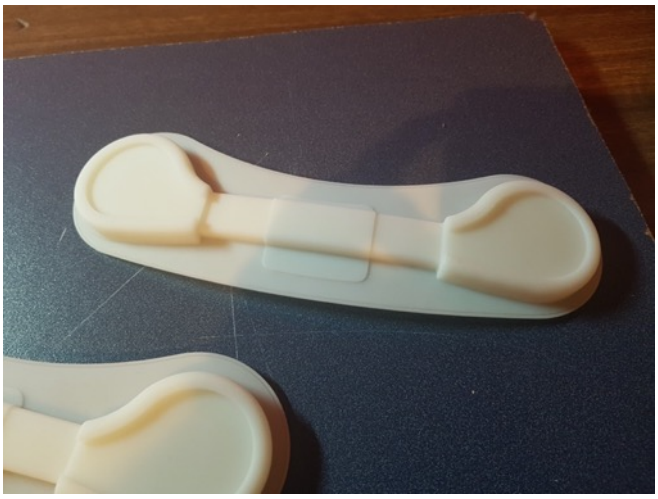
Figure 33 - Solidworks, Adding details Cooling System

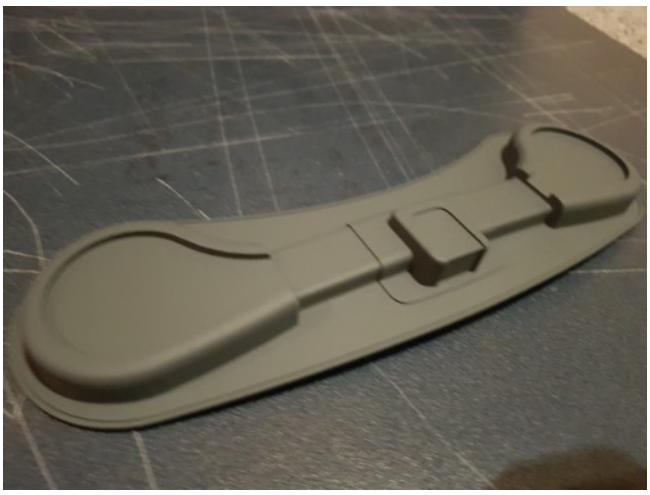
4.8 Hard Model Fabrication History

To create the Final model a mix of machine sewing, and 3D printing was used. To create the shirt portion of the design, the original plan was to consult or hire a seamstress or tailor to flush out the pattern or garment. Unfortunately, due to the COVID-19 situation it was decided to be done at home. The patterns developed in CLO3D we're used as reference and adjusted accordingly. A plain black shirt was used as the base with fabric elements attached. Iron-On adhesive was used to secure the fabric in place then stitched to lock it in. All hard goods we're sent to Agile Manufacturing to be 3D printed, the parts we're then painted and small details (not included in CAD) were added to the prints.









5. Final Design

5.1 Summary

In summary Firep is a family of products designed to mitigate the dangerous effects of heat exhaustion/stress. Providing firefighters with cooling on the job to tackle the problem at the source. It does so through the use of a wearable system and an improved and modern helmet featuring the same cooling technology.

Firep differs from traditional firefighter rehab gear in the sense that it is meant to be used in action. By providing firefighters cooling while in action they are able to fully concentrate to the task at hand. Current rehab solutions are large and require external devices to use. Firep makes use of microelectronics to provide firefighters with a low-profile cooling system to reduce bulk.

5.2 Design Criteria Met

5.2.1 Ergonomics

Due to the nature of firefighting gear Firep would be offered in a range of sizes to fit the individual correctly. It is designed to fit similar to an athletic top to provide a snug fit. Its full sleeve construction provides sweat wicking to the entire upper body to quickly expel heat just beneath the turnout gear. The family of products covers the full body from waist up ensuring the 3 essential touch points. The products cover touch point such as the head, chest, hands and arms. One of the main priorities when designing Firep was to ensure easy donning and doffing such that firefighter could still quickly respond to emergency calls.

5.2.2 Materials, Processes, & Technologies

Given that Firep compromises of two different product the materials differ slightly. The wearable system is made up of lightweight bamboo-based rayon fabric. This rayon fabric is used for all parts of the shirt. Bamboo provides a soft comfortable feel while also sporting great moisture wicking properties. The main body of the body mounted cooling system a constructed using Covestro Apec due to its great heat resistance and durability. The main housing hold components such as the battery, the water pumps and the cross-body water line. The cross-body water line is held in place by an aluminum brace to provide a sturdy yet lightweight mechanical connection. The helmet shell similar to the cooling system would make use of Apec again for its excellent properties. With the internal foams of the helmet being made of TPU to provide optimal energy absorption while providing excellent comfort. The LED headlamp cover would be created from Makrolon to provide the best lighting performance. Finally, the helmet straps are to be made like most helmet straps out of nylon webbing to provide long lasting strength and durability. All electronic components will be sourced separately to fit into the overall product system.

Due to the fact that half of this product family consist of soft goods this component will be manufactured through the use of machine sewing with quality and comfort in mind. In terms of the plastic parts the bulk of them are to be manufactured through injection molding. The body mounted cooling system is connected to a thin rear backing plate under the shirt that is ultrasonically welded to provide a clean and secure connection. The aluminum brace meant to hold the water line is made from simple metal bending or stamping. Finally, the foam lining in the helmet is compression molded to provide dimensionally stable parts with less waste compared to injection molding.

5.2.3 Manufacturing Cost Report

The table below present the price breakdown on each available component of Firep. These prices are simply an estimate or are actual prices based on hard model construction. For the more cost heavy parts internet sources, we're used to give a very general estimate.

Part (Material)	Cost (CAD) / 1 Unit
Helmet Shell (Apec)	$30
Cooling System Housing Front (Apec)	$10 x2
Cooling System Housing Rear Plate (Apec)	$7 x2
Helmet Foam Lining (TPU)	$30
Helmet Chin Straps (Nylon)	$5
Chin Strap Buckles (ABS)	$0.50
Headlight Cover (Makrolon)	$1
LED Lights (Sourced)	$0.90
Helmet Internal Water Lines (PVC + Nylon)	$2.50
Lithium Ion Battery, Helmet (Sourced)	$6
Litium Ion Battery, Body Mount System (Sourced)	$6
Water Pumps (Sourced)	$15
Helmet Headphones (Sourced)	$15
Helmet Microphone (Sourced)	$12
Water Line Brace (Aluminum)	$7
Long Sleeve Top (Bamboo Rayon)	$30
3M Reflective Tape	$4
	Total: $198.90

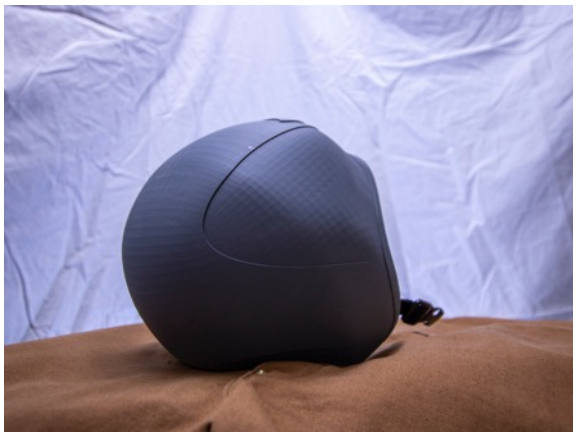
5.3 Final CAD Renderings


FIREP


FIREP
FIREFIGHTER COOLING SYSTEM


FIREP
FIREFIGHTER COOLING SYSTEM

5.4 Hard Model Photographs



5.5 Technical Drawings

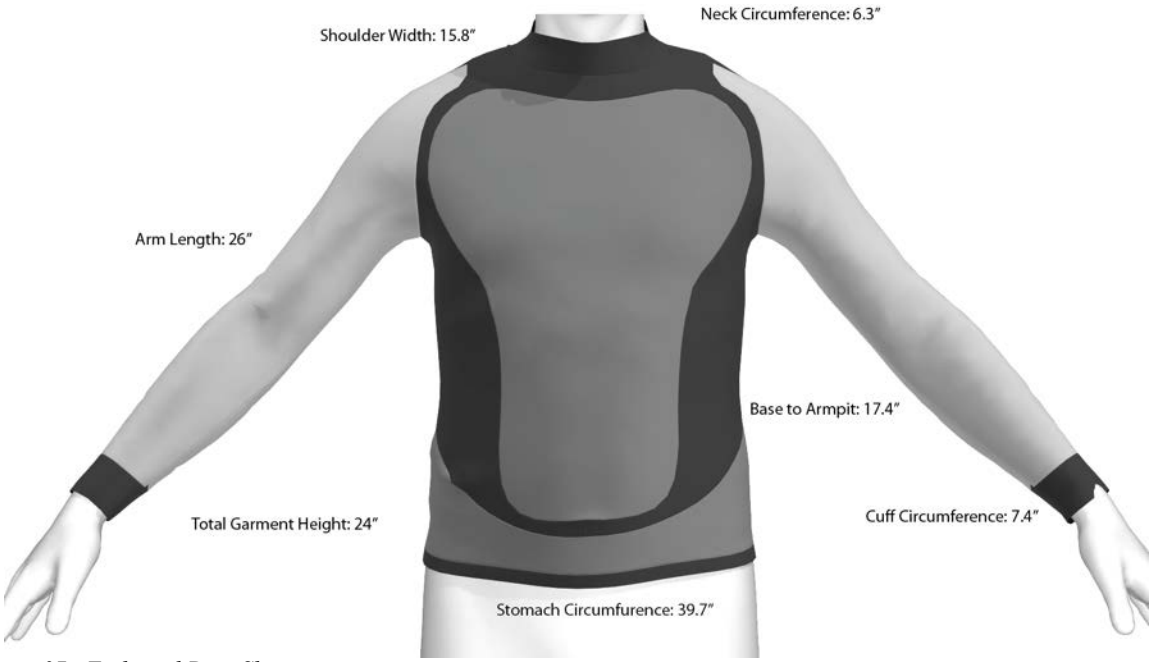


Figure 37 - Technical Data Shirt

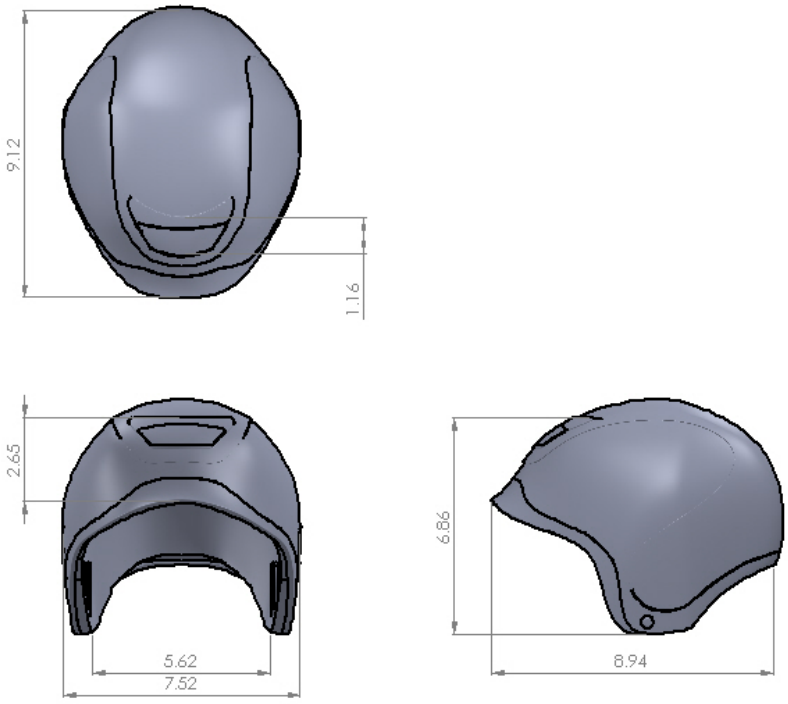


Figure 38 - Technical Drawing, Helmet

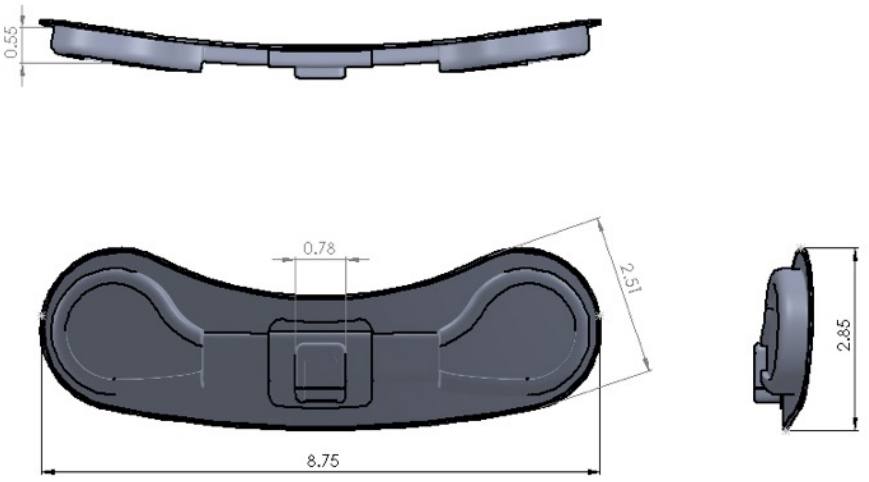


Figure 39 - Technical Drawing, Front and Back Cooling Systems

5.6 Sustainability

Despite the major focus on sustainability within the firefighting sector Firep aims to provide sustainable effort through not only materials and manufacturing but also business/ personal sustainability. This focus start with the shirt which is constructed using bamboo-based rayon fibers. Bamboo is one of the fastest growing plants thus making it widely renewable. Bamboo is also a much cleaner source of fiber as compared to the likes of cotton or polymer-based synthetics. While talking about materials Firep also makes use of high durability polymers to increase the overall life span of the helmet and cooling system. This also aid due to the harsh environment in which these products will exist in. The final area of sustainability is within the business, every year a large number of firefighters are injured on the job due to the effects of heat exhaustion. By aiding and alleviating the problem at the source Firep can help firemen stay healthy and safe while performing on the front lines.

6. Conclusion

Current firefighter equipment does a lot to help keep firefighters protected from the extreme heat and dangers of the job. However aside from post suppression rehab equipment there is no device or system to aid with heat stress/exhaustion in action. Firep aims to fit into this space by providing fire departments with an integrated and lightweight cooling solution for in action use. Firep achieves this by making use of a family of products including a helmet and a full sleeve shirt. Both these components possess internal cooling to alleviate the effects of heat stress at the source. To this degree Firep ensures firefighters remains healthy, safe and able to complete their job to the fullest of their potential.

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8. Appendices

Appendix A

Discussion

Based on the images above we get a general overview of who is working as a firefighter and what they look like. From the images it can be observed that the typical firefighters appear to be between the ages of approximately 21 to 45. It is also apparent that the overwhelming majority of firefighters are of Caucasian ethnicity. In these instances, the income is a harder statistic to infer as there is really no factor to base that on. An education level of at least a high school degree was inferred. College education was inferred on some occasion where there seemed to be more career firefighters. It was deduced that these fire departments were predominantly staffed by volunteers with a few individuals being career firemen. With the statistical data in front of us, it's clear to see that the images portray a realistic view of the "average" firefighter.

Demographics of Firefighters	
Age	21 - 40
Gender	Mostly Male (94%)
Ethnicity	White
Income	$40k - $80k
Education	Bachelor's Degree

Retrieved from *https://datausa.io/profile/soc/firefighters*

Retrieved from https://www.nfpa.org/-/media/Files/News-and-Research/Fire-statistics-and-reports/Emergency-responders/osfdprofile.pdf

Overall, the overwhelming majority of firefighters seem to fit into the classes of being a 36-year-old male of Caucasian ethnicity earning around $40k to $70K with a minimum of a high school diploma.

Primary User	Firefighter
Secondary User	Victim of fire/ Homeowner
Tertiary User	Fire Department/ Fire Squad

User Profile Summary

Primary User: Firefighter

Secondary User: Victim of fire/ Homeowner

Tertiary User: Fire Department/ Fire Squad

Primary User Profile

Demographics		**User Behavior**		**Personality**		**Cognitive Aspect**	
Age	20-50	**Frequency of Use**	On Call 10-25 times/ month	**Locus of Control**	↑	**Technical Skill**	↑
Gender	Predominantly Male (~95%)	**Duration**	Varies N/A (20 mins to x hrs)	**Self-Efficacy**	↑	**Pre-Required Knowledge**	↑
Ethnicity	Caucasian (+80%)	**Social**	High-Social	**Changeability**	-		
Income	Middle Class ($40,000 to $80,000)	**Level of Focus**	High	**Uncertainty Avoidance**	↑		
Education	High School Diploma	**Location**	Residential – Rural/ Urban				

Appendix B

Interview 1

Findings/ Evidence:

Background Information: Interviewee preferred to remain anonymous, 33, Male, New England Area. Career and volunteer. 12 years of service. 11 paid, 12 volunteer.

Date and Place: 10/10/2019 Interview was conducted through private message via Reddit.

Transcript:

Q: How would you describe the typical Firefighter demographic?

A: In my opinion it's basically white middle-aged men. There has absolutely been a culture shift towards hiring women, minorities, etc. but the majority of people I've met have been white males.

Q: What made you pursue firefighter either as a career or as a volunteer?

A: Honestly, I don't have a very good answer. I woke up one day when I was about 21 and went down and joined the volunteer FD in my town. I fell in love with it after doing the training and going to a few fires and calls. It's just snowballed from there.

Q: What is the most enjoyable part of the job?

A: The most enjoyable part of the job is if you're able to make a difference in someone's life. It can be something as important as a CPR save or just comforting someone inside a car that's crashed while they're extricated.

Q: Alternatively, what is the least enjoyable part of the job?

A: The least enjoyable part of the job is trying to get certain tasks done with 25 people's opinions on how one thing should be done. It's not uncommon to find tools moved, supplies in the firehouse moved etc. because someone didn't like where they were. Sometimes the firehouse

feels more like adult daycare than it does a group of professionals. But we will it together when needed.

Q: What are your greatest fears while on the job?

A: Probably not living up to expectations. I went on a call that made national news a few weeks ago and I was the officer on the truck. I find that I continually go over the decisions I made that day in my head and I'm always finding some error in something I did, even though it probably looked fine from an outsider prospective. For something physical fear, I am not a big fan of operating on roofs. I'll do it but it makes me nervous as hell.

Q: What are some of the primary equipment used in firefighting?

A: Primary equipment would be your engine, hose, ladders, hooks, halligans, 4 gas meters, thermal imaging camera, turnout gear and SCBA's.

Q: Could you briefly describe what happens when you are called to a residential fire? What is the process?

A: On a residential structure fire we get on the engine and usually follow the directions from a FD officer already responding to the call in an SUV or pick up. They'll usually tell us the best access. Depending on how much fire it sounds like we have we will either bypass the closest hydrant and stretch a line to run off of tank water, or we will stop at the hydrant, lay supply line and drop off a hydrant man, then the engine continues to the scene. Line gets pulled off the truck and the crew goes in with the engine officer, some tools and the line. Fire is found and extinguished. Obviously, this is the readers digest version. There is a lot more that happens, but that's it for the sake of brevity.

Q: Are there any points of frustration with current equipment? If so what are they?

A: Sometimes the fire service included technology just for the sake of having it. An example would be one truck we have has electronically operated pump valves. It adds an unnecessary level of complexity to a design that's proven to work via mechanical linkage. Lots of times I see futuristic looking masks with built in people finders, heat cameras and tons of built in stuff. That stuff is only great when it works and sometimes simple = better.

Q: How much of your time is spent actually fighting fire vs other calls? To add to that approximately how long does it take to extinguish a house fire?

A: We run a lot of medical calls, so those take up time. We have down time where we do chores, work out, study, and repair work. I'd say it's about 50% calls and 50% down time. A house fire in my town takes anywhere from 5 minutes to an hour to put out. We're a small town so most of our fires are knocked down quickly with tank water. That makes clean up and the entire operation much quicker. If the place is fully involved when we arrive it obviously makes much longer.

Q: How much time is dedicated to searching the building and what is protocol for that task?

A: Depends on a lot of factors. You'd be surprised how many people live in complete filth with stuff everywhere. Those places take either much longer, because there is junk everywhere, or can be much easier because there is literally no space a person could be. The homes I've searched under fire conditions take maybe 5 minutes.

Q: Are there currently any needs that Firefighters have that current equipment isn't addressing?

A: Not that I can think of.

Q: Finally, is there anything else I should know about firefighting that may not be extremely obvious?

A: Not entirely sure. If your town has volunteers just, please realize how much time those people put in to training and some (not all) get literally nothing out of it. We get a small stipend in my

town where I volunteer, but some towns get literally nothing. They operate on pencil thin budgets, do their own fundraising, maintain their own equipment and some pay for their own training. We have it pretty good in both my departments but it's not that way for a lot of small rural departments.

Discussion/ Conclusion:

Key Points:

1. The fact of incorporating technology when it is not needed is quite interesting. This point seems to be very important as if technology is added to something it's just one more thing that can go wrong. It would also require a specialized technician to repair.
2. Thinking about the way people live is a good point, not everyone's house is spotless. In some instances, residents may have items in their house that create a great danger to the firefighters if exposed to fire. This could also greatly increase the time it takes to search a house due to these obstacles.
3. Realizing that volunteers are doing this job out of the goodness of their heart is quite an important distinction. These people are not being paid to do this and seems that in some cases are paying their way through it. Due to it being professional gear fire fighters gear is not cheap and quite a large sum of money to pay for individuals.

Interview 2

Background Information: Interviewee chose to only be identified as Reed, 18, North Carolina, Male, Volunteer trying to go Career, 1 Year Volunteer

Date and Place: 10/10/2019 Interview was conducted through private message via Reddit.

Transcript:

Q: How would you describe the typical Firefighter demographic?

A: In my area it's primarily white males but as of late it has been becoming more diverse, I've seen more women joining departments, and I've seen more people of color joining.

Q: What made you pursue firefighter either as a career or as a volunteer?

A: I wanted to pursue firefighter because of my family. I unfortunately lost my father to cancer when I was 5, and all the memories I have of him are as a firefighter, so I decided to join in and continue his legacy. I also joined because of my grandfather. He's been doing it for almost 50 years now and having him in my neighboring department has really helped me.

Q: What is the most enjoyable part of the job?

A: In my opinion the most enjoyable parts of the job for me are: being able to give back and help in my community, it means a lot to be able to give back and do something to contribute. The other thing is seeing the look on kids faces when they see you on like fire prevention week or situations like that, it always manages to put a smile on my face.

Q: Alternatively, what is the least enjoyable part of the job?

A: There are a few least favorite parts of this job. Bad car wrecks (ones that involve serious injury/death), codes(cardiac arrests/overdoses), people losing their houses, their lives. That kind of stuff is always hard, but you learn to deal with it in different ways.

Q: What are your greatest fears while on the job?

A: My biggest fear while on the job is "am I going to make it home" because you don't know what you're about to pull up on, it could be something little, or it could be the biggest call you may ever go on, you just never know until you get there.

Q: What are some of the primary equipment used in firefighting?

A: Some of our primary gear is number 1: our turnout gear, nothing else even comes close, without that we can't do half of the things we need to do. Varying on the call I would say our extrication tools, stabilizers for wrecks, and our hoses and nozzle for fires.

Q: Could you briefly describe what happens when you are called to a residential fire? What is the process?

A: For structure fires it all just varies on what's going on, the location (is there any hydrants around, if so what's the pressure? If not where's the closest hydrants? If there's no hydrant, where's the closest water source?) the type of building (Is it commercial or residential? What is it made out of? Is it 1, 2, 3 stories tall? Is there a basement?) If there's a hydrant near the house the first due engine would drop a 5" line at the hydrant and pull up to the house, pull off the attack lines and go to work while everyone else is arriving. If there is no hydrant near, the first arriving engine pulls up to the scene and still pulls off the attack lines and goes to work, but the 2nd arriving engine/tanker/etc. that has a portable water tank will drop it next to the primary engine, and there will proceed to be a tanker shuttle while the primary engine gets water by drafting out of the portable tank.

Q: Are there any points of frustration with current equipment? If so what are they?

A: There's always going to be frustration with equipment, sometimes things break and it's annoying when you need it.

Q: How much of your time is spent actually fighting fire vs other calls? To add to that approximately how long does it take to extinguish a house fire?

A: I would honestly say about 10-15% of fire calls are actually spent fighting fire. The rest of the time it's all car accidents/medical calls (if the department runs first responder program), fire alarms, and other calls. When it comes to the time on a house fire a bunch of different factors go

into that (the size of the house, how involved is it when we arrive on scene, the amount of manpower on scene, what exactly is burning inside) I've seen house fires out in 10 minutes, I've seen some go for hours.

Q: How much time is dedicated to searching the building and what is protocol for that task?

A: Once again that all just depends on the circumstances, if we know it's all clear, we don't worry about it, but if there's any doubt, a primary search team with an attack line are going to search the building.

Q: Are there currently any needs that Firefighters have that current equipment isn't addressing?

A: Expanding population, the district may be growing and they may not have the equipment or the man power to cover what is happening, or their equipment is old and is breaking and it may not work the next time you try to fire it up.

Q: Finally, is there anything else I should know about firefighting that may not be extremely obvious?

A: Firefighter really isn't all going into burning buildings. Everybody wants to be the guy on the nozzle, but only one guy can do that, there is so many more important jobs on the fire ground that don't get the same recognition but are vital to the situation at hand.

Discussion/ Conclusion:

Key Points:

1. Realizing that firefighters are not entirely sure of the situation they are going to be put in seems quite significant. They have to worry if something may happen due to the situation being much worse than they might have anticipated. Although this plays

more to the emotional side of things, there may be a way for design to aid in mitigating the fear and anxiety of facing the unexpected.

2. It's interesting to note just how much analysis is done before the crew even attempts to enter the building. Realizing that there is not a "one size fits all" approach to firefighting. That different situations require the crew to adapt their process.
3. There is an entire crew of people working to extinguish a fire and it's not just the ones doing the house search and rescue. There are areas beyond the primary and secondary rescue firefighters that could also experience difficulties in design could aid and improve the process overall.

Appendix C

1.1 Needs Statement

The overall objective for this thesis project is to aid Firefighters to complete their job in a less strenuous fashion, thus limiting the effects of conditions such as heat exhaustion, heat stress and possibly heat stroke. By accomplishing this, firefighters may be able to perform their job at one hundred percent capacity for a longer duration of time without feeling the effects of the heat.

1.2 Description

This user observation is being conducted to evaluate the highs and lows of the process of firefighting. Examining the individual activities that exist during the firefighting process. Through this research it will be possible to pinpoint areas of improvement. The user observation also gives a clearer understanding of a key activity in turn breaking down preconceived notions or biases the designer might have.

1.4 Key Activities

Firefighters perform many tasks during their time on the job, however, for this thesis project the main focus was mainly on the area of structural fires. Due to this, the main key activities to be observed were:

- Donning of turnout gear and SCBA
- Entry into Fire Tanker
- Search & Rescue
- Fire Suppression – From Tanker
- Fire Suppression – First Rescue Unit
- Fire Ventilation

1.5 Target Users

The target user for this thesis project consist of the Firefighter (Primary), Victim/ Homeowner (Secondary) and Fire Squad/ Fire Chief (Tertiary).

Primary (Firefighter): As the primary user the firefighter will have the most direct contact with the proposed design solution. In this instance the firefighter is part of the group that is entering the structure to perform the fire suppression, search and rescue as well as the fire ventilation.

Secondary (Victim/ Homeowner): This user may not always be applicable in every structural fire attended by the fire department. However, in the case that they are they are extremely important to design to accommodate them as it is a situation of life or death.

Tertiary (Fire Squad/ Fire Chief): This user is important within the process as they are responsible for the overall success of the fire suppression. They are also accountable for all their crew members and must ensure their crew follow correct procedure.

1.6 User Environment

The user observation was conducted at the Penetanguishene Fire Department in Penetanguishene, Ontario on October 22nd at 10am. The observation took place within the fire engine bay with the Fire Chief and Deputy Fire Chief. The activity being observed was a firefighter donning his turnout gear. As this was not an emergency situation the firefighter went through the process slower than normal. In this instance it should also be noted that the firefighter did not put on the SCBA gear as it has been prepped for when the next call comes in. Pictures were substituted to show how the mask and oxygen tank are connected.

Preliminary Video Observatio

2.2 Video Observation

Figure 40 - South Metro Fire Rescue PIO. (2019). Fire Academy. Retrieved from https://www.youtube.com/playlist?list=PL294kN9yZUsIxkQYFoomFaYVzPDOHqBZL

Brief Description: This series of videos showcase a group of Recruits going through 15 weeks of fire academy training. The videos showcase everything from putting on Turnout gear, Building search, Ladder techniques, Car Extrication, Medical Training and more.

Relevance to Topic: This playlist of videos is relevant to the thesis topic as it showcases how firefighter are trained to act. Seeing how they are trained may give some insight into the reason they make certain choices. Due to the fact that it is training it shows many different aspects of firefighting.

Figure 41 - Andeusmc. (2017). Structure Fire with Clear Footage of Entire Attic Lit Off! 02/26/2017. Retrieved from https://www.youtube.com/watch?v=TB9b9fpjX2A

Brief Description: This video showcases a firefighter wearing a GoPro camera. The video shows the crew tackling a structure fire where the entire attic caught on fire. The video shows the interactions between the firefighter and the rest of the crew. In the video it can also be seen how the firefighter is breaking the roof to expose the hidden fire burning in the attic.

Relevance to Topic: This video is relevant as it actually shows the action inside a live fire. Showing the cooperation between the group. The video also shows just how fast the environment changes. Once the attic is broken the entire house floods with smoke and visibility is severely reduced.

Figure 42 - Itzsteve11. (2012). GoPro HD: Fire Fighting- Rescue 19 Working Fire. Retrieved from https://www.youtube.com/watch?v=KDNgqFyOWww&t=125s

Brief Description: This video shows a fire crew responding to a residential structure fire. This video shows the firefighter in subject is working on forcible entry into the residence. This is being done to ensure the entire house is searched for victims as well as canvas the entire fire.

Relevance to Topic: This video is relevant as it shows the firefighters working on trying to enter a house using power tools such as a chainsaw and a metal saw. Another process that can be seen is the setup of all the tools in the firemen stretcher.

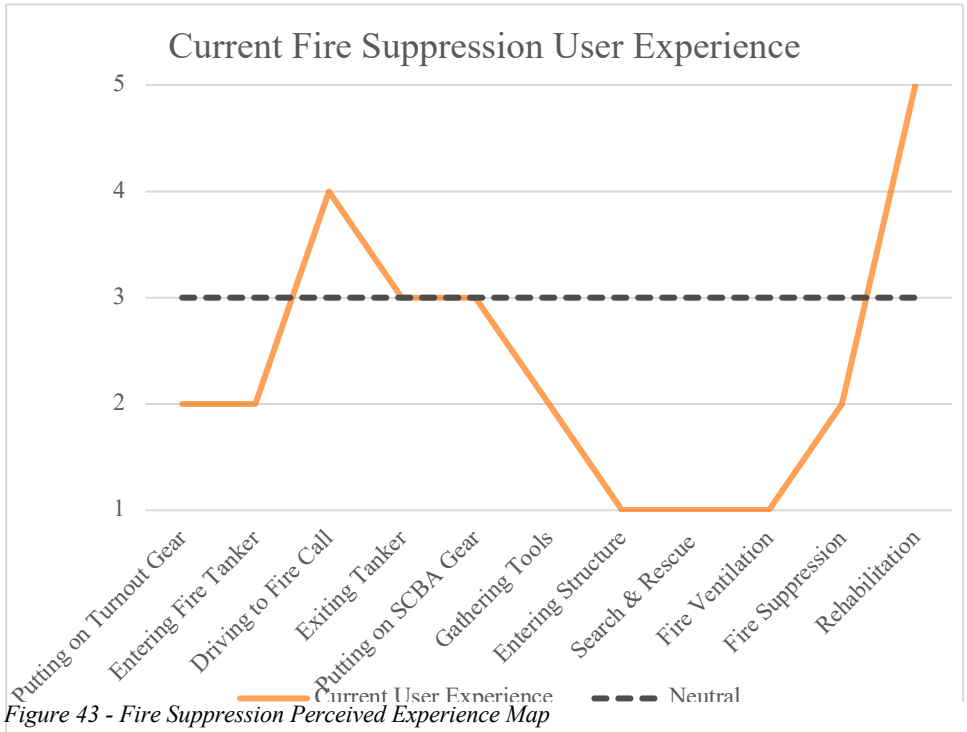


Figure 43 - Fire Suppression Perceived Experience Map

2.4 Key User Activities

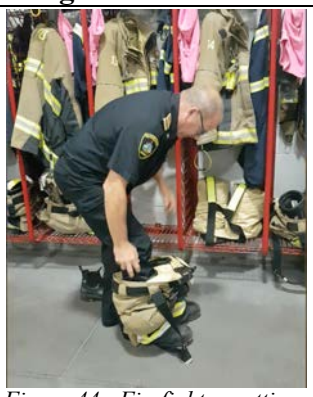
The following list is four key activities chosen from the preliminary video search that may help inform the design for the thesis project. These activities were found in the videos listed above. As seen on the chart above everything that occurs during the fire rescue is seen to be relatively difficult on the bodies of the firefighters. Once the fire is over the task of recovering is still difficult however the firefighters aren't dealing with the difficulty of the extreme heat and physical exertion.

- Search & Rescue
- **Putting on Turnout Gear**
- Using Attack Line
- Venting Structure Fire

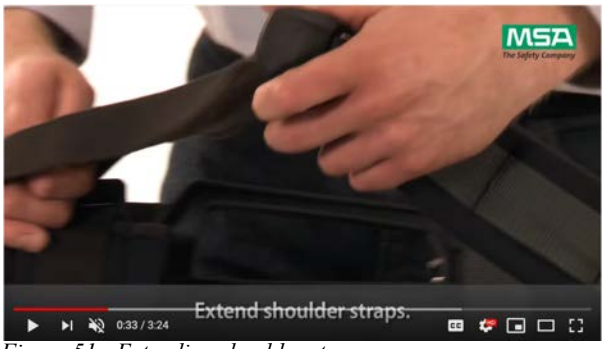
Direct User Observation

3.1 Chronology

The following table puts the steps of putting on Turnout gear in chronological order, along with providing a description of each action. Again, it should be noted that due to the SCBA gear already being set up it was not put on by the firefighter. In this case a supplementary video has been used.

Step	Action	Description	Image
1.	Putting on Turnout Pants with boots	The firefighter starts off by putting on the pants/ boots combo. This is a fairly quick and easy action which doesn't require much effort. **Note:** Not all turnout gear has boots attached to pants	 *Figure 44 - Firefighter putting on pants*
2.	Securing Straps and clasps	Once the pants/ boots are on the firefighter must ensure the straps are correctly tightened. This is done by pulling down the straps to adjust the fit. At this point the fireman will also make sure all snaps and clasps are securely fastened. **Note:** Turnout gear is almost always fit to the firefighter. The straps adjust the fit on to a small degree.	 *Figure 45 - Securing the pant straps*

3.	Putting on balaclava	To keep the neck area safe from the fire Firemen put on a balaclava under their helmet. Similar to the pants this action is quick and simple, requiring little effort.	 *Figure 46 - Putting on balaclava*
4.	Putting on Turnout Coat	One of the most important aspects of the turnout gear is the coat. The coat is put on like any other zippered jacket and is easy to put on.	 *Figure 47 - Putting on Turnout Coat*
5.	Zipping up Coat	To make sure the body is completely sealed off from the heat the fireman zips up his jacket all the way up. This is surprisingly one of longest part of the entire process.	 *Figure 48 - Zipping up Turnout Coat*

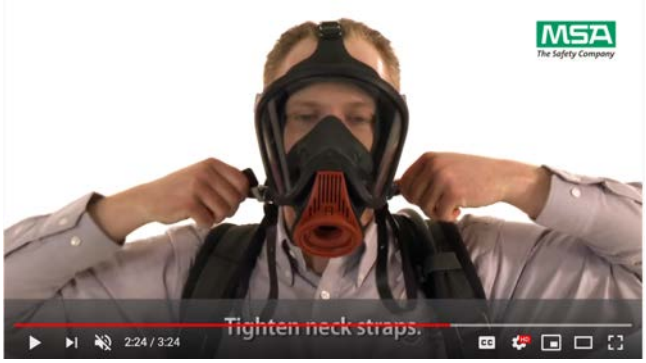
6.	Putting on Firemen Helmet	After all the soft gear is on, one of the final steps is putting on the fire helmet.	 *Figure 49 - Securing Firemen Helmet*
7.	Putting on Gloves	The final step to the fireman's gear is to put on the gloves. It is important to note that while putting on the turnout gear is not necessarily difficult it is extremely heavy and not very breathable. At this point the firefighter is already starting to get hot without expending much energy.	 *Figure 50 - Putting on gloves*
8.	Extend straps * **Supplementary Video Used**	Note: This action is entirely dependent on department protocol. Certain station put SCBA gear on at the station other on the site. The first step is to untighten all the straps to easily put the harness on. This done	 *Figure 51 - Extending shoulder straps*

		similarly to backpack straps.	
9.	Donning SCBA harness	The SCBA gear is worn like a backpack slinging it over ones shoulder. Depending on the model, the tank may be relatively heavy.	 *Figure 52 - Putting on SCBA harness*
10.	Tightening waist belt	The firefighter then tightens the waist belt making a more secure fit to the body. In this case the straps are pulled forward to tighten.	 *Figure 53 - Tightening harness belt*

11.	Tightening shoulder straps	After that the shoulder straps are tightened, this is done again similarly to a backpack, pulling down on the straps creates a tighter fit.	 *Figure 54 - Tightening shoulder strap*
12.	Turning demand valve off	The process to begin operation of the apparatus begins with turning of the demand valve this is done by depressing the red button as to not allow oxygen through the line.	 *Figure 55 - Switching off demand valve*
13.	Connecting demand valve to pressure gauge	The demand valve is then connected to a pressure gauge. This is done by pressing in a jack like cable into the gauge.	 *Figure 56 - Connecting demand valve*

14.	Opening cylinder valve	The cylinder valve is then opened to allow oxygen pressure to be read on the gauge. Note this action is done by reaching behind ones back to twist the valve knob clockwise.	 *Figure 57 - Opening cylinder valve*
15.	Checking cylinder pressure	The firefighter then checks the pressure gauge to ensure the reading is correct and that the line is working correctly. The gauge is located on the left side just under the armpit.	 *Figure 58 - Checking cylinder pressure*
16.	Closing the cylinder valve	The cylinder valve is then close to shutoff the oxygen flow through the line. This is once again done by reaching back and twisting the knob in the counter clockwise direction.	 *Figure 59 - Closing cylinder valve*

17.	Activating flushing mode	The firefighter then depresses the green button on the demand valve to release the pressure through the line.	 *Figure 60 - Activating Flush mode*
18.	Switching off demand valve	The demand valve is then closed to stop oxygen from running through the line.	 *Figure 61 - Switching off demand valve*
19.	Putting on SCBA mask	The firefighter then takes the mask spreads open the head harness and pulls it over their head. This action may require the user to loosen the straps if they are too tight to pull over the users head at first.	 *Figure 62 - Donning Mask*

20.	Tightening mask straps	This is a crucial step in donning the facemask. Once correctly in place the firefighter tightens the neck, temple and head strap. This is done by pulling the straps towards the back of the head.	 *Figure 63 - Tightening mask harness*
21.	Ensuring proper mask seal	To confirm that the mask has been properly put on and has proper seal the firefighter covers the input valve with their hand, inhales and holds their breath. If there is no suction the user might tighten the straps some more until it is achieved.	 *Figure 64 - Checking mask seal*
22.	Opening cylinder valve	The user then open the cylinder valve by reaching backwards and turning the knob in the clockwise direction. This allows oxygen to flow through the line.	 *Figure 65 - Opening cylinder valve*

23.	Clipping demand valve to mask	The demand valve is then clipped into the mask via a port in the front of the mask. In this example a secondary person is assisting in clipping the demand valve.	 *Figure 66 - Attaching demand valve to mask*
24.	Inhaling to ensure device is functioning correctly	The firefighter then takes a deep breath to confirm that the oxygen is flowing through the line correctly and sufficiently.	 *Figure 67 - Inhaling to ensure proper seal*

3.2 Organizing the Data

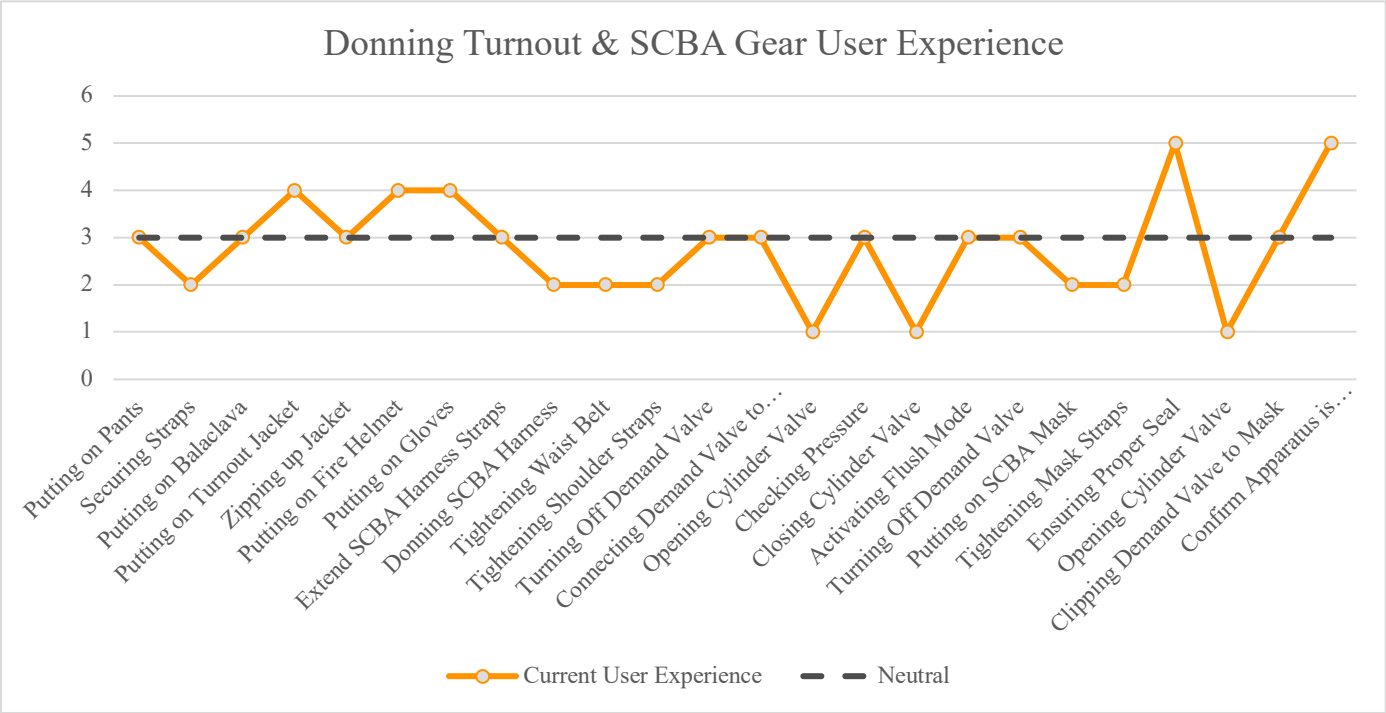
From this user/ video observation there are a few key activities that could prove significant in developing a thesis concept. One of the bigger activities is simply the **donning of the SCBA gear** with the many steps involved in confirming it is working correctly there is a lot of room for user error. There is also the awkward action of reaching behind their back to use activate the cylinder. In the instance of keeping a firefighter cooler to it would be possible to implement a product before **putting on the fire pants**.

User Experience

4.1 User Experience Map

The following graph present the user experience of donning the turnout gear as well as the SCBA gear. The current process is relatively straight forward, however, the process for donning the SCBA is somewhat lengthy and prone to user error. Additionally, after putting on the turnout gear the firefighter must deal with the heat and poor breathability of the turnout gear.

4.2 Potential User Experience Improvement Chart



The chart below represents the current user experience of donning of Turnout and SCBA gear. Additionally, the targeted user experience has been added to showcase the desired outcome for the User Experience the Targeted areas are predominantly contained within the SCBA actions where the task has many steps with a few awkward reaching actions. Actions such as turning on and off the cylinder valve and tightening the harness straps.

Figure 68 - Current User Experience

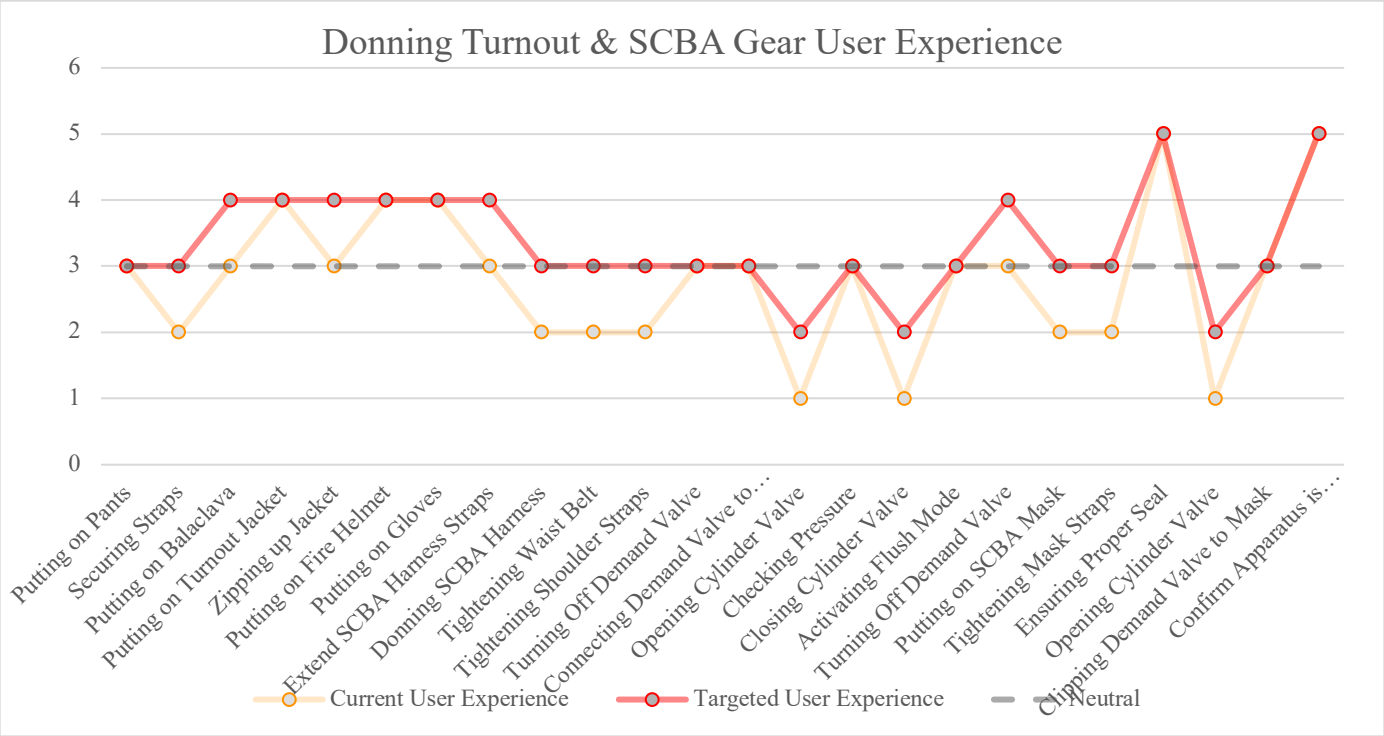


Figure 69 - Current User Experience vs. Targeted User Experience

Overall Analysis

5.1 Conclusion

In terms of key areas that informed design opportunities would be in the areas of wearable technology to be put on at the same time as the turnout gear. A secondary area is in the overall build of the suit. It may be possible to create a unibody suit to cut down on the response time. The third area would be within the process of donning the SCBA gear, with the specific step by step requirements.

Aside from the needs observed in the user observation, there are still several areas that need to be studied. One of the other major areas to study would be the needs during any other emergency call or car fire.

Overall this observation was fairly successful, however with the topic at hand of making firefighters jobs easier. It would have been helpful to see a fire academy demonstration or live fire training. Things to be done differently next time would be to get the firefighter to put on the SCBA gear without turning it on. This could be done to get better understanding of the whole process.

Appendix D

Benchmarking Pool

Product 1: Axis PBI Max™ 7.0 Bunker Coat
URL: https://www.thefirestore.com/store/product.aspx/productId/37439/Quaker-Safety-Axis-PBI-Max-7-0-Bunker-Coat/

Figure 70 – Quaker Axis PBI Max Bunker Coat. [Image] Retrieved from https://www.thefirestore.com/store/product.aspx/productId/37439/Quaker-Safety-Axis-PBI-Max-7-0-Bunker-Coat/

Description:
PBI™ Max 7.0 Gold Outer Shell:
7.0 ounces per square yard
Blend of 70% PBI/KEVLAR® spun yarns and 30% KEVLAR® filament yarn
Twill weave
Teflon F-PPE enhanced water repellent finish
Moisture Barrier: CROSSTECH® Black, 2F
4.7 ounces per square yard
NOMEX® IIIA woven pajama check substrate with a water repellent finish laminated to a CROSSTECH® enhanced bicomponent membrane comprised of an expanded PTFE (Teflon®) matrix with a continuous hydrophilic and oleophobic coating that is impregnated into the matrix
5-year warranty
Coat lengths: 32” regular length; 34” tall and 28” or 30” short lengths available
Innovative Flexion Patterning in all layers Three panel body with a full cut back
Four layers, 3” high stand-up collar with four-layer contoured throat strap provides internal moisture protection. Throat strap is secured with fire retardant hook and loop tape closure with no exposed hook and loop tape when in use
Advanced Thermal Enhancement System: Shoulders and upper back are thermally enhanced with an extra layer of outer shell and thermal reinforcement material. Elbows are thermally enhanced with an extra layer of thermal liner material
Streamlined narrow four-layer storm flap with heavy duty nylon zipper and 1.5” fire retardant hook and loop tape closure provides internal thermal and moisture protection

Cuffs are fabric reinforced for extended wear life (or your choice of Ara-Shield® or leather) featuring 4” black NOMEX®/Spandex Comfort-Fit wristlets
Fully detachable liner includes a liner inspection opening and an oversized pocket lined with moisture barrier material to keep contents dry
Drag Rescue Device: Fully removable Drag Rescue Device (DRD)
Underarm Bellows: Two-piece contoured sleeves with built-in underarm bellows for mobility, fit, a full range of arm movement, and limited coat rise
Bellows/Handwarmer Pockets: Two versatile expandable bellows/handwarmer pockets 9” h x 9” w x 2” d with fire retardant hook and loop tape closures and drainage eyelets
Scotchlite Triple Trim: 3" wide, Lime-Yellow

Quaker Safety garment moisture barriers and moisture barrier seams are tested for resistance against liquid and bloodborne pathogens and chemical penetration resistance against 5 common chemicals as specified in the NFPA 1971-2018 Edition Viral Penetration Resistance Test and the Liquid Penetration Resistance Test. Quaker Safety structural garments also meet requirements of OSHA 29 CFR 1910.156.

The requirements of this section apply to fire brigades, industrial fire departments and private or contractual type fire departments. Personal protective equipment requirements apply only to members of fire brigades performing interior structural firefighting. The requirements of this section do not apply to airport crash rescue or forest fire fighting operations.

Outer Shell: First line of defense to protect against heat, flame, cut, tear and abrasion resistance. Outer shell material is inherently flame resistant so the protective qualities will never wash out or wear away. The material is treated with a Teflon® finish to provide water and stain repellency.

Moisture Barrier: Second layer resists water and protect against body fluids and five common chemicals defined by NFPA 1971. The moisture barrier is also a key factor in managing the amount of energy transferred through the layers (total heat loss (THL) or breathability).

Thermal Liner: Third and thickest layer is a key factor in determining the thermal protective performance (TPP). This multi-layer material is comprised of a woven face cloth quilted to a batting of insulation. Most face cloths are treated with a wicking finish to enhance comfort by moving perspiration away from the body and spreading moisture for improved dissipation.

Price: $1459.99

Product 2: Crew Boss Gen II Response Jacket — S469/S362
URL: https://crewboss.store/collections/all-shirts-and-coats/products/gen-ii-response-jacket-s469-s362

Figure 71 - Crew Boss Gen II Response Jacket — S469/S362. [Image] Retrieved from https://crewboss.store/collections/all-shirts-and-coats/products/gen-ii-response-jacket-s469-s362

Description:

The future of single layer wildland PPE has arrived with the introduction of the Crew Boss Gen II Response Jacket. This NFPA 1977 certified jacket achieves new levels of breathability, thermal protection, and comfort. Combine the Crew Boss Gen II Response Jacket with a pair of Crew Boss Gen II Tactical or Uniform Pants, and you have the most advanced wildland garment system on the market.

Features

- Certified to NFPA 1977
- Extra-large YKK zipper closure
- Sewn in radio pocket
- Bellowed chest pocket lies flush when not in use
- Dual mic tabs
- Scotchlite silver reflective trim on both biceps
- Hook & loop collar closure
- Hook & loop cuff closure
- Bi swing back for added mobility

Performance

Style 469 (Arms)

- Heat protection (RPP): 10.5 cals/cm²
- Breathability (THL): 650 W/m²

Style 362 (Body)

- Heat protection (RPP): 9 cals/cm²
- Breathability (THL): 720 W/m²

About the Gen II Program

The Gen II system was created in conjunction with the US Department of Homeland Security, the Army's Natick research center, and numerous other government agencies. The goal of the program was to develop garments that could offer optimal protection against the risks faced by modern wildland firefighters. Flame resistance was a priority, but a high emphasis was also placed on breathability to reduce the risk of heat stroke and exhaustion in warm environments.

The program set high standards, all of which are met or exceeded by the Crew Boss Gen II Garment System.

Tencate Style 469™ and 362™

This version of the Gen II Response Jacket utilizes an innovative dual fabric system to maximize protection and function. For the body we used Tencate Style 362. This lightweight fabric is known for its superior breathability characteristics, so it is only natural that you would find it where most of your body heat is generated.

Since extremities are more prone to burns on the fire line, we needed a tougher, more protective material for the arms. For this we turned to TenCate Style 469, the same fabric that can be found in the Crew Boss Gen II Pants.

Both Style 362 and 469 were engineered for the optimum combination of thermal protection and durability while still providing unparalleled comfort. These rugged fabrics stand up to the toughest terrain, long hours and hard labor of real-world wildland firefighting.

Price: $312.00

Product 3: Globe Athletix Turnout Jacket
URL: https://globe.msasafety.com/Turnout-Gear/Jackets/ATHLETIX%E2%84%A2-Jacket/p/athletixJacket

Figure 72 – Globe Athletix Turnout Jacket. [Image] Retrieved from https://globe.msasafety.com/Turnout-Gear/Jackets/ATHLETIX%E2%84%A2-Jacket/p/athletixJacket

Description:

ATHLETIX™ JACKET New material technology enables all-new athletic design with stretch fabrics that allow closer, body-contoured fit to provide unprecedented range of motion with less bulk, more flexibility, and lighter weight.

MATERIALSNEW KOMBAT™ STRETCH PBI®/KEVLAR® fabric allows closer, less bulky fit with unprecedented range of motion and more flexibility, while providing premium thermal break open protection.

NEW NOMEX® NANO thermal barrier material is thinner, lighter, more flexible, more breathable, and quicker drying.

NEW 3M™ SCOTCHLITE™ COMFORT TRIM reflective material is segmented, and heat sealed to be lighter, more flexible, and breathable without sacrificing visibility.

GORE® CROSSTECH® BLACK moisture barrier provides the highest breathability in the widest range of environmental conditions to reduce heat stress.

JACKET FEATURESMORE STREAMLINED DESIGN with vertical seaming reduces oversize in front chest, bulk under SCBA, and stiffness in front closure.

YOCCO™ DRAG RESCUE DEVICE is easy to deploy when you need it, out of the way when you don’t.

EXTENDED BACK option allows you to choose to extend the back by 3” or 6” for additional overlap and lettering below the SCBA.

LINER ACCESS OPENING allows for easy access between the layers.

NEW, MORE FLEXIBLE SEAMS are safety-stitched and double-needle top-stitched for strength but are less bulky and lay flatter. Because ATHLETIX™ is loaded with standard features and the nature of the stretch outer shell fabric.

Certified to NFPA 1971 (Structural Fire Fighting).

LESS BULKY, SOFTER & MORE ADJUSTABLE COLLAR interfaces better with hood and helmet and reduces head restriction.

STRETCH PANELS in the thermal liner work with the stretch outer shell to provide maximum range of motion and minimum restriction.

DRD OPENING IN THE COLLAR takes bulk out of the upper back and allows better access above the SCBA.

ELASTICIZED SIDE PANELS provide flexible, more athletic fit at the waist.

ARTICULATED ELBOWS for body-contoured fit with minimum restriction.

OVERLAPPING FRONT CLOSURE WITH OPTIONAL ZIPPERGRIPPER™ to reduce bulk and permit quicker and easier donning and doffing.

CARGO POCKETS WITH GRIP TABS for quicker and easier access to all your stuff in the minimum amount of time.

TELESCOPING SLEEVE BAND WITH DOUBLE WRISTERS keeps water out and adds thermal protection.

Price: n/a

Product 4: Fire-Dex EMS Gear
URL: https://www.firedex.com/product/ems/

Figure 73 – Fire-Dex EMS Gear. [Image] Retrieved from https://www.firedex.com/product/ems/

Description:

EMS Gear by Fire-Dex provides the durability and protection your job demands.
Built specifically for Emergency Medical professionals and certified to NFPA 1999, our EMS gear offers a comfortable fit with a construction that is waterproof, breathable and bloodborne pathogen-resistant to protect you from line-of-duty hazards.

Certified to NFPA 1999.

EMS Gear by Fire-Dex provides the durability and protection your job demands, plus an array of customizable options to make this gear perfectly suit your needs. The outer shell is 6oz. Nomex®, available in yellow, navy, royal, or tan and comes with 3M™ Scotchlite™ Reflective Material. This gear is lined with Crosstech® EMS Fabric which provides great breathability and heat stress relief while maintaining liquid penetration resistance from blood, bodily fluids, and water.
Standard EMS Jacket

- 29" or 33" length jacket
- 6.0 oz. Nomex® outer shell available in yellow, navy, royal or tan
- Sewn-in Crosstech® EMS fabric
- Inner zipper/outer hook & loop closure
- 3M™ Scotchlite™ Reflective Material in 2" NFPA standard configuration, Lime/Silver or Red/Silver
- Two combination semi-bellows/hand-warmer pockets (9" x 9" x 2")
- Radio pocket on right chest (9" x 3" x 2")
- Patch pocket on left chest (8" x 6")
- Hook & loop cuff adjusters
- Optional zip-in fleece or nylon liners are available

Standard EMS Pant

- 6.0 oz. Nomex® outer shell available in yellow, navy, royal or tan
- Sewn-in Crosstech® EMS fabric
- Easy-on elastic waist*
- Two full-bellows pockets (8" x 8" x 2")
- 15" outer zippers on legs
- 3M™ Scotchlite™ Reflective Material in 2" Lime/Silver or Red/Silver around cuffs

Price: $1074.50

Product 5: 5.11 Tactical Responder Hi Visibility Parka
URL: https://www.511tactical.com/responder-hi-vis-parka-mens.html

Figure 74 - 5.11 Tactical Responder Hi Visibility Parka. [Image] Retrieved from https://www.511tactical.com/responder-hi-vis-parka-mens.html

Description:

Engineered specifically for EMS professionals, the Responder Hi-Vis Parka™ gives you the utility, performance, and reliability to respond effectively.

- Meets the requirements of ANSI/ISEA 107-2015 (not tested according to EN standards) Type R & P, Class 2 on high vis side
- Waterproof, breathable, functional
- Abrasion panels at shoulders
- High performance, waterproof 10,000mm fabric
- Partial hi-vis construction
- Zippered utility pockets at the sleeves
- Front flap pockets
- Zippered storage pockets at left chest
- Water resistant radio pocket
- Mic loops at each shoulder
- ID panel at right chest
- Three-way adjustable hood
- Reflective tape at sleeves, mid-line, and hem
- Hook and loop storm cuffs
- Double storm flap
- Elastic corded hem
- YKK® zipper hardware
- Prym® snaps
- Imported

Price: $424.35

Product 6: PGI Double Duty™ Green Indura® Ultra Soft® BDU Pants

URL: https://www.edarley.com/double-dutytm-green-indurar-ultra-softr-bdu-pants/

Figure 75 - PGI Double Duty™ Green Indura® Ultra Soft® BDU Pants. [Image] Retrieved from https://www.edarley.com/double-dutytm-green-indurar-ultra-softr-bdu-pants/

Description:

PGI Double Duty™ Green Indura® Ultra Soft® BDU Pants offer maximum comfort and protection with a functional design.

PGI's Double-Duty™ pants are dual classified to NFPA 1975 and 1977 Standards by Underwriters Laboratories for use as both station wear and wildland firefighting PPE. Now you can get the best of both worlds – a good looking and comfortable station wear pant which is great for working around the station or being worn in pubic yet rugged and protective enough to be worn on the fireline. PGI's signature relaxed fit and functional design is sure to make the Double-Duty™ BDU pant a station wear favorite.

- Signature relaxed fit for maximum mobility and comfort
- Rear of waistband is elasticized for maximum freedom of movement and comfort
- Oversized double needle top stitched bellowed cargo pockets on thighs expand to give you plenty of storage capacity for firefighting accessories and secure with hook and loop flap closures
- Front slash pockets have extra deep bags and are contoured to keep contents from falling out
- Two large rear double needle top stitched patch pockets with hook and loop flap closures
- Corrosion-resistant brass snap at waist
- Double reinforced crotch panel extends wear life
- Hook and loop ankle straps backed with self-fabric adjust close through metal box ring take up
- Leg outseams are sewn with five-thread safety stitch, then top stitched with a double-needle lockstitch
- All points of stress are bartacked
- Meets or exceeds NFPA 1977 Standard on Protective Clothing and Equipment for Wildland Fire Fighting (Current Edition)
- Compliant with NFPA 70E (Current Edition) – Meeting the performance specifications of ASTM – F-1506 for wearing apparel used by electrical workers exposed to arc and related thermal exposures
- Meets CAL-OSHA Requirements – Passes Fed. Test 191, Method 5903.2; CAL-OSHA Sections 3406(d)
- Complies with OSHA Rule 29 CFR Part 1910, 269

Price: $189.95

Product 7: Arcteryx Ski Guide Jacket

URL: https://arcteryx.com/ca/en/shop/mens/ski-guide-jacket

Figure 76 - Arcteryx Ski Guide Jacket. [Image] Retrieved from https://arcteryx.com/ca/en/shop/mens/ski-guide-jacket

Description:

Durable, full featured GORE-TEX Pro jacket designed for professionals.

Hardwearing and highly versatile, the Ski Guide Jacket is designed for guides and mountain professionals to carry the tools of their craft while operating in harsh mountain environments. Light and rugged, the N80p-X 3L GORE-TEX Pro fabric is proven in severe conditions. Maximum pocket configuration includes a high-volume chest pocket and internal mic clip to accommodate radios. The helmet compatible DropHood™ delivers full protection without impeding peripheral vision.

Weight:
555 g / 1 lb 3.6 oz
Fit:
Regular Fit, Hip Length, with e3D patterning, Centre back length: 78 cm / 30.75 in

Technical Features

- Waterproof
- Windproof
- Breathable
- Lightweight
- Durable

Construction

- Micro-seam allowance (1.6 mm) reduces bulk and weight
- Strategically placed narrow GORE seam tape (8mm width)

Patterning

- e3D Ergonomic 3-Dimensional patterning for enhanced comfort and mobility
- No-lift gusseted underarms

Hood Configuration

- Laminated brim
- Helmet compatible DropHood™
- Highly visible Orange hood is easily identifiable from the ground or air
- Cohaesive™ hood adjustments for ease of use with mittens or gloves

Collar Configuration

- Laminated chin guard with brushed microsuede facing for added comfort
- Removeable Recco® reflector in back collar

Zippers & Fly Configuration

- WaterTight™ external zippers
- Pit zippers for easy venting
- Full front zip with wind flap
- TPU zipper pulls

Cuff & Sleeves Configuration

- Die-cut Velcro® cuff adjusters reduce bulk, and won't catch or tear off

Hem Configuration

- Drop back hem
- Cord adjusters are split to prevent accidental clipping with a carabiner
- External Cohaesive™ hem adjusters' function as Hemlock™ to prevent jacket from slipping out from under a climbing harness

Pocket Configuration

- Two hand pockets with WaterTight™ zippers
- Left chest pocket is sized to be radio compatible with internal routing and mic clip for comms
- Internal zippered pocket
- Internal mesh dump pocket
- Two high, crossover hand pockets with WaterTight™ zips
- Note: Our WaterTight™ zippers are highly water resistant, but not waterproof. We do not recommend keeping items in your pockets that may be damaged by moisture
  Fabric Treatment
- Arc'teryx Nu water repellent treatment

Price: $1050.00
Product 8: Patagonia Iron Forge Hemp® Canvas Insulated Overalls

URL: https://www.patagonia.ca/product/mens-iron-forge-hemp-canvas-insulated-overalls-regular/55765.html?dwvar_55765_color=COI&cgid=sport-workwear-mens#tile-23=&start=1&sz=48

Figure 77 - Patagonia Iron Forge Hemp® Canvas Insulated Overalls. [Image] Retrieved from https://www.patagonia.ca/product/mens-iron-forge-hemp-canvas-insulated-overalls-regular/55765.html?dwvar_55765_color=COI&cgid=sport-workwear-mens#tile-23=&start=1&sz=48

Description:

Made from our innovative 12.9-oz Iron Forge Hemp™ canvas, which is 25% more abrasion resistant than conventional cotton duck canvas and needs no break-in, these rugged overalls keep you warm with quilted 60g Thermogreen® insulation. Features heavy-duty nylon double-denier reinforcements at main contact points; strategic pockets and handwarmers on the bib. The doubled knees have bottom openings that accommodate knee pads and allow easy cleanout. Ankle-to-thigh zipper/snap closure legs for easy on/off. Fair Trade Certified™ sewn.

Built to stand up to day-in, day-out work, our Iron Forge Hemp® Canvas Insulated Overalls are made from strong and supple 12.9-oz 55% industrial hemp/27% recycled polyester/18% organic cotton cloth that's 25% more abrasion resistant than conventional cotton duck canvas and needs no break-in. One of the world's strongest natural fibers, the hemp content provides superior toughness and durability; the recycled polyester and organic cotton provide a soft hand and allow a tighter weave for increased abrasion resistance. Quilted 60g Thermogreen® insulation keeps you warm in blustery weather, while reinforced nylon double-denier fabric at the knees, seat and kickplate ankles adds protection at high-contact points. The bib features adjustable suspenders, a zippered chest pocket for valuables with an added snap-closure pocket, a pencil holder and handwarmer pockets. Horizontal gussets on the deep front pockets hold an everyday-carry knife or tape measure. A button-front adjustable waist, a zipper fly and zippered legs from ankle to thigh make for quick on/off even while wearing boots, and a snap closure covers the zipper to prevent damage and icing. The doubled knees have bottom openings that accommodate knee pads and allow easy cleanout; reinforced seat pockets and a hammer loop keep your hand tools handy. Hang 'em high at quittin' time with the locker loop. Inseam is 32". Fair Trade Certified™ sewn.

- Made from strong and supple 12.9-oz 55% industrial hemp/27% recycled polyester/18% organic cotton cloth; quilted 60-g Thermogreen® insulation
- Adjustable suspenders; locker loop; zippered chest pocket for valuables with an added snap-closure pocket, pencil holder and handwarmer pockets
- Horizontal gussets on the deep front pockets for everyday-carry knives or tape measures; reinforced seat pockets; hammer loop
- Button-front adjustable waist and zippered fly
- The doubled knees have bottom openings that accommodate knee pads and allow easy clean out. Ankle-to-thigh zippered legs with snap closure cover for easy on/off. Reinforced double-denier nylon kick-plates on seat, knees and ankles

- Inseam is 32"
- Fair Trade Certified™ sewn
- 2,067 g (72.9 oz
  12.9-oz 55% industrial hemp/27% recycled polyester/18% organic cotton.
  Lining: 100% recycled polyester taffeta.
  Insulation: 60-g Thermogreen® 100% polyester (92% recycled).
  Fair Trade Certified sewn

To accommodate a wide range of movement and layering, our Workwear styles have a generous cut. The pants fit true to waist size but are roomy through the legs. The jackets are bigger than most of our styles—especially around the shoulders and back. Folks who have a leaner build or don't wear multiple layers might want to order one size smaller than usual.

Price: $249.00

Product 9: Patagonia Airshed Pullover ¼ Zip
URL: https://www.patagonia.ca/product/mens-airshed-running-pullover/24190.html?dwvar_24190_color=BLK&cgid=sport-trail-running-mens-jackets-vests#tile-3=&start=1&sz=24

Figure 78 - Patagonia Airshed Pullover ¼ Zip. [Image] Retrieved from https://www.patagonia.ca/product/mens-airshed-running-pullover/24190.html?dwvar_24190_color=BLK&cgid=sport-trail-running-mens-jackets-vests#tile-3=&start=1&sz=24

Description:
The Airshed became an instant favorite among our endurance testers for its on-the-go breathability and wind buffering—it inhabits the sweet spot between baselayer and light shell. Born of discoveries from our revolutionary Nano-Air®, the Airshed uses a soft, stretchy, whisper-light 100% nylon mechanical-stretch ripstop fabric that helps create a highly breathable and fast-drying microclimate, whether worn over a thin tee or more insulative underlayers. The quarter-zip allows for venting, a zippered chest pocket doubles as a stuffsack (with reinforced carabiner clip-in loop) and the stretch-knit cuffs and hem seal out weather and maintain comfort. With reflective logo on left chest and center-back neck, and a DWR (durable water repellent) finish.

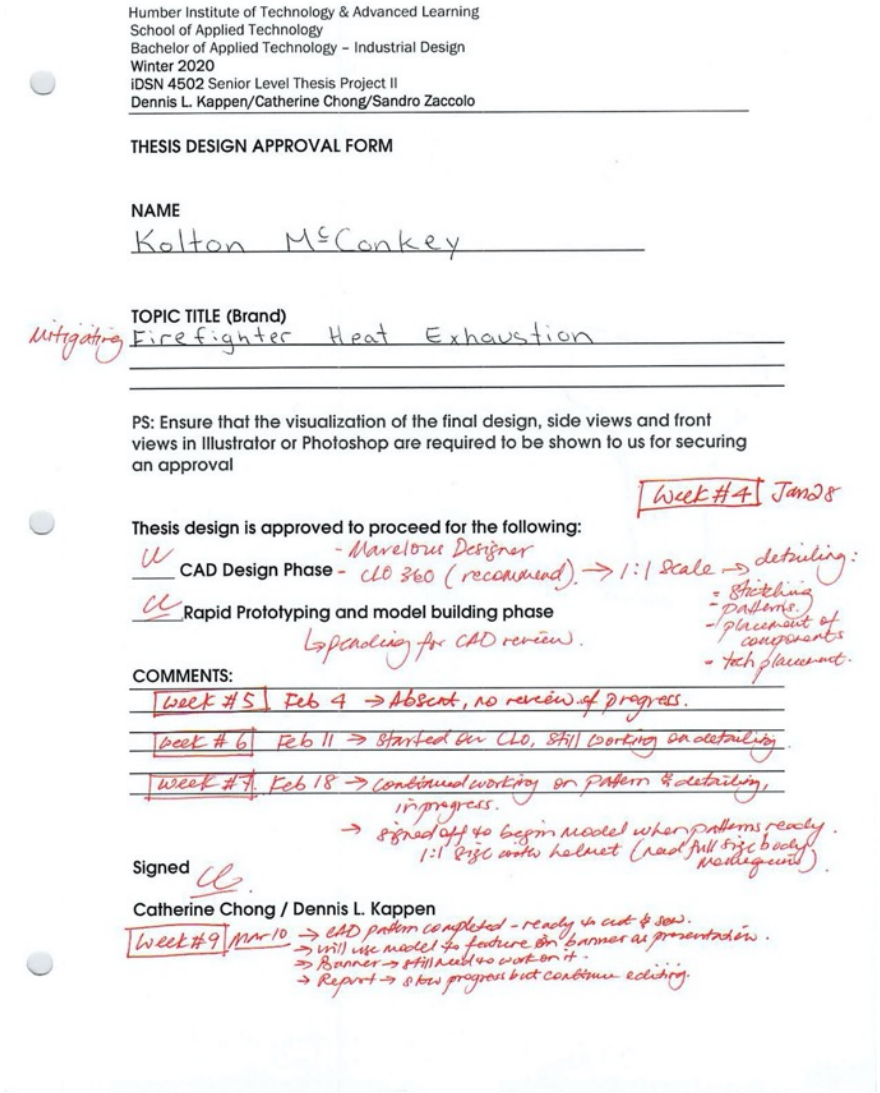
Features

- Ultralightweight 100% nylon ripstop with stretch for ease of movement. A DWR (durable water repellent) finish provides additional moisture protection, while a 4.2-oz jersey fabric wicks moisture along the cuffs and hem
- Zippered chest pocket converts to stuffsack with a reinforced carabiner clip-in loop
- Quarter-zip allows for venting
- Reflective logo on left chest and center-back neck
- Stretch knit at cuffs and hem keeps out weather, dries fast and wears softly under gloves or a pack
- Fair Trade Certified™ sewn
- 105 g (3.7 oz)

Materials
Body: 1.3-oz 20-denier 100% nylon mechanical-stretch ripstop with a DWR (durable water repellent) finish.
Hem and cuff panels: 4.2-oz 79% nylon/21% spandex jersey.
Fair Trade Certified™ sewn

Price: $149.00

Appendix E



Humber Institute of Technology & Advanced Learning
School of Applied Technology
Bachelor of Applied Technology – Industrial Design
Winter 2020
iDSN 4502 Senior Level Thesis Project II
Dennis L. Kappen/Catherine Chong/Sandro Zaccolo

THESIS DESIGN APPROVAL FORM

NAME
Kolton McConkey

TOPIC TITLE (Brand)
Mitigating Firefighter Heat Exhaustion

PS: Ensure that the visualization of the final design, side views and front views in Illustrator or Photoshop are required to be shown to us for securing an approval

Week #4 Jan 28

Thesis design is approved to proceed for the following:

u CAD Design Phase - Marvelous Designer - CLO 360 (recommend). → 1:1 Scale → detailing:
- Stitching
- patterns.
- placement of components
- tech placement.

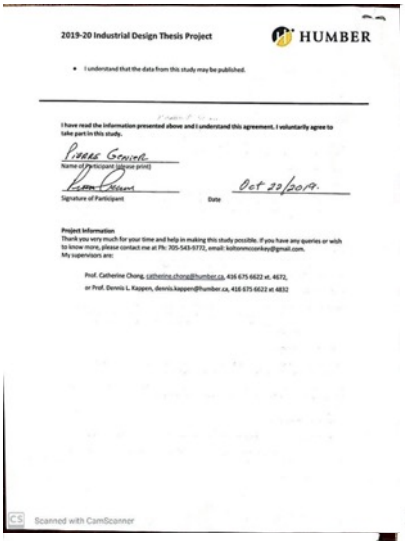
u Rapid Prototyping and model building phase
↳ pending for CAD review.

COMMENTS:
Week #5 Feb 4 → Absent, no review of progress.
Week #6 Feb 11 → Started on CLO, still working on detailing.
Week #7 Feb 18 → continued working on pattern & detailing, in progress.
→ signed off to begin model when patterns ready. 1:1 size with helmet (need full size body mannequin).

Signed u.
Catherine Chong / Dennis L. Kappen

Week #9 Mar 10 → CAD pattern completed - ready to cut & sew.
→ will use model to feature on banner as presentation.
→ Banner → still need to work on it.
→ Report → show progress but continue editing.

Appendix F


2019-20 Industrial Design Thesis Project

HUMBER

- 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.

Name of Participant (please print)

Signature of Participant Date Oct 20/2019.

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, please contact me at Ph: 705-543-9772, email: koltonmcconkey@gmail.com.

My supervisors are:

Prof. Catherine Chong, catherine.chong@humber.ca, 416 675 6622 xt. 4672,

or Prof. Dennis L. Kappen, dennis.kappen@humber.ca, 416 675 6622 xt 4832

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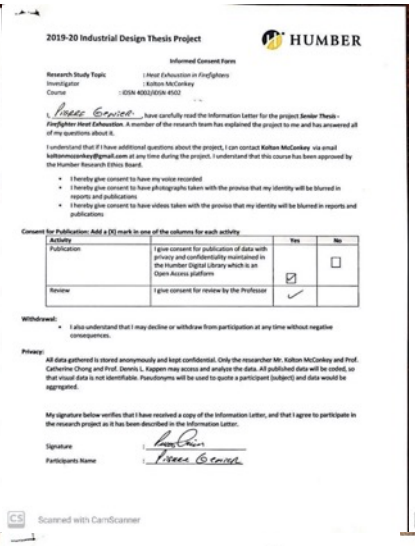
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HUMBER

Informed Consent Form

Research Study Topic : *Heat Exhaustion in Firefighters*

Investigator : Kolton McConkey

Course : IDSN 4002/IDSN 4502

I, [signature], have carefully read the Information Letter for the project ***Senior Thesis - Firefighter Heat Exhaustion***. 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 **Kolton McConkey** via email koltonmcconkey@gmail.com at any time during the project. I understand that this course has been approved by the Human Research Ethics Board.

- I hereby give consent to have my voice recorded
- I hereby give consent to have photographs taken with the proviso that my identity will be blurred in reports and publications
- I hereby give consent to have videos taken 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 of data with privacy and confidentiality maintained in the Humber Digital Library which is an Open Access platform	☑	☐
Review	I give consent for review by the Professor	✓	

Withdrawal:

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

Privacy:

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Signature :

Participants Name : [signature]

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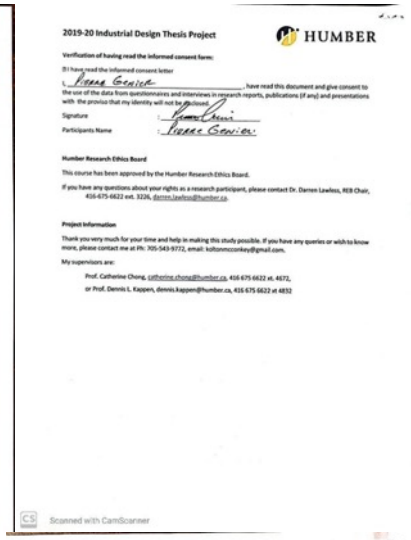
2019-20 Industrial Design Thesis Project

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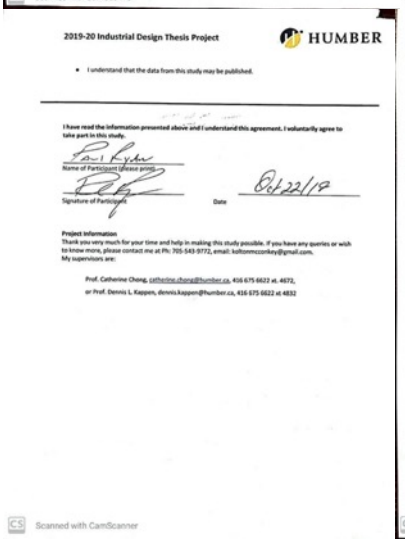
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Name of Participant (please print)

Signature of Participant Date 06/22/19

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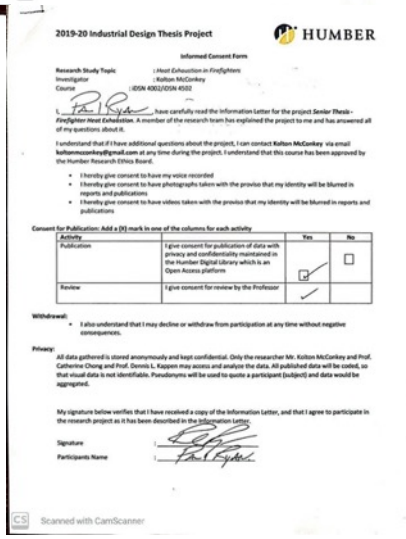
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Course : IDSN 4002/IDSN 4502

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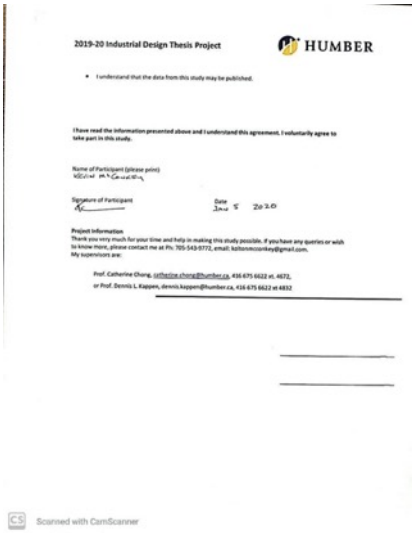
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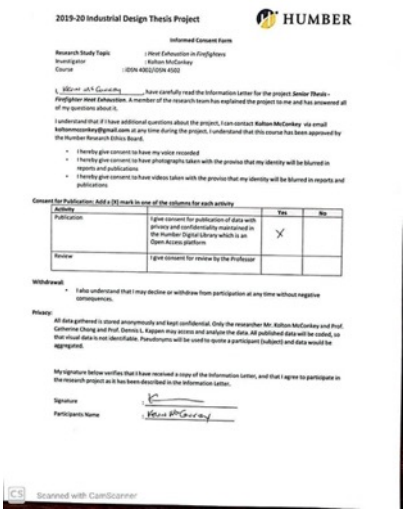
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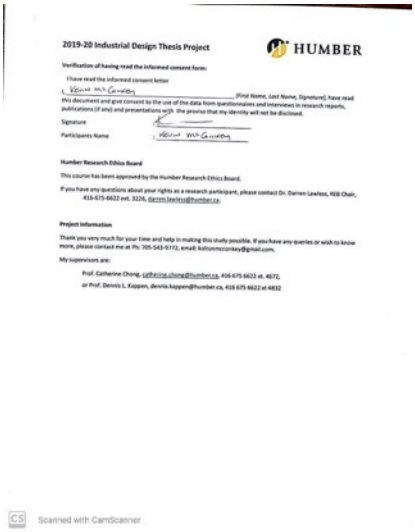
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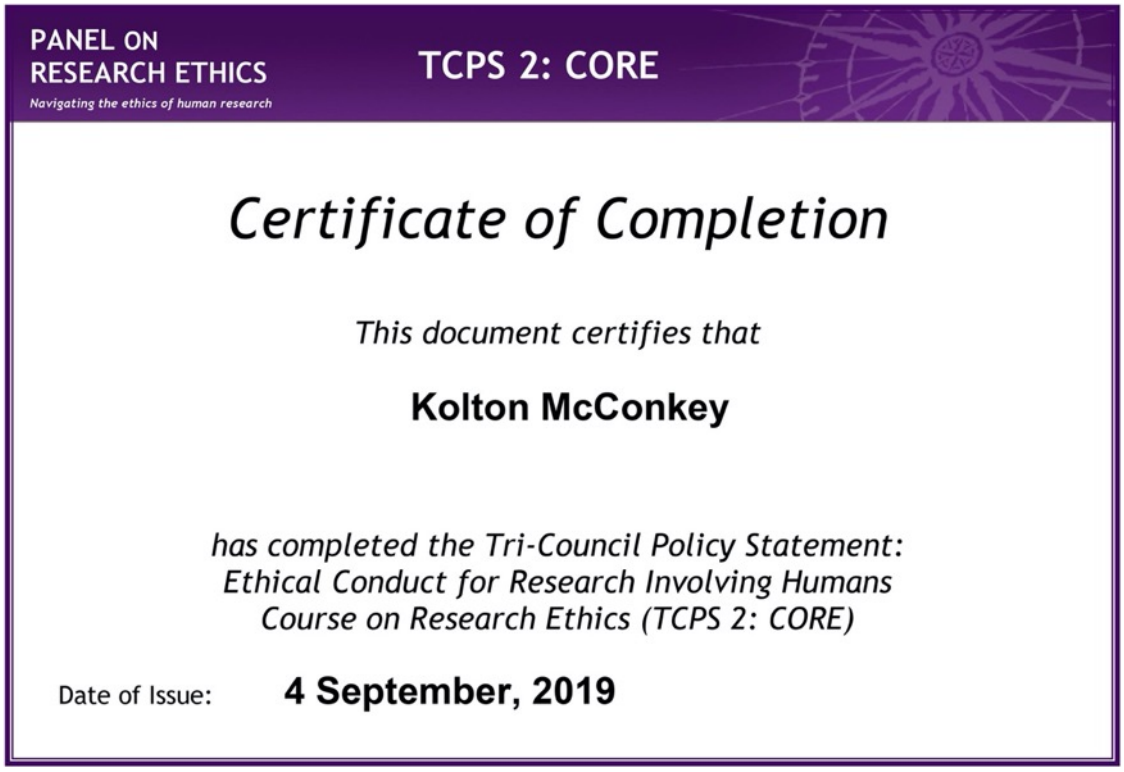
Appendix G



PANEL ON RESEARCH ETHICS
Navigating the ethics of human research

TCPS 2: CORE

Certificate of Completion

This document certifies that

Kolton McConkey

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

Date of Issue: **4 September, 2019**