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Paramedic Safety Project

by

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Abstract

The ability of paramedics to provide the most efficient care is closely dependent on the effectiveness of the tools with which they work. As technology improves, the quality of care offered by paramedics should also advance. This project presents a background dealing with paramedics' safety and establishes changes to improve the safety of paramedics. In the course of the investigation several areas of potential improvement are identified. One such area of improvement is the development of a new paramedic suit that is light and equipped with technological and storage capabilities. The storage capacity of the new suit provides an opportunity for paramedics to readily access clinical pocket instruments and materials that support paramedics work. A GPS tracking system is incorporated into the new suit. The GPS in the new suit will gather aerial data and transmits them into a central computer. Paramedics are often integrated with search and/or rescue teams, and in unfamiliar and rough terrains paramedics may become separated from one another. The GPS in the new suit will help to track and locate every paramedic in an accident scene or terrain. Paramedics that need help can be located and supported. Additionally, it can increase effectiveness by improving the ease of coordination between EMS station and paramedics. The new suit is gender neutral and is built to be flexible in order to support wide range of body movements. New materials are used for the suit to withstand certain levels of hot temperatures and water penetration. The pockets in the new suit are located in areas that minimize the necessary movements of the paramedics. Pockets play a crucial role in the functionality of paramedics' uniform. The revised design uses different size, shape, and quantity of pockets deemed necessary for paramedics' safety. Because of the simpler movements required by the new suit, the long term risk for the occurrence of injuries will reduce

substantially. The new suit is also built to decrease the risk of exposure to bodily fluids and fluid borne viruses. It allows paramedics to comfortably maneuver in a wider variety of scenarios without the fear of contaminants. The proposed new suit provides significant improvements over what paramedics are currently using.

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CHAPTER 1: THE IMPORTANCE OF PARAMEDICS

Emergency Medical Services had existed for several decades but as time went on and technology improved, the EMS field of progress grew slower. For an Emergency Medical Technician, safety was the most vital aspect of the job. Ironically, safety of the EMT was rarely examined and that is why this project aims to improve safety for the medic. In the 1970's EMS was used primarily for transport and no pre-hospital work was done on the patient. However, that was no longer the case in EMS which had evolved to be the Emergency Room on wheels. For this reason, paramedics had been called upon to take on more responsibility. With increased training came a greater variety of emergency scenarios, which included car accidents, water rescue, and transport among others. The pronounced increase in calls and training had made more equipment necessary to allow the EMTs to be ready for any situation. It was a trend which was only likely to increase in the future; more training resulted in more patients and more calls, and necessitates the use of more equipment.

This project began asking medics what they would like to see in the uniform: How would redesigning a uniform improve the safety of the medic? The more the current uniform design and the uniforms used by firefighters, police, and NASCAR drivers were examined, the more apparent it became that this uniform idea for medics would provide better safety while on duty. This project aimed to create a uniform that was comfortable to wear during a typical twelve-hour shift or a twenty-four hour on call shift. It not only wanted the uniform to provide comfort but also to be functional in different climates; the revised uniform design aimed to be able to provide support, versatility, and protection for the medic on duty. The ultimate goal of the project was to

make the uniform so diverse, that it would be worn in urban or rural areas, and in private or state ambulances.

Initially both a one piece and two piece suit design were considered. Although a one piece suit seemed to have had certain merits, after extensive consideration it seemed more practical and beneficial to improve upon the current two piece suit design. One feature that would be beneficial to medics but was not currently a part of the EMS uniform was some form of fire protection. In some states, and particularly in small towns, it had becoming increasingly common to have EMS and Fire together for financial purposes. Although medics were not always trained in fire safety, nor would they respond to a call involving fire, it was still beneficial for the medic to be wearing some type of fire protection during any situation because the nature of field work could be somewhat unpredictable. As such, it seemed apparent that some fire protection would benefit the medic from any branch of EMS. Although EMS would not be entering a burning structure, medics had to enter in hostile situations including motor vehicle accidents, transporting a patient to and from the hospital, or house calls. Adding an extra layer of fire protection to the EMS uniform would provide help to the medic in any situation.

The background information examined in Chapter 2 summarizes the history and development of EMS and provides a starting point for future. Chapter 3 examines the development and final form of the new suit design. This includes sections discussing material properties and options, development of a GPS device and tracking method, and fundamental change and additions incorporated in the overall design of the suit. The final Chapter summarizes the work done and discusses areas that can be further developed with continued work.

CHAPTER 2:THE HISTORY OF EMS AND PARAMEDICS

2.1: EMS World History

Although Emergency Medical Services (EMS) has existed for many centuries, it wasn't until relatively recently that the name was established. Some of the earliest forms of medical ambulances first appeared in Europe in 1487, when Spain recorded the first use of an ambulance. These ambulances were primarily used by the military to carry wounded soldiers off the battlefield; but according to records there was no medical care given to the wounded onboard (Ambulance [1]). In the 1800's, a similar use of an ambulance vehicle on the battlefield was used. However in these cases it was used not just for the transport from an ambulance off the battlefield, but also for providing medical aid to the wounded. One of Napoleon's surgeons was the first to design a special vehicle that could carry a medical attendant and be able to go directly to the battlefield, treat the wounded, and transport them to a nearby hospital for additional medical treatment (Ambulance [1]).

2.2: USA EMS History

In 1860 the same idea of an ambulance and medic was adopted in the United States during the Civil War. Five years later the first civilian ambulance was established by the Commercial Hospital of Cincinnati, Ohio (Ambulance [1]). It was the nation's first ambulance service but within a few years a tremendous rise of hospital ambulance services was created throughout the United States. Boston, Massachusetts is one of the cities with the oldest ambulance delivery service that transported its first patients as early as 1890 (City [2]). The

ambulances used in Massachusetts during that time were typically carriages manned with medically trained personnel, which allowed for the administering of medical treatment before arrival at the hospital. If the patient required more intense care such as included surgery, then a surgeon would then be dispatched and would ride with the ambulance crew to better provide to those needs. Boston medical services were making additional progress in the 1900's by establishing a simple communication system that was used by ambulance personnel (City [2]). A communication device was placed at the front of hospital gates and when an ambulance was approaching the hospital, a gatekeeper would phone in the emergency hospital staff to decrease the delay between patient arrival and continued treatment. Then the hospital staff members would bring stretchers and meet them where the ambulance parked.

Communication was not the only improvement made during that time frame. Ambulances were also beginning to change when police department ambulances quickly replaced the commonly used horse-drawn ambulances. In Massachusetts, the majority of the work being done by medical personnel was done on police department ambulances. There were city hospital ambulances present during that time and in many cases they remained until the twentieth century. By the early 1900's there were "interns" riding on the ambulances in attempts to provide medical care (Steward [3]). These interns would generally be dispatched by hospitals aboard the ambulances to provide better quality care on the scene as well as to help with the transportation. Although EMS was emerging in cities throughout the United States, it was also being used extensively in the military. All military personnel were required to be examined by medical officers in order to qualify for duty. The size of the regiment was also key in determining what ambulance was assigned to them. All ambulance personnel were fully trained

to provide care for the soldiers in need of medical attention. The use of medics riding in the ambulance had come a long way since the Civil War.



Figure 1 World War II Ambulances [20]

During World I, medical teams used electric, steam, and gasoline powered carriages for transportation. It was the first war to use a traction splint which is still commonly used today. Another innovation was made in communication, namely the use of signal boxes by soldiers in the field to help medical teams locate the injured on the field. World War I impacted not only the world but it also changed EMS drastically. Later, in World War II physicians were commonly drafted into the military in order to provide medical services. One of the vehicles used in medical transport during war can be seen in Figure 2 on the following page. At this time period, EMS was run primarily by funeral homes which was a tremendous change from the early 1900's when EMS was mainly run by hospitals. The shift came about because the hospitals were neither able to fully staff ambulances nor to acquire sufficient qualified medical personnel to provide onboard aid. As a result hospitals began to discard the concept of emergency healthcare provided by ambulances. Eventually, funeral homes began to provide this community service but only at a

transportation level, rather than offering treatment. In addition to services run by funeral homes, EMS was also used by commercial services and occasionally by voluntary rescue units (Steward [3])



Figure 2 1948 Cadillac Miller Ambulance Model #76-481 [21]

In the states, a modern EMS had begun to establish. During the 1950's EMS was used in five different types of business. The main business using EMS was funeral homes, followed by other businesses such as towing operators, medical equipment companies, hospitals, and police/fire departments (History, [4]). Funeral homes provided half of the country's ambulances, such as the one displayed in the Figure above, and the rest was distributed amongst the four other businesses. By the 1960's, there was a public outcry to make a more organized EMS program. The president of the Commission of Highway Safety called to institute a program that would train emergency personnel to be able to provide emergency care and transport the sick/injured

(Rockwood [5]). However, it wasn't until 1965 that a wave of newspaper articles and publications showed the drastic need to begin an EMS system. One report found that at least fifty percent of the nation's ambulances at that time were being provided by twelve thousand morticians (Department of Health [6]). Another publication made by the National Academy of Sciences (NAS) titled "Accidental Death and Disability: the Neglected Disease of Modern Society" began to receive popularity. It showed that in 1965 there were approximately fifty two million accidental injuries which killed one hundred and seven thousand Americans in that year alone. Ten million Americans were temporarily disabled and four hundred thousand were permanently impaired adding up to a total cost of eighteen billion dollars that year (Department of Health [6]). NAS made several recommendations in trying to come up with a solution to this problem. In later publications, NAS stressed the need of establishing a standard ambulance design, the need to train adequate personnel, and the need of adding more equipment/medical supplies to the ambulance services. All of the publications drew enough public attention to get noticed by Congress. In 1960 President John F. Kennedy declared that "Traffic accidents constitute one of the greatest, perhaps the greatest of the nation's public health problems" (History [4]). Then in 1966 President Lyndon B. Johnson and the president's Commission on Highway Safety/NAS created the National Highway Traffic Safety Act. This act standardized EMS training, recommended radio communication, and stressed a single emergency number (911) (History [4]). Not only did this act suggest changes to the current EMS system they had in place but it also formed the Department of Transportation (DOT).

There were several issues concerning EMS programs at that time. The first issue was that there was a lack of adequate federal, state, and local laws. During that time only six states had written laws. The second issue regarded the poor equipment on the ambulances; they were of

inadequate design and quality which was hindered by lack of space for the patient and proper equipment. The third issue was radio communications between emergency personnel and hospitals: only five percent of the nation's ambulances had radio contact with hospitals. The fourth problem was that the training that EMS personnel had in order to administer adequate quality care was insufficient. About fifty percent of the nation's EMS personnel's were American Red Cross certified and the majority of them had no training at all. The fifth difficulty faced was that emergency rooms were being staffed by physicians that were in adequate to deliver emergency care or had no experience/training with trauma (Rockwood [5]). One of the biggest hindrances presented to the nation was federal funding. With adequate funding, EMS would be able to correct all of these problems and be up to standards. The first nationally recognized training occurred in Wausau, Wisconsin (Department of Health [6]). The DOT curriculum was coordinated by Dr. Joseph D. 'Deke' Farrington of Minocqua. Some of his famous accomplishments for the EMS system were inventing the spine board, proper use of extrication and establishment of the original eighty one hour curriculum to become an EMT (Department of Health [6]). Dr. Farrington became very passionate in the EMS system and encouraged many other physicians to become involved in their state/local EMS programs. A textbook for EMS personnel by the American Academy of Orthopedic Surgeons (AAOS) was created in the late 1960's. The book was called "Emergency Care and Transportation of the Sick and Injured" (Hyatt [7]). To this day, that textbook is known as the very first authorized textbook for EMT's. The newly developed EMS program became so popular that in 1971, a television show was created called "Emergency!" The show caught attention of the media and the public was able to connect with the people to show them what paramedics do and why their services are

important. It depicted paramedics as life savers and presented them in a rescue team rather than being able to administer medical care.

Now that the program was beginning to be popular from state to state, the majority of the EMT's that graduated from the programs worked as volunteers. More ambulance services were formed but training required more time. Wisconsin was the first state to begin an extensive program that certified more than four thousand EMT's. The training they received was at the Basic Life Support care (BLS). During this time other states were trying to create a different version of that program, a paramedic program that would include the administration of medications and the delivery of advanced protocols (Department of Health [6]). Some cities such as Milwaukee provided a paramedic course that was at the Advanced Life Support care (ALS). Assessments in the EMS system became evident in the early 1970's. Helicopters were being used for testing purposes on how it could adequately be used for medical purposes. They used military helicopters and paramedics in civilian emergencies (Gonsalves [8]). The testing of medical helicopters occurred five times that year. In 1971, EMT training was brought to an even greater level. The committee in injuries of the AAOS hosted a national workshop on the training of EMTs (Gonsalves [8]). They endorsed basic and refresher courses, and that EMS be organized not only on a regional level but also on a district basis with state protocols. It also pushed a standard use of textbook which at that time was the "Emergency Care and Transportation of the Sick and Injured". The text was continuously revised updated (Gonsalves [8]). The workshop also stressed that physicians should be responsible for the excellence and completion of the course and recommended that physicians should try to teach as many courses as they can. Furthermore, the instructors had to receive special training in an "Instructors Training Course" (Gonsalves [8]). Advanced Red Cross first aid certification was encouraged as a prerequisite to

the basic level of EMT's. There were courses offered dealing with extrication and equipment handling. In 1973, the EMS Systems Act was created which established three hundred EMS systems throughout the United States. Not only was the program beginning to come together, but there was also over five hundred million dollars in funding for the EMS programs. At this time, DOT adopted a training curriculum for first responders, EMT-B, EMT-I, and EMT-P.



Figure 3 1976 Easton EMS Ambulance [19]

2.3: Different Levels of EMS Certification

The first level of emergency medicine is the first responder's curriculum. The certified First Responder has successfully completed an approved First Responder Course which is typically 40-60 hours in length. First Responders are trained in the use of Automatic External Defibrillators (AED), CPR, oxygen administration, bandaging, splinting, and emergency childbirth (Bureau of Labor [9]). The second level is an EMT-Basic. The EMT-Basic has



Figure 4 Typical EMT Uniform [22]

successfully completed an approved EMT Course which is typically about 150 hours in length. EMTs are trained in the use of all First Responder procedures and additionally non-visualized airways, administration of nitroglycerin, epinephrine with an Epi-Pen, aspirin, and activated charcoal (Activated Charcoal is no longer used) (Bureau of Labor [9]). The third level is EMT-

Intermediate. The Advanced EMT has successfully completed an approved EMT Course plus an Advanced EMT Course which is typically a total of about 250 hours in length. Advanced EMTs are trained in everything covered up to EMT Basic and also in the use of manual defibrillators, intravenous access (IV), and cardiac monitoring. The most advanced level is EMT-Paramedic. The Paramedic has successfully completed an approved EMT Course plus a Paramedic Course which is typically a total of about 1,500 hours. Most advanced paramedic courses now take between 18-24 months to complete. Paramedics are trained in all of the BLS skills and in the use of manual defibrillation, transcutaneous cardiac pacing, 12 lead ECGs, advanced airway management, including surgical airways, intravenous access, which involves placing a needle in a bone and using the bone marrow as a fluid, medication route and pharmacology (LifeMed's paramedics have access to nearly 40 medications). Additionally, paramedics are trained perform pleural decompression which is a treatment to inflate collapsed lungs, CPAP and Rapid Sequence Induction.

A public Law 93-154 “EMS Systems Act of 1973” amended the Public Health Service Acts of 1944 by adding title XII (93rd Congress [10]). The following amendments were made:

1. Terms were defined
2. Grants and contracts are authorized for feasibility studies.
3. Monies were made available nationally to plan, establish, and provide initial operation of EMS systems.
4. Provisions were made to expand and improve existing EMS systems
5. EMS was placed under the Director of EMS programs, Health Services Administration, US Department of Health, Education, and Welfare.

6. Research grants were provided.
7. Requirements for funding were set forth.

In the late 1970's, EMS received continual funding at the federal level. But by 1982 all of the federal funding ended and it was up to the states and local government to provide all of the necessary funding to adequately keep improving EMS (93rd Congress [10]). Today EMS has made several changes from what it used to be. For example there are three types of ambulance services; public, private, and air ambulances. With the public ambulances, these ambulances are dependent on funding through the state. This state funding is one of the reasons it is becoming more common to see some states join fire and EMS for cost purposes. Private ambulances on the other hand operate on a fee-for-service basis to the patient, or by means of contracts with local municipalities (Bureau of Labor [9]). In today's era, air ambulance is becoming one of the most widely used emergency ambulance types. There are some instances where it is difficult for an ambulance to get to or the hospital could be too far away, in special cases such as these a helicopter would respond. However, air transport has not become the only other way of transportation for EMS. Today in some areas we are even seeing EMT's on bikes. Since EMTs are needed in a variety of events such as a concert, camps, sporting events, etc., EMTs need a different type of transportation. Allowing EMT's to respond on bicycles is being more widely adopted in recent years.

CHAPTER 3: RESEARCH AND APPLICATION OF A PARAMEDIC SUIT

3.1: Timeline of Research Progress

- External safety harness
 - Paramedic safety in ambulance
 - Crash test videos
 - Paramedics thrown, dangerous, current harnessing systems turn paramedic into pendulum
 - New harness design with 3 points of connection to reduce ability to swing
 - Not practical
 - Mobility issues
 - Possible restraining issue in CPR situations would necessitate the harness having a quick release at which point paramedic is no longer protected
 - Current seatbelts and safety protocols are not followed and not used
 - Not comfortable
 - Not esthetically pleasing or professional looking
- Incorporated the harness into the suit
 - Entire suit acts as a harness
 - One piece 'life flight' uniform
 - Inconvenient for restroom
 - If any part fails, the whole things must be replaced
 - Back support
- Oxford meeting
 - Tour of ambulance
 - Space for harnessing system not sufficient
 - Discussion of GPS in suit
 - Field work/ rescue efforts
 - Is a given unit still at hospital or on the way back to the station?

- Harnesses discarded for space , comfort, and quick release issues
- Comparison of 1 piece uniform and 2 piece uniform
- What they want out of a current suit
 - Waterproof breathable
 - Weight
 - Pocket space
 - Preferably concealed pockets to maintain more professional appearance
- Protect head
- Regulation of temperature
 - Crystals
 - Fluid vest
 - weight
- Inside vs. outside the ambulance
- Concept for GPS and suit
 - Hand drawing
 - Possible GPS tools
- Researched for materials
 - Costs
 - Weights
- Radio communication
 - Stick to current technology
 - Discuss placement
 - Clip locations and falls
- Oxford Meeting
 - Decided on 2 piece suit
 - Looked at belt
 - Carry a lot of things on their belts
 - Multipurpose belt
 - Price of suit and accessories
 - Contaminated clothing disposed of rather than cleaned

- Reflector patterns on jacket and vests
- Planned possible testing procedures
- Material properties
- Finalized design details

3.2: Timeline Summary

In the back of the ambulance, there is a bench located on the side and a chair at the head of the patient. All of the chairs in the ambulance have a seatbelt placed in, which the medic working in the back are supposed to wear while working on the patient. By law, it is required to be worn; however, medics rarely wear the seatbelt because it often makes it difficult to work on the patient as effectively.

The way that ambulances are designed force the medic to move around while treating a patient. However, the amount of space in the back of the ambulance is minimal and the addition of the ambulance's speed and potential pot holes results in a very dangerous ride for the medic. It is a common misconception that the public believes that public service vehicles (police cruisers, ambulances, fire engines, etc.) do not have to abide by regulated driving laws; however, even in severe cases of emergency, all public service vehicles must abide by state and federal driving regulations. Contrary to what people think, most drivers on the road do not pull over. Most people hear the sirens and move to the opposite side of the road. Some people panic when an ambulance approaches and stop abruptly. All of these reactions can and do cause serious accidents if the ambulance driver is not being careful. An ambulance involved in a car accident can lead to many problems. The weight, size, and length of the ambulance can cause serious damage to cars involved. It can also have a devastating effect for the medic working in the back, who may or may not be wearing a seatbelt. Crash test videos have shown that even if the medic

working in the back has a seatbelt on, the lap seatbelt does not completely protect the medic from harm and becoming airborne. Most crash tests and statistics over the past years show that medics typically do not survive these types of accidents. Whether they were fully strapped with a seatbelt covering their chest cavity or a harness built into the ambulances, which are typically used in Europe, the effects can the medic are often very severe.

The project group is very lucky to have an EMT working with them. This is her experience:

“During the summer, I was at Oxford Fire Station/EMS and it proved to be a typical day in EMS.

A tone came in saying to respond to an elderly patient’s home complaining of blood in their urine. As we arrived to the scene, we loaded the patient into the stretcher. The driver that day was fairly new, and did not know where this particular hospital was located. My partner and I were in the back of the ambulance working on the patient, while en route the medic driving the ambulance forgets to stop at a stop sign, causing the medic to slam on the brakes trying to avoid hitting any cars. As the medic slammed on the brakes, the ambulance made a quick turn which sent my partner and me flying. The patient was strapped in completely, did not move at all, but myself and my partner became airborne. Fortunately, this incident lead to only minor bruises, but that was the moment that I realized how important safety was in the back of the ambulance.”

This frightening idea lead to the establishment of making safety as the top priority of the project. Safety could be significantly improved be a practical and implementable harnessing system for the paramedics to use while working on the patient. There exist many examples of harness ideas advertised in EMT magazines, but none of have been successfully integrated into use. The project originally considered taking on this daunting task because it was known that

some form of seatbelt that the medics would actually use in practice could save thousands of lives each year. Because the harness idea was becoming more and more popular in Europe, the group decided to research all different types of harnesses used for different applications, such as in sports like NASCAR, pilots, NASA, military, etc. The group wanted to develop a harness that not only protected vital organs, specifically around the chest cavity, but also provide mobility for the medic to work. One aspect of the idea researched was to have the harnesses built into the ambulance coming out of the wall. Crash test video's demonstrated that, although it did provide support, the dummy in the video remained strapped in but its body rose to the top of the ambulance resulting in the possibility of major head trauma. The second idea was to have the harness come from the ceiling of the ambulance and the wall, all of which creating three specific points of attachment. Videos proved that the dummy on the video went flying backwards and suffered considerable injuries.

Once again, research continued for other harness ideas to see if it was practical to continue forward and come up with a design. The key goals in designing this harness were for it to be comfortable and provide mobility. The group knew that the harness would be very uncomfortable for medics to wear in their long shifts, so the idea came up for a retractable harness. It would contain a lock in the back where the medic could hit to release themselves and be able to work with the patient more. The second idea was to have the uniform equipped with a link of some sort where it could attach to the harness while the paramedics would work in the back and then release the harness once arrived at the hospital. The biggest issue was the amount of mobility the medic would have while on the ambulance and wearing the harness. Would the medic be able to move from one end of the ambulance to the other end? Furthermore, could a harness be designed that would be versatile enough for the paramedics to wear in practice. There

have been numerous seatbelt designs in the past and medics still seemed to have not accepted any of them. The basic concept of this project was to provide safety for the medic in a very simplistic way that does not interfere with their work. As the harness idea became more and more complicated, it lead to the next solution which was to incorporate the harness idea into a suit concept.

The group knew that it was going to be difficult for the medic to accept the harness idea, and with limited time it was agreed that there needed to be something more practical. The group knew that the medic would have to wear their uniform to work, so having the harness built into the suit was a more efficient way to incorporate the idea. As research of current uniforms worn today progressed, it was revealed that the current uniform is very basic. The current suit consist of the EMS pants which typically had some form of padding and lots of pockets, a dress shirt, and sometimes a jacket depending on the season. The group then decided to deviate from the two piece uniform worn and instead consider a design for a single one piece uniform, because they were selectively common in EMS; one piece suits are frequently worn in emergency helicopters. The group looked into suits worn on Life Flight, the emergency helicopter service for UMASS Medical Center. The group saw that the suit used was a one-piece suit and could allow for a harness mechanism to be attached. Although the group used the same suit concept as emergency helicopters, further exploration of different options was done to see what was currently used for suit designs in the military, specifically for pilots.

As research continued on the materials, the cost of the suit and the potential design concepts, the group decided to meet with Oxford Fire/EMS and get their input on the subject matter. The group knew that the harness idea would become quite complicated, but decided to still maintain the idea until further suggestions were obtained from the Chief at Oxford. The first

meeting at Oxford was to meet paramedics and take a look at the ambulances. One of the ideas that rose from that tour was a GPS system being used while responding to calls or rescue missions. The medics informed the group that there was no system out there yet that had been used in EMS itself but advised that it would be rather helpful for them in the long run. The second question that was asked to the medics was what they would like to see changed on the suit. They did not go into too many specifics but did suggest the use of more pockets. Although several ideas had been brought up about a suit/harness concept, the opportunity to see the ambulance and what it looked like on the inside gave the group a deeper understanding of the space the paramedics had to work with. One of the ambulances was being serviced at the time, thus making Ambulance-Three the one that was toured. The group took pictures of the ambulance and all of the different areas inside. The paramedics were very helpful in providing information about the ambulance, with their experiences about procedures in the back, as well as what issues they faced while on duty.

While taking the tour of the ambulance a tone came in, and the two medics had to leave and respond to a call in regards to a fire emergency. As the group watched them go from a medic uniform into a firefighter suit, it was quickly realized that a two piece suit was the best approach for the project. While departing from Oxford it was decided that the project would discard the harness idea and establish the two piece suit design after seeing the complexity experienced by the paramedics in putting turnout gear on over their current paramedic suit.

Now that the group had the basic suit design and how it would look the next issue that was researched was temperature. The group noticed how the firefighters put on the jacket even during warm weather, and it became apparent that medics wore a jacket during the winter so the thought came as to whether or not they were the same material. Since the jackets firefighters

wore were fire retardant, the group wanted to research whether or not the medic jacket was the same. Staying with the firefighter suit design the group wanted to see how temperature fluctuations affected the design of the suit, inside and outside the ambulance. While doing the research it was discovered that the material of the jacket was very basic and did not have much protection, if not any. Even though EMT's rarely go into fires the group wanted the medic to have some form of fire protection as well as protection from any fluids that would come in contact with the suit itself; whether its urine, blood, vomit, or any other bodily fluid. One of the biggest issues was general comfort which lead us to the temperature regulation in the back of the ambulance. Since the temperature is kept at a specific temperature in the back for patient care, the group wanted the medic to also have the comfort while walking around in the ambulance. This led to the crystal and fluid system. The idea of having a crystal gel inside the suit to provide cooling or a fluid system commonly used in NASCAR would allow the medic to be comfortable in any environment. After great deliberation the group decided that although these ideas were great, the suit would become more bulky and hence the purpose of the suit would not be feasible. It was decided to keep it very simple and instead just focus on the original suit design which was taken from the EMS uniform commonly worn today and make minor changes on it. The first drawings of what the suit would look like were hand drawn; these drawings included lots of pockets for the medic to use at their convenience. The second idea that was pursued was the GPS system and how it could be implemented into the suit concept.

Now that the group had some collaborative ideas of what the design was going to look like, a business plan had also begun to take place. The group wanted to see what the prices were for a typical EMS uniform, as well as to know what companies were available to collaborate with, and how the group could promote the product for future EMS companies to potentially

buy. Although the group did not have a definite suit yet, it was apparent what the group had to look forward too. The cost of material came to be around the same cost as most EMS uniforms except the suit would be a little bit more because of the extra layer of fire retardant. As well, the group tried looking into radio communications and how it could be improved. However, the more research that was done, the more it was realized that changing the communication system would be an even more daunting task. So it was decided to keep the existing communication technology and to focus more on how the communication system affected the suit design. The group looked into where the communications were placed in the suit and if it caused any problems for the medic while on duty. Different jacket designs that were already available were looked at, as well as where they placed their radio communication devices. Some jackets had a pocket for the radios which was found out later on that placing the radio in that side, caused the radio to fall out and caused more problems later on.

3.3: Materials Background

3.3.1: Fabrics and Necessary Qualities

Although many uniforms for emergency medical personnel appear the same, the materials used often vary between distributors because there is no standardized regulation. This is an approach that may have some benefit as many small towns transition to combining EMS and Fire services, while larger cities maintain the separation between the departments.

The current suits can be made of any of several materials. The most common choice currently used is a cotton and polyester blend fabric. However, some suits do use Nomex® or Nomex® cotton blends. The suits must be able to serve not only to define the medical personnel

as EMTs, but also to protect and aid them in their duties. As such it must be sufficiently comfortable to allow the movement and extended wear by the personnel. Additionally, it must be strong enough to not tear or rip easily. The pant knees should be sufficiently padded to allow for kneeling on the ground with little discomfort while maintaining ease of motion.

A primary function of the uniform is to provide a protective barrier between the medic and the elements or any fluids the patient loses. This function necessitates the suit be designed to repel water, blood, and other bodily fluids to a degree that prevents penetration that could result in medic exposure. Analogously the suit should also be impervious to bacterial and viral infections that may be carried in said fluids. It is required that the suits also be fire retardant or fireproof in case the medic is exposed to flame in the line of duty. In the following sections specific test procedures, fabric qualities, and potential materials were outlined in greater detail.

3.3.2: National Fire Protection Association Codes 1999

The National Fire Protection (NFPA) Codes of 1999 and later revisions govern regulations for the protective clothing worn by emergency medical personnel. Because of the risk associated with blood borne pathogens, there is particular emphasis on protection against exposure to contaminated or potentially contaminated fluids. These protective elements include gowns, lab coats, gloves, masks, face shields, resuscitation bags, eye and mouth protection, and ventilation devices (National Fire Protection Association, 2003 Edition [14]). These devices have to be capable of preventing penetration of bodily fluids such as blood. Materials have to be tested

to show the ability to prevent this transmission of fluid and viruses for a specified amount of time under a given pressure.

Regulations also govern other crucial properties of materials used, including material strength, seam strength and general liquid resistance. Eye and face protection must allow sufficient visibility for procedures to be performed while maintaining the integrity as a barrier. The standards addressed in NFPA 1999 Act address the problem of protection from blood and other potentially infected fluids; however it does not account for the potentials of radioactive exposure, hazardous chemicals, respiratory, or fire/ thermal protection. As such it is not designed to be used as protection against vaporized and airborne pathogens.

This act sets several important standards which a uniform is required meet. For protection reasons, all garments are required to be resistant to penetration by fluid; however the barrier used for protection must be a single layer which cannot be separated. Tests to certify that garments met this requirement are carried out in accordance with the procedures and supplies outlined in ASTM F 1359a, *Standard Test Method for Liquid Penetration Resistance Integrity of Protective Clothing or Protective Ensembles Under a Shower Spray While on a Mannequin* for liquids with a surface tension of $40\text{ dynes/cm} \pm 2\text{ dynes/cm}$ and a mannequin with arms hanging by sides and straight legs (National Fire Protection Association, 2003 Edition [14]). The mannequin is subjected to the spray for eight minutes, two minutes in each of the four orientations. Results recording amount of liquid absorbed are conducted within ten minutes of the end of the test, and locations of leaks are to be documented and constitute failure. Samples are also tested in accordance with ASTM F 1671, *Standard Test Method for Resistance of Materials Used in Protective Clothing to Penetration by Blood-Borne Pathogens Using Phi-X174 Bacteriophage Penetration as a Test System*, to evaluate the resistance to contamination by blood and potential

blood borne pathogens which could be encountered in the course of emergency medical work. This test needed to only be performed on barrier layer and barrier seams.

The mechanical strength of the garment also requires evaluation. As such, the tensile strength are tested according to Section 11 through Section 15, Breaking Strength, Procedure A — Grab Test Method, of ASTM D 751, *Standard Test Methods for Coated Fabrics* and recorded to the nearest 0.5 N of force. For separable layers a burst test in accordance with Section 11 through Section 15, Breaking Strength, Procedure A — Grab Test Method, of ASTM D 751, *Standard Test Methods for Coated Fabrics* are also required. All garments have to be tested for puncture-propagation and tear resistance. This test is carried out on at least 5 samples in agreement ASTM D 2582, *Standard Test Method for Puncture-Propagation Tear Resistance of Plastic Film and Thin Sheeting* and the results recorded to the nearest 0.5 N of force. If the material failed in any direction, then the sample is determined to have failed. The specimens are also be subjected to a tear resistance test. The tests had to abide to the ASTM D 5598, *Standard Test Method for the Tearing of Fabrics by Trapezoid Procedure*. If a garment consists of multiple layers, then each layer will be tested individually. The strength of each layer will be recorded to the nearest 0.5 N of force. Because the clothing items could not be practically made of a single piece of fabric, seams were a necessary part of the garment, and therefore had to be tested.

The breaking strength of the seam was evaluated compliant with Section 71 through Section 76, Seam Strength, of ASTM D 751, *Standard Test Methods for Coated Fabric*, with at least 100mm of fabric on each side of the seam. Breaking strength was to be recorded to the nearest 0.5 N of force. For outer layers such as coats the water repellency was evaluated in accordance with AATCC 22, *Water Repellency: Spray Test* with the fabric samples oriented in

the same manner they would be in the clothing item. Additionally the total heat loss would be evaluated according to Part C of ASTM F 1868, *Standard Test Method for Thermal and Evaporative Resistance of Clothing Materials Using a Sweating Hot Plate*. using the appropriate apparatus. This test would yield the thermal resistance, average apparent intrinsic evaporative resistance and total heat loss. All previously defined tests had to be passed before and after 25 launderings for the garment to be certified as passing.

3.3.3: Waterproof Breathable Materials

By the nature of their profession, Emergency Medical Service Personnel are exposed to the elements as well as bodily fluids. Therefore, it is highly desirable for the uniform to be able to protect the paramedic from these conditions. However, there is also a concern about compromising the ability to regulate body temperature by reducing the effectiveness of evaporative cooling through sweat loss. For these reasons a waterproof breathable fabric would be a viable option for a revised suit design. A waterproof breathable fabric is one which repels water droplets but allows water vapor to pass through the fabric. What is colloquially referred to as waterproof may be further broken into two more specific subcategories: truly waterproof and water repellent. A waterproof fabric is one that prevents liquid water from penetrating the fabric or being absorbed entirely; whereas, a water repellent fabric is intended to delay the penetration compared to a normal fabric. Wear ability and workability are major concern for clothing design, so water repellent fabric are selected more often. Additionally, full waterproofing can reduce the effectiveness of vapor transfer through the material, causing concerns about impeding the escape of perspiration.

The ‘breathable’ qualities of waterproof breathable textiles may be more accurately be referred to as the water vapor permeability of the fabric, which means that the fabric allows vapor to diffuse passively; however, it does still slow the process. The dissipation of body heat through perspiration is crucial to the health of the individual, and becomes a greater concern in extreme temperatures or when very active. Below is a table summarizing work rates and perspiration rates for relative activity levels.

Table 1: Perspiration Rates as Related to Activity Level (Keithley, 1985 [12])

Activity	Work rate (Watts)	Perspiration rate (g day ⁻¹)
Sleeping	60	2 280
Sitting	100	3 800
Gentle walking	200	7 600
Active walking	300	11 500
With light pack	400	15 200
With heavy pack	500	19 000
Mountain walking with heavy pack	600–800	22 800–30 400
Maximum work rate	1000–1200	38 000–45 600

Because paramedics work in the field and may also be involved in search teams, it is necessary to account for this when evaluating fabrics. And fabric considered must be able to transmit moisture at a sufficient rate to accommodate the above rates. Although waterproof breathable fabrics cannot transmit the same amount of perspiration as is produced, they transmit a sufficient amount, about 5000 g m⁻² day⁻¹ of water vapor (Lomax, 1991 [13]), for most situations faced by paramedics.

Waterproofing is generally achieved by one of three methods: dense weaving, membranes, or coatings [(Horrocks & Anand, 2000)]. The dense weave Ventile was among the first waterproof

breathable fabrics developed. Cotton fibers were aligned and tightly woven to reduce the space as much as possible. When the fabric was moistened the cotton fibers would absorb the liquid and swell as seen below. The swelling closed any remaining gaps in the fabric, yielding it waterproof. This waterproofing is an inherent property of the material and cannot be changed or washed out in time, making it a reasonable candidate for paramedic uniforms.

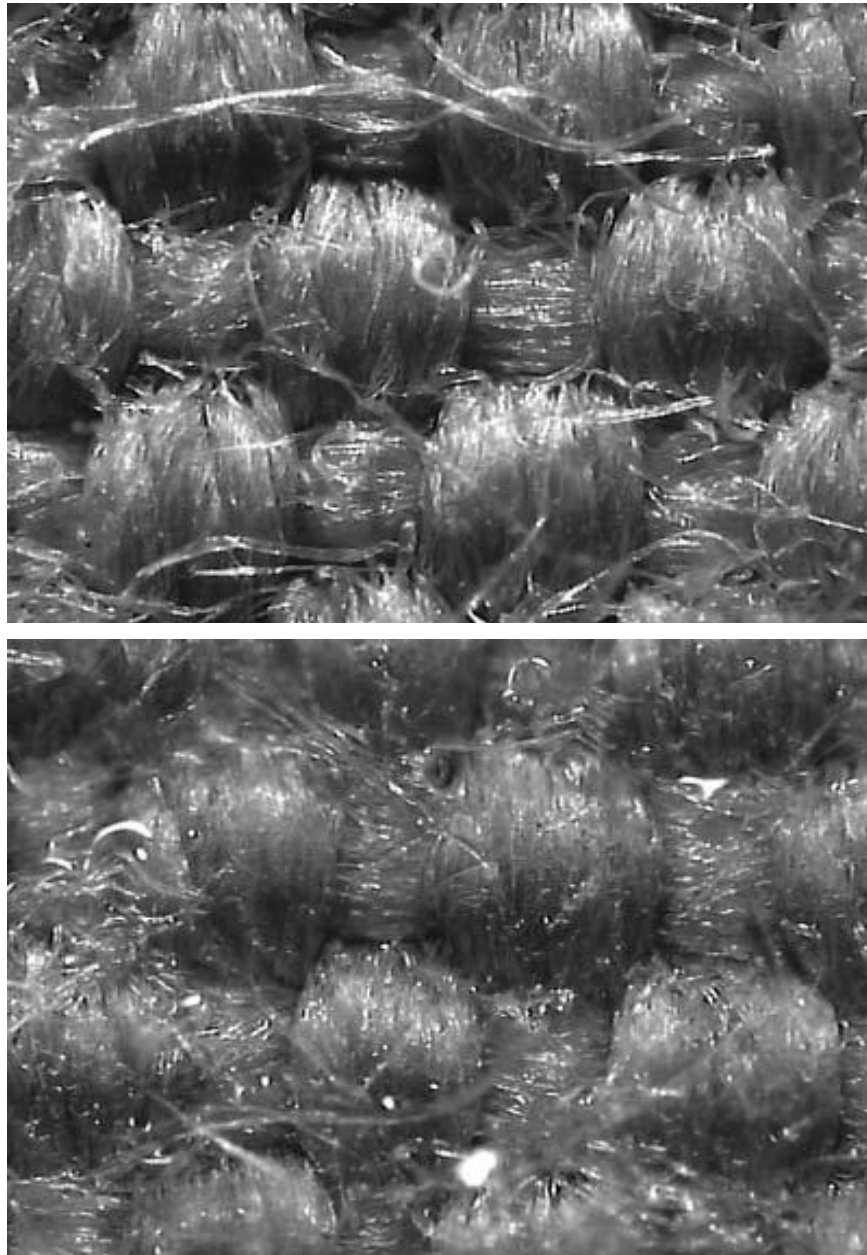


Figure 5 Ventile fabric while dry, pore size approx. 10 (top) Ventile fabric while wet, pore size approx. 4 μm (bottom) (Horrocks and Anand[11])

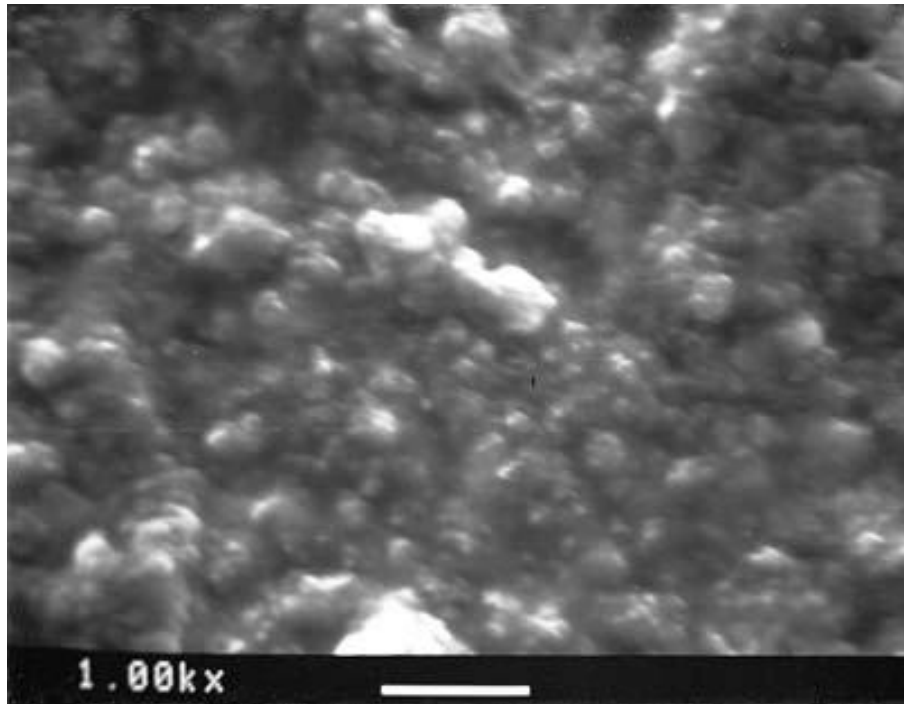


Figure 6 SEM image of a micro porous surface (Horrocks and Anand [11])

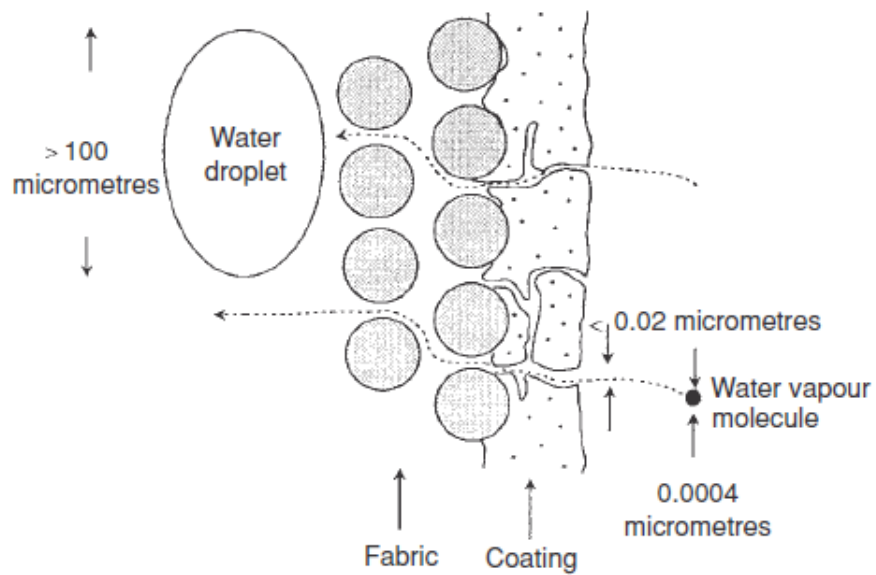


Figure 7 schematic of water vapor transport through a micro porous coating

Alternatives may include a lower thread count weave with a waterproofing agent. Some more recent woven fabrics use synthetic fibers, generally polyamide or polyester. These fibers

can be much more efficiently organized, resulting in a closer weave. However, they do not swell when wet; as a result these super dense weaves are not entirely waterproof. Membranes may also be used to waterproof clothing. A membrane is a thin polymeric film designed to resist penetration by liquid while allowing vapor permeation [(Horrocks & Anand, 2000) 11]. Membranes are generally very thin, so they are applied on a fabric that can provide the general

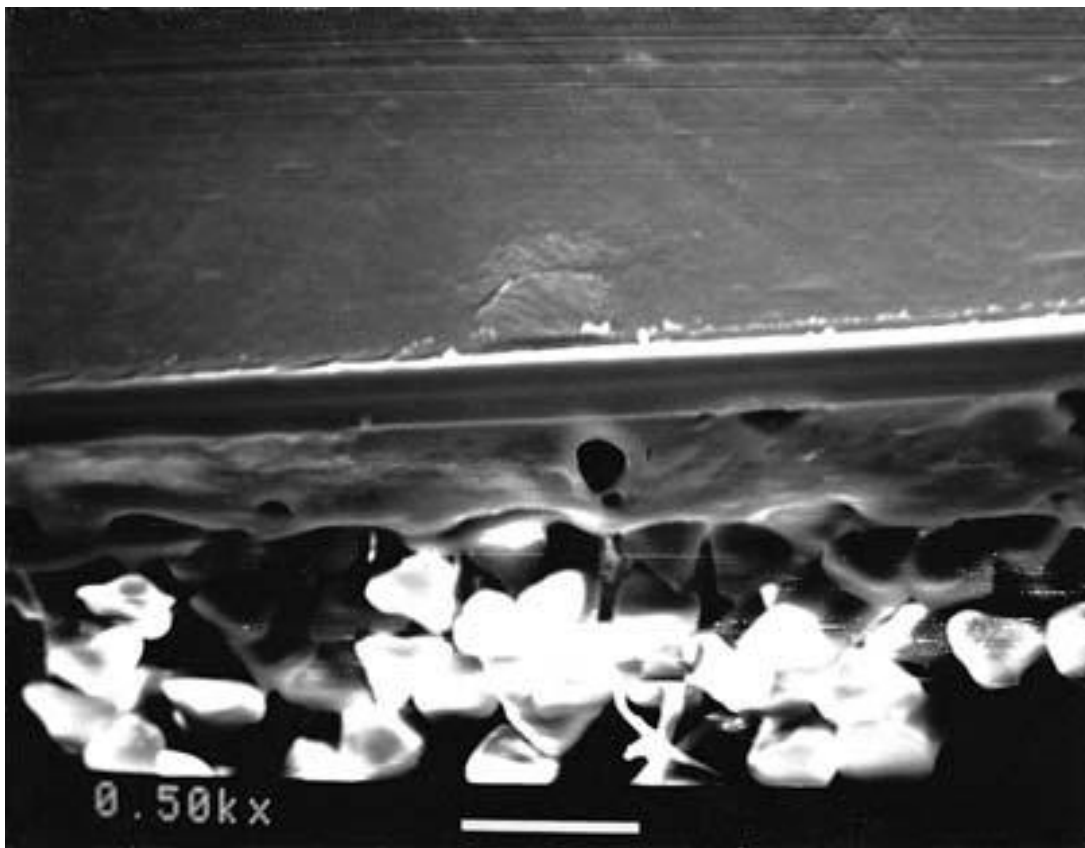


Figure 8 SEM image of the hydrophilic layer (Horrocks and Anand [11])

needed. Gore-Tex is one famous example of a membrane waterproof breathable material. Gore-Tex is one famous example of a membrane waterproof breathable material. Gore-Tex uses a polytetrafluoroethylene (PTFE) coating with up to 1.4 billion ventilation holes per square centimeter. However, there is a risk of these ventilation holes becoming blocked because of their small size. The pores may become clogged by skin oils, dirt, pesticides, insect repellent, salt, detergent, or sunscreen (Horrocks & Anand, 2000 [11]); this problem is commonly addressed by

pairing the membrane with hydrophilic layer to reduce contaminants. The hydrophilic layer allows water to pass through amorphous regions, but has no holes to be affected by contaminants. The hydrophilic layer allowed water to pass through amorphous regions, but had no holes to be affected by contaminants. However these systems often require separate layers of fabric to achieve a pleasant drape of the fabric which would not be ideal in warm weather when multiple, albeit thin, layers may prove uncomfortable. The waterproofing option of coatings will not be considered because they have a similar method as membranes but are bulkier.

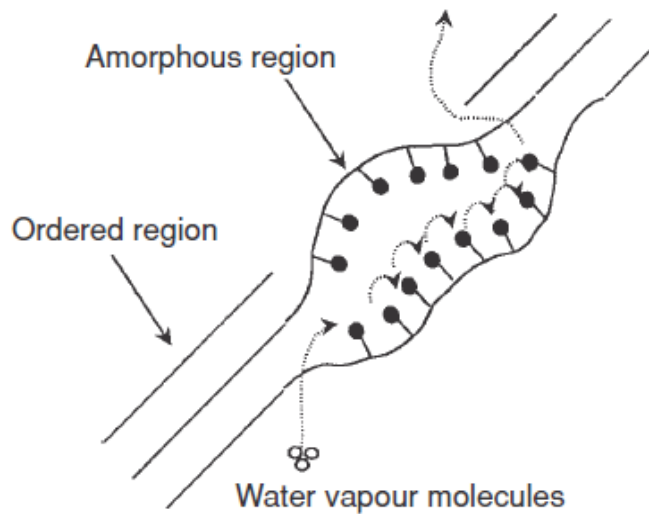


Figure 9 schematic of how water vapor is transported through a hydrophilic amorphous region

3.4: Fire Resistant and Heat Protection Textiles

As many small towns begin to combine Emergency Medical and Fire Protection Services, it is becoming increasingly practical for paramedic clothing to have an increased resistance to heat and fire. Considerations that must be taken into account when evaluating the viability of a

fabric for protective clothing include the thermal and burning characteristics of the material: toxicity and smoke production upon burning, affinity for charring, shrinking, or melting, ignition temperature, thermal conductivity, specific heat capacity, and burn rate. When heated, fabrics may melt, degrade, or combust. In the case of protective garments, it is desirable to have a material that will not ignite from ambient heat or flame source.

In the case of ignition, it is advantageous to have a fabric that does not emit large amount of heat and does not allow the fire to spread rapidly. Materials such as polyester and nylon are thermoplastic based do qualify as fire retardant because they will shrink away from heat preventing combustion and slowing the spread of flame; however, they also tend to melt when ignited. Melting is a dangerous quality for clothing to have because it often results in the liquid fabric adhering to and damaging the flesh, additionally if it is blended with a charring fabric, the chars will create a matrix that will suspend the melted thermoplastic, causing a greater danger and more intense flame (Horrocks & Anand, 2000 [11]). In general, the behavior of fabrics as temperature changes can be an important factor. Seen below is a table containing information on fabrics as the temperature changes.

A fabric with a high pyrolysis and combustion temperature should be selected for applications. Because of the risks associated with melting, fabrics that are prone to melting at low temperatures should be avoided in clothing applications. Reasonable selections for protective clothing would include those which neither shrink nor melt, but char upon decomposition. Several options that meet these specifications include flame retardant cotton or wool, aramid fibers, such as Nomex, and partially oxidized acrylics. Fiber such as cotton and wool char upon burning. This charring results in a lower density, which corresponds to a higher thermal resistance. Essentially as it chars, the fabric creates an insulating effect. Conversely,

thicker thermoplastic material results in more melting material contacting the skin and more extensive injuries. It must be kept in mind that, although more durable and insulating, a thick fabric can be uncomfortable, heavy and cumbersome to the point of reducing the effectiveness of the EMT.

Like waterproof breathable fabrics, flame retardant fabrics may be sorted into categories based on the cause of the fire resistant properties. The first category to be discussed includes

Table 2: thermal and flame retardant properties of several fabrics (Sengupta & Bajaj, 1992 [15])

Fibre	T_g (°C) Glass transition	T_m (°C) Melt	T_p (°C) Pyrolysis	T_c (°C) Combustion
Wool	–	–	245	600
Cotton	–	–	350	350
Viscose	–	–	350	420
Triacetate	172	290	305	540
Nylon 6	50	215	431	450
Nylon 6,6	50	265	403	530
Polyester	80–90	255	420–477	480
Acrylic	100	>320	290	>250
Polypropylene	–20	165	469	550
Modacrylic	<80	>240	273	690
PVC	<80	>180	>180	450
PVDC	–17	180–210	>220	532
PTFE	126	>327	400	560
Oxidised acrylic	–	–	>640	–
Nomex	275	375	310	500
Kevlar	340	560	590	>550
PBI	>400	–	>500	>500

materials that are inherently resistant to burning, meaning that fire resistance is a property of the fabric itself. These fibers include aramids, modacrylic, polybenzimidazole (PBI), Panox (oxidised acrylic) or semicarbon, ceramics, and phenolic (Horrocks & Anand, 2000 [11]). There is a correlation between the degree of aromatic structure present in the molecular or arrangement and the degree of natural fire resistance in a material: materials with a higher ‘degree of are more

likely to have a high natural flame resistance when compared to those without a highly aromatic structure. Meta aramids, such as Nomex are among the most widely implemented fire retardant and heat protection fabrics. They are currently used for protective suits for military personnel, such as tank crews and fighter pilots, astronauts, fire fighters, industrial workers, and racecar drivers. Nomex is the brand produced by the DuPont Company, and most readily available in the United States, but other meta aramids are also produced and used throughout the world. Nomex will generally char with little or no melting. These fibers may be blended with Kevlar for increased mechanical strength. However this also adds additional weight which is undesirable. Alternatively, it can be blended with fire resistant cottons or wools, which may increase comfort and wear ability of the material.

Another fabric option is Poly(amide-imide) fibers, the most common brand being Kermel fabrics. These fabric are currently used in military uniforms and firefighting equipment. When burned, Kermel will carbonize rather than melting. Kermel may be blended with fire resistant viscose or wool to reduce costs and increase comfort and appearance of the resulting garment. Polybenzimidazole (PBI) is a non-combustible organic fiber which emits little smoke when burned. Additionally, the comfort level has been evaluated to be comparable with that of cotton clothing, making it a very implementable option. Some current applications include racecar driver and firefighter suits. One particular type of PBI fabric could be a highly practical choice: PBI Gold ® which offers thermal and chemical resistance, as well as strength and resistance to punctures, tears, and rips (Horrocks & Anand, 2000 [11]). Poly phenylene sulphide (PPS) is a chemically resistant fabric that remains stable under a wide variety of conditions and will not combust under atmospheric conditions. Semicarbon and Panox fibers are made by thermally treating viscose or acrylic. The materials have good heat and fire resistance, however are not

mechanically strong and have to be blended with other materials, often aramids, to increase mechanical strength. However it has a high thermal conductivity, so it is best implemented with a layer of fabric under the material to protect skin from the heat transferred. This was undesirable because it added another layer which decreased breathability and ease of movement for the wearer. Below is a table summarizing properties of several of the fabrics discussed.

Table 3: A table summarizing crucial properties of inherently flame resistant fibers (Smith, 1994 [16])

Fibre properties	Aramid ^a	Carbon ^b	Glass (type)	PBI	Novoloid phenolic	PPS	Polyacrylate	PTFE	Polyimide	Polyamide-imide
<i>Tensile and physical properties</i>										
Tensile strength (Gpa)	0.6M 3.4P	4	3.5E 4.6S	0.37	0.26	0.42	0.22	0.18	0.35	0.32
Modulus (Gpa)	17.0M 99P	230	72E 87S	5.7	3.0	7.3	4.36	4.5	6.2	N/A
Elongation at break (%)	22M 3.0P	1.8	4.8E 5.4S	30	30	40	20–30	19–140	19–21	15–20
Moisture regain (%)	6.5M 4.0P	9	<0.1	15	6–7.3	0.6	12	0	3.0	3.4
Density	1.38M 1.45P	1.40	2.55E 2.48S	1.43	1.27	1.37	1.50	2.10	1.41	1.34
Abrasion resistance	Good M Poor P	Poor	Poor	Good	Poor	Good	Fair	Good	Good	Good
Resilience	Excellent	Poor	Poor	Excel	Fair	Good	Good	Poor	Fair	N/A
<i>Chemical resistance</i>										
Acids concentrated	Fair P	Poor	Excel	Excel	Poor	Good	Excel	Excel	Excel	Fair
Alkalis concentrated	Good P	Poor	Fair	Good	Excel	Excel	Excel	Excel	Poor	Good
Ultraviolet	Poor	Good	Excel	Good	Excel	Excel	Excel	Excel	Good	Good
<i>Thermal properties</i>										
LOI	30M 29P	55	>100	38	33	34	43	>95	40	32
Thermal conductivity (BTU-in hr ⁻² °F ⁻¹)	0.26M 0.30P	<0.03	7.20	0.26	0.28	0.30	0.31	0.20	N/A	0.08
Usable temperature (°C)	315–370	V.High	V.High	>595	400	260	°	430	<485	>420
Short term continuous	230	500	315	315	205	205	160	288	260	250
Smoke emission density	1.0	N/A	Low	Trace	<0.30	NA	Trace	Low	<1.0	<2.0

PPS = Poly(phenylene sulphide).

^a M = poly meta-aramid (Nomex); P = poly para-aramid (Kevlar129); modulus (GPa) = (gpd × density) /11.33. ^b Celion 3000 (HS). ^c Auto ignition at 450°C and 100%

The other category includes fabrics that have been chemically treated or modified to increase fire resistance. Certain fibers can be treated in such a way that their structure is altered making them inherently fire retardant. Fire resistant viscose is produced by adding fire resistant chemicals or additives, such as Sandoflam 5060 (Sandoz), polysilicic acid or polysilicic acid and

aluminium (Horrocks & Anand, 2000 [11]), before extruding the fibers. These additives can result in a produce that forms an incombustible char on the surface if exposed to flame and exerts self-extinguishing effects. Some of the materials previously discussed in the waterproof breathable section, namely polyester, can be treated to make them more flame resistant. Methods include both additives in production and coatings on the final product. Additionally they can be made to be less toxic than wool and fire resistant cotton when burned, as seen below.

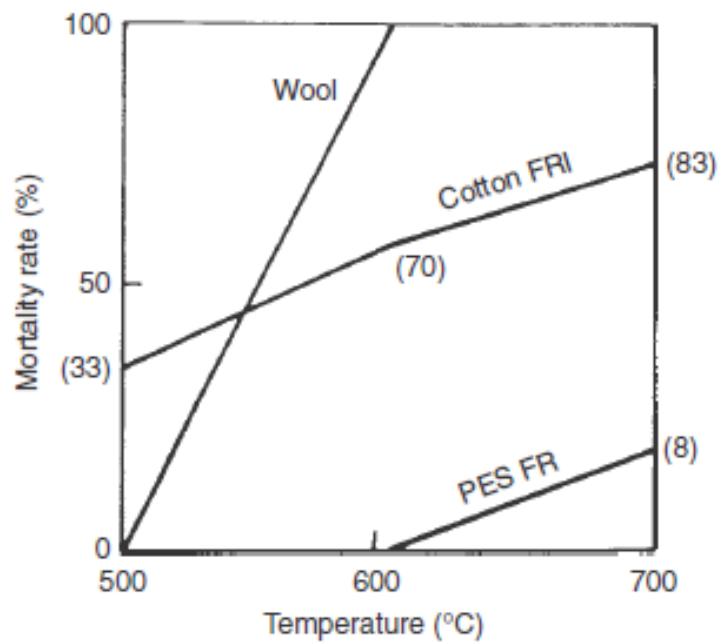


Figure 10 toxicity of wool, fire resistant cotton and polyester burned at different temperatures [(Horrocks and Anand)]

It becomes even more dangerous when combine with a charring fabric which will creates a support system that prevents the liquid nylon from dripping away. Acrylics are also not ideal. Although they will shrink away from heat reducing the chance of ignition, they burn rapidly and produce heavy smoke. Additionally several Flame resistant coating exist, but are not preferable because the effectiveness of these finishes are more likely to be reduced with time than the effectiveness of fibers treated in production.

3.4: Paramedic Suit

The paramedic suit is the primary defense and protection for the wearer. Just as each paramedic, EMT, or firefighter must put on additional personal protective equipment (PPE), the suit acts as the first and/or last line of defense against cuts, punctures, burns, and other possible accidents that could occur on scene. However, examination of the current suits clearly demonstrated that the uniforms that paramedics are given today do not offer the necessary standard of protection required by the job. Just as the human skin provides these certain functions to the human body, the new suit will offer a higher level of safety and protection for the user than what is being used today. Function is a key factor when it comes to the products used by paramedics. When on a call, there is no time to waste trying to set a machine up or activate so many functions on a device. Because time is a critical factor, it is important that when a device is turned on it is ready to use immediately. Reducing the time to perform tasks is one of the central goals of the new suit developed in this project. By adding in more functions to the suit while preventing any hindrance or time for set-up, this suit will be more efficient, more productive, and more functional.

When an EMT goes on a call, their primary ‘toolbox’ was their medical pack. This pack carries various types of medical equipment, ranging from band aids, gauze pads, and slings, to Bag-Valve Masks (BVMs), suction units, and neck braces. Each piece of equipment has a function and purpose. However, when one combines all of the necessary equipment that goes into a pack, it becomes bulky, heavy, and at times cumbersome. In order to alleviate some of that weight, paramedics often try and carry what small equipment they can directly on their person.

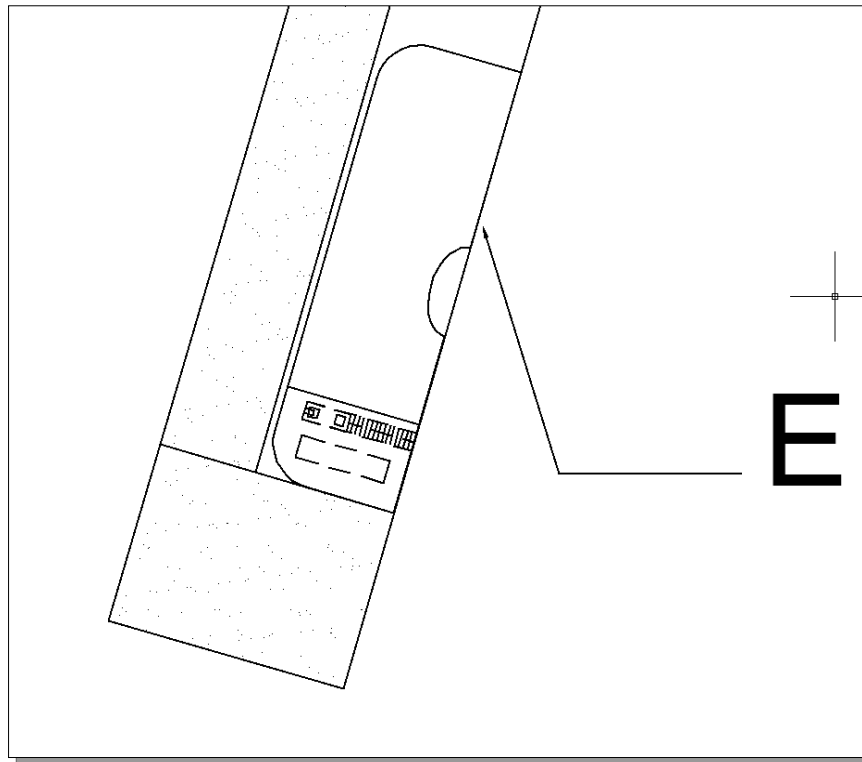


Figure 11 Glove Pocket Design, E Header, See Attached

Notepads, pen, scissors, bandages, gloves; these are just some of the equipment carried on them. More pockets would allow for more equipment to be carried on the medics. On the other hand, strategically placing the pockets in proper locations allows for better organization and ease of access. Additionally, all pockets must have a functional purpose to be justified. By just adding more fabric to the suit for unnecessary storage called for a higher price in cost for material used that would ultimately lead to the decrease in use of the suit, which would lead to decreased demand.

Gloves are the first piece of equipment taken into consideration when creating the suit. It is one of the vital tools central and mandatory to a medic's ability to perform his job. Since PPE is vital in medical care and, compared to the volume of calls experienced during only one week (see attached), it is necessary that medics have enough PPE to cover the necessary volumes of calls received in a shift. For this reason, and for the sake of minimizing the time spent to restock on PPE, a special pocket has been designed into the wrist area of the suit for gloves. One

of the things needed in the suit is an effective way to make the gloves more readily accessible for the paramedics.

As could be seen on Figure 11, a small opening is designed into the pocket so the paramedics can pull out as many gloves are needed for the call, much like what is seen on many tissue box openings. With this, the paramedics have a designated location for their gloves as close to the hand as possible and ready to be used when necessary. However, it is crucial that the pocket can be easily restocked when gloves run out. It is clear that another opening was necessary for the gloves to go in rather than using the same opening used to extract them. However, along with the consideration there is a concern about the issue of contamination. Gloves are used as a PPE device to protect not only the paramedic from infection, but also to protect the patient from anything the medic may have or any contaminants the medic may have been handling prior to treating that patient. Any form of contamination on the glove is an unacceptable risk that would render the glove a liability rather than precaution, thus forcing the paramedic to dispose the gloves and obtain a new pair. Preventing contamination inside the pocket was a vital point to have for this and every pocket. Because of the importance of the gloves it is fitting that the pocket opening is doubly protected against contaminants. A zipper alone is too open against bodily fluids because of gaps between the teeth. Velcro flaps are ill-secure and too probable for accidental opening and contamination. For those reasons, both forms of concealment are used on the glove compartment.

The next pieces of equipment to be placed on the suit is the smaller first aid interventions, such as gauze pads, bandages, and gauze rolls. For any paramedic, there is never enough equipment one can carry to a call. Preparedness is key for every situation. In a report from 2003 the Council of Foreign Relations states that.

'On average, fire departments across the country have only enough radios to equip half the firefighters on a shift, and breathing apparatuses for only one-third. Only 10 percent of fire departments...have the personal and equipment to respond to a building collapse.'(Rudman [18])

It was also later reported that

'...two-thirds of fire departments do not meet the consensus fire service standard for minimum safe staffing levels. Additionally, public health systems across the country are dangerously underfunded and lack the capacity to do what is increasingly expected of them.' (Rudman [18])

This poses a considerable threat to emergency response services when fire departments and paramedic services are combined into one. With the call for more training and equipment, emergency responders are becoming overwhelmed by the insufficient number of staffed personnel as well as a lack of equipment. For this reason, the need for more storage was stressed. By providing the suit with more pockets for smaller intervention devices, such as bandages and gauze, the paramedic can be better prepared for an incident without having to open his pack. For a Mass Casualty Incident (MCI), when dealing with multiple patients, it is vital for emergency responders to never run out of equipment, but simultaneously act as efficiently as possible. By adding more storage to the suit, this design increases the efficiency of the responder and cuts down on restock time. For any MCI, the emergency responders are responsible for giving aid to patients, but they must also *'...confront a terrorist incident and will play the central role in managing its immediate consequences...reestablishing order, and preventing mass panic.'* (Rudman [18])

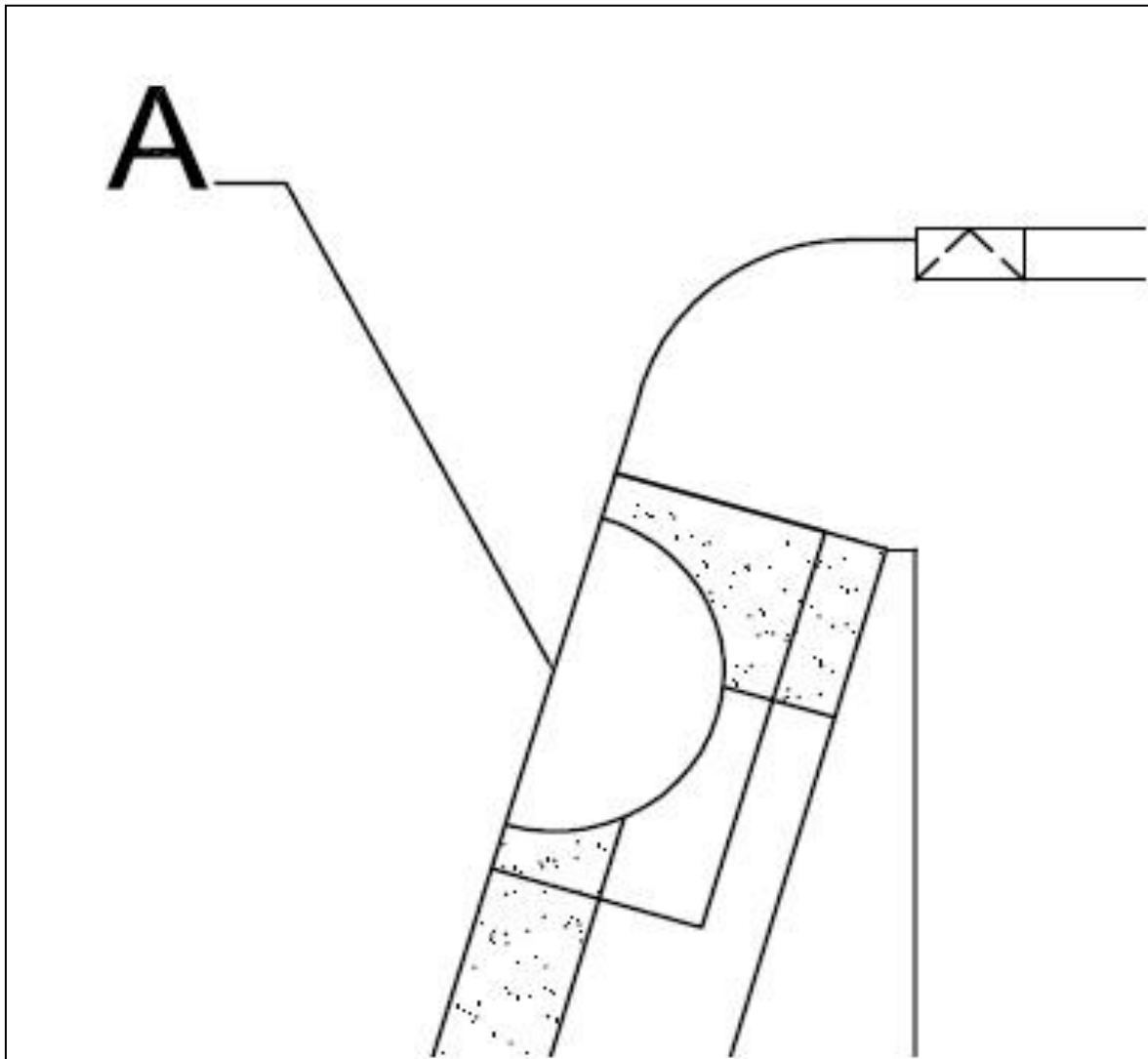


Figure 12- Right Sleeve Pocket with Patch

After the attacks on September 11, it was realized that the preparedness of the country's fire and paramedical services was not up to par. The various pocket positions are determined by ease of access and position in comparison to other features on the suit. As could be noted, the first suit concept has only four pockets; 2 on the front chest area as displayed on the current suit designs, as well as two extra pockets located on each shoulder. Notice how the shoulder pockets

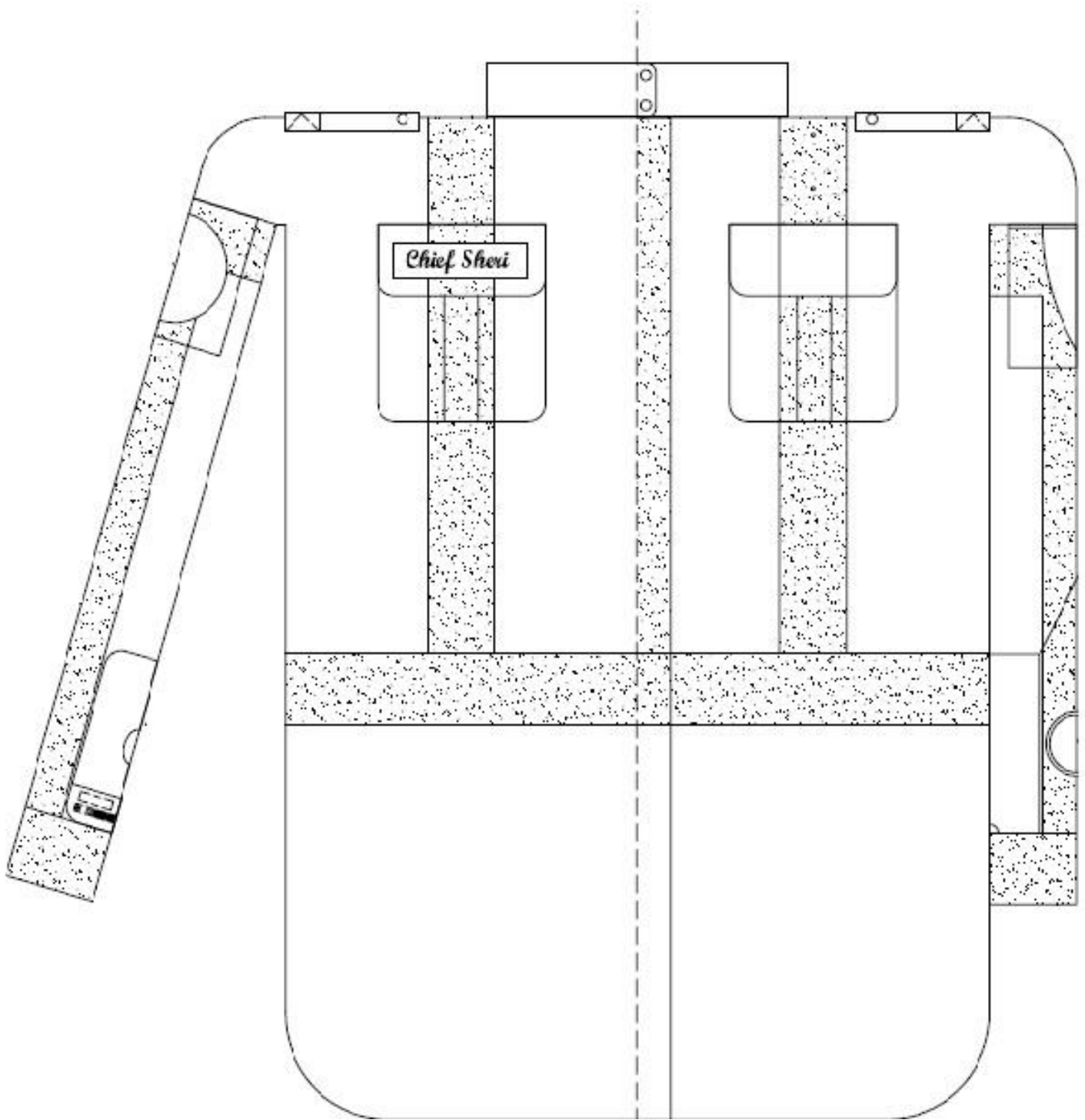


Figure 13-Suit Concept 1 with Reflective Tape Design

appear to not have flaps or any openings. This is because the entire front face was a flap covering the entire area of the pocket. The pocket is covered by an entire front face and the patches sit on the top center of the flap. This is preferable because it allows the spacing on the

sleeves to be as open as possible and appear less crowded. because paramedics needs to wear their respective ambulance patch as well as their state EMT patch, both shoulder pocket flaps cover the entire face of the pocket with the patches resting on top of the flaps.

Conversely, one does not necessarily know how much extra storage is needed, or whether or not they need the extra space. For this reason, multiple suit designs were developed and evaluated for usability. The first design contains two front chest pockets as well as the two shoulder pockets and the paramedic gloves pocket located on the right wrist sleeve area of the suit. This design is based off of the current suits worn today, with the addition of the pockets located on the extremities. Additionally, there is the second suit concept design. This suit design incorporates the same pockets as used in Concept 1, but with additional storage spaces. In the main body of the suit, there are four pockets located in the front area of the suit. These pockets, which are distributed for even spacing and size, along with two more pockets, one located on each forearm, provide the user with extra storage for supplies.

The next key issue to will be discussed is visibility of the medic while on a call. From the information the group gathered from talking to paramedics, especially one of the group's own members, who was certified in Massachusetts as an EMT, for every road call or highway emergency, by state law every paramedic is required to put on a reflective vest to make them more visible to drivers. It is a concern that using the traditional vest could void the function of the pockets on the new suit design. For this reason, reflective tape is already incorporated onto the suit itself. The addition of reflective tape to the suit is among the first steps to eliminating the necessity of the extra vest; however due to current laws complete elimination cannot be guaranteed by design changes alone. In doing this, the pockets remain accessible to the paramedic without compromising the safety of the medic by reducing visibility in a roadside

setting. However, there is also one more factor to the tape that was not known by the group. From discussion with the group's MA EMT member, she indicated that though fire departments and paramedic services were being integrated together, there still was a distinction between the placement of the tape for paramedics and firefighters. As could be seen on current firefighter suits, the reflective tape encompassed the suit in a circular fashion. However, for paramedics, the vests were installed in an 'H' form, as seen on Figure 11. This pattern, which is specifically called for by paramedic vests, is the design installed on the new suit. The tape also runs along the length of the arm, circling around the armpit and wrist areas.

The next critical piece of the suits is located on the left sleeve wrist area. As a paramedic responds to a call, it is important that all of the information on the patient, the situation, and steps taken are marked down properly and well-noted. Paramedics carry a small notepad with them on calls to take down such necessary pieces of information. Vitals, patient history, patient information, and other details that are explained during any incident could mean life or death for any patient. If a paramedic is given inaccurate information about a patient, or cannot recall accurate information, it could cost the patient their life. However, when a paramedic arrives to a very critical scene where there is no time to stop and take notes, it becomes even more difficult to make sure that the necessary information needed of the emergency and the patient is being asked for and taken down. It is for this reason that the new suits are designed with a clear viewing space for notecards and paper could be inserted to take down this information. Rather than pulling out a notepad to take down information, the concept is for the paramedic to grab the pen and just write in the space provided, taking down the notes on their own arm. While the transfer of care is being made from one paramedic to another, the necessary information taken down could be removed and passed on to the person receiving the patient. Although ambulance

services are beginning to switch from paper forms to electronic filing while on a scene, the convenience that a laptop could bring does not aid the emergency responder when he/she would be busy treating a patient. It was why even today many services still use traditional notepads for taking down notes. This project wants to simplify the work for the medic by providing them with a space to take down crucial notes without having to reach for more than their pen.

As critical it is to take notes while on the call, it is especially important for the medic to have one more piece of equipment on their person. In the critical step of taking vitals from a patient, it is critical that accurate information can be taken with precision. Although the main tools used for this process consist of the BP cuff and stethoscope, the most important piece of equipment needed for taking accurate vitals is a timepiece. The watch provides the paramedic with an accurate reading of the vitals from the patient, which allows them to determine if there is any posing danger to the patient. However, it is not unheard of that a paramedic would forget to bring a watch, thus rendering them incapable of acquiring accurate vitals. That is why the new design incorporates a space on top of the left sleeve wrist of the suit to lock in the head of a watch to the suit. This function provides the paramedic the ease of always having a watch on their person to accurately measure vitals. The space would work with a twist-lock mechanism, which requires the user to lock in the head piece of the watch. Once the user is done or needs to change out of the suit, the user just needs to twist and unlock the watch from the sleeve to remove it. The focus of this project makes sure all necessary pieces of equipment are on the suit. In making sure all equipment are incorporated into the suit, the paramedics become more efficient and more capable to do more while on the scene.

Although Concept 1 is a more advanced version of current suit designs, the project wanted to go even further with the suit. Functionality is the main focus of the suit. By providing

more function to the suit the hopes are to improve the capabilities of the paramedic. Thus, Concept 2 was designed. This design features more pockets, more functions, and more capabilities. As was noted previously, Concept 2 has more pockets incorporated into the design than Concept 1 has. Storage has been a key figure that has been asked for by paramedics to be incorporated into the suits they wear today. With the various amount of equipment the medic must carry to different calls, paramedics have long stressed for needed storage for some of the smaller materials. Concept 2 is intended to go beyond that call. With the number of pockets and storage being offered by the suit, paramedics are able to utilize the storage applied and reduce the number of materials within the pack that they carry with them already. Along with the safety reflective tape and the other features that are displayed in Concept 1, the other important feature in Concept 2 is the Global Positioning System (GPS) tracking device.

Paramedics must undergo various types of training before entering active duty, which includes training for search and rescue emergencies. Whether the call is to the woods or to an urban area, it is vital that paramedics maintain contact with the Unit Commander. In a situation where there is an MCI, communication is vital for operations to work and duties to be fulfilled, as well as for relaying important information to any or all personnel. However, one other important piece of information that has to be communicated was point of location of all personnel. Having knowledge of where all personnel are is important to make sure all people are on hand for the call.

According to a 2003 report, a total of \$6.8 billion was budgeted for Interoperable Communications (Rudman [18]). The purpose of this spending was ‘...*funding to ensure dependable, interoperable communications for first responders as well as funding for public alert and information system programs and capabilities.*’ ((Rudman [18])

Though it is important to have a means of relaying any information to the public in case of an emergency; if communication is not maintained within the system itself, then it would fall apart. Especially, if the location of one or more personnel is unknown during an emergency, then the situation becomes even more critical. Such occurrences have been a concern for many paramedics and chiefs. The safety of the personnel is important to the function of the service. For this reason, the project has designed a GPS tracking system for the suit, which can be

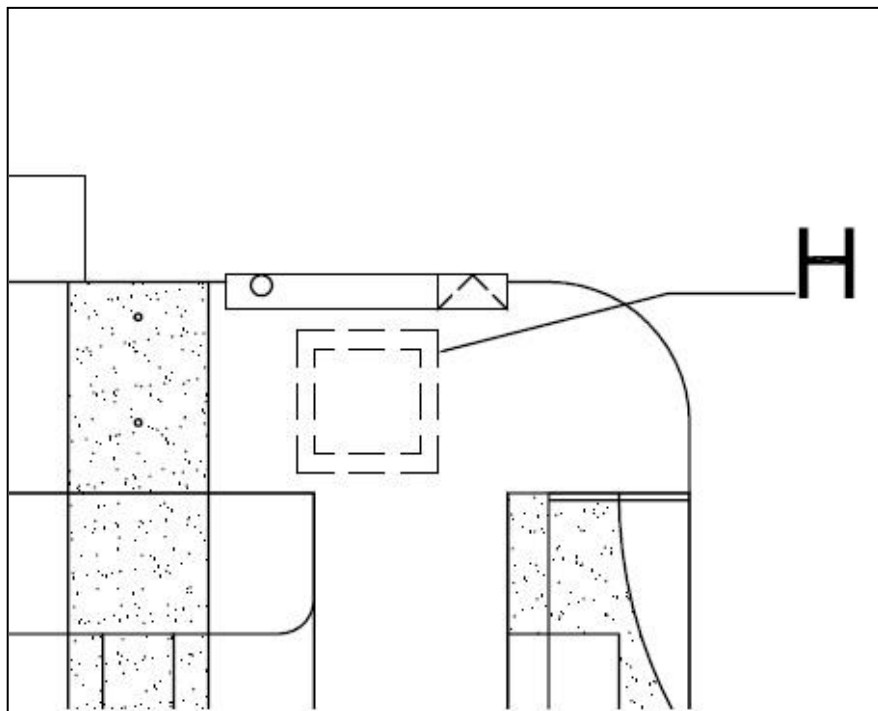


Figure 14-GPS Device Incorporated onto Concept 2

embedded into the suit itself. The device is designed and intended to relay GPS positions to the main source of contact either at headquarters or base of command. It is a very important aspect

of Concept 2 because it encompasses the mission of the project: Paramedic Safety. This device gives the Unit Commander or Chief the assurance and location of their personnel; they only needed to look online and by using the GPS tracker information, find the exact location within the designated radius of the personnel. Safety was the aim for this project, and the GPS tracker is one of the many attributes that this and both design concepts offer.

Finally, there is one part of the design aspect that proved to be the most difficult, but was seen as one of the most important features to this project. From talking with several experienced and fresh paramedics alike, one major concern that had haunted paramedics for the longest time is spinal safety. As the tasks of an emergency responder became more and more demanding, it has become very common to find retired paramedics with spinal injuries that are the direct results of performing duties in the field. As the tools and equipment that is being used become more simple and easy to handle, a common trade-off is safety. For example, the most commonly used piece of equipment in an ambulance is the stretcher. It is mainly described as a bed on wheels with a locking mechanism that allows it to be set at different heights. The main characteristic that paramedics looked for when using a stretcher was weight. Paramedics do not seek to bring heavy equipment to calls. They seek lighter equipment for ease of transport. The trade-off however is that as simple as the stretcher is today, it does not aid the paramedic with positioning. Having watched various moments where EMTs have loaded and unloaded stretchers from their ambulances, every time they loaded the stretcher struggle with lifting and loading it into the ambulance. The strain from lifting the stretcher with a patient on it takes a heavy toll on the paramedics doing the lifting. No stretcher is the same and no patient is the same weight. The strain from having to lift a loaded stretcher time and time again with no support is one of the main causes for many paramedics to retire early.

On the other hand, there have already been certain interventions in place to try and alleviate that strain from paramedics. Back supports and other forms of spinal reinforcement are offered to paramedics and often recommended. However, cost and comfort are the two main factors that deter many paramedics away from using these offered devices. When a newly hired EMT is put on the squad, the station puts forth money to buy his or her uniforms. The station might pay for will pay for suits, pants, shoes, a belt, and other start up equipment deemed necessary. On the other hand, when it comes to saving money in today's economy, safety has frequently been the victim of cut backs. The more features of the equipment offered, the higher the cost value, which deter many paramedics who cannot afford such equipment. Though it is a sad fact, the budgets many stations operate on resulted in selecting equipment that will save the town money rather than improving the safety of the medics.

The other factor that must be considered is comfort, which always affected the selection of paramedic gear. It is vital that whatever equipment the paramedics used during any situation does not inhibit or interfere with how they perform. The first sign of any hindrance on performance, the equipment is either replaced or removed from use by the paramedic, even when this places their physical safety at risk. The main focus for the paramedic is performance. With this in mind, project designed with a special back support design to aid paramedics by providing them with a back support system that not only provides stiffness when required, but also could provide comfort while not on call. If the back support is not comfortable enough to wear throughout the shift, then there is no purpose in including it. If it does not provide the amount of support needed, then it would fail to serve any significant purpose. These concerns are what guided the design. In terms of comfort, one of the points brought up by some paramedics was that since they must wear their uniform the entire time while on duty, one could not remove a

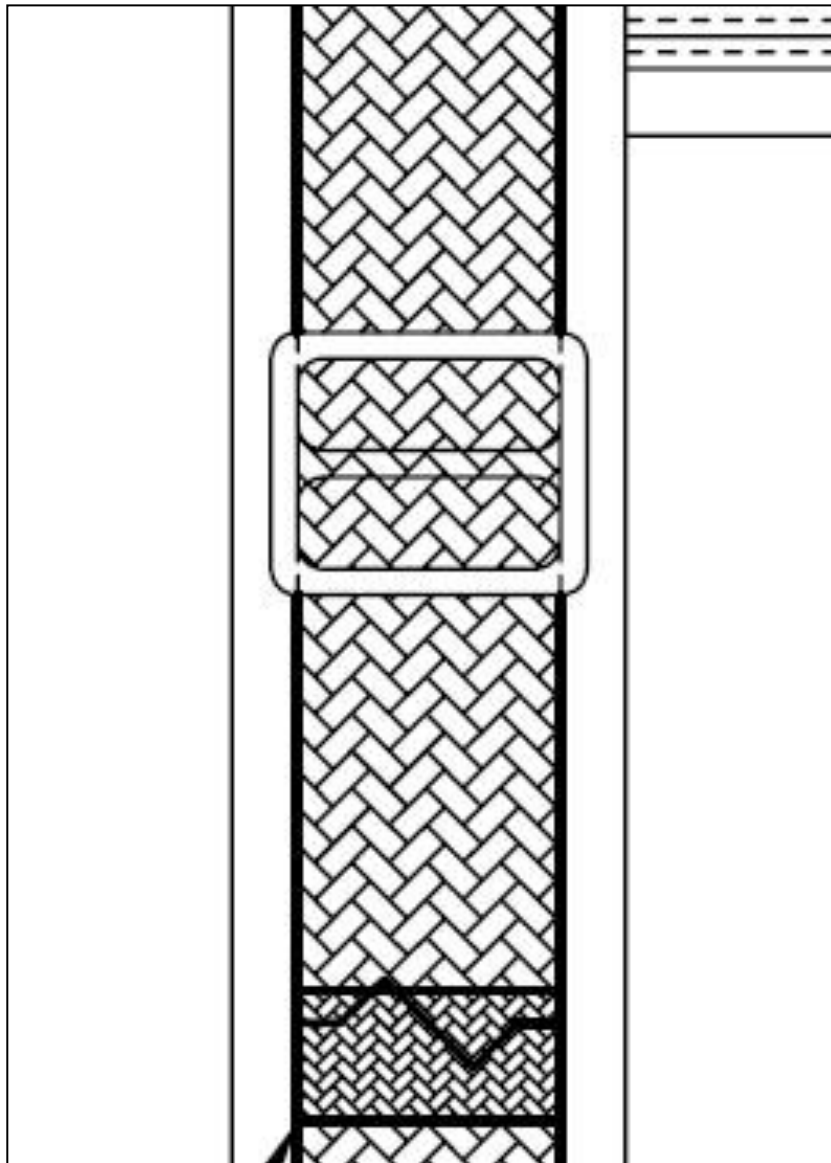


Figure 15- Pull Strap on Back Support Concept

part of their uniform, including the back support. Thus having to remain with the back support on the entire time on duty becomes very uncomfortable for paramedics.

To resolve this problem, several features have been put into the back support design. The most important design features of the back support are the pull straps along the front two sides as well as the waist support. The front straps can be seen in Figure 15 are used a buckle system to set the tightness on the support. This also pulls the spinal support against the user, providing alignment as well as comfort because of the ribbed foam padding along the length of the spinal

support. The ribbed formation allows for the pads to sit in between the spinal bones, evenly spacing them and providing eased comfort to the user. The straps can be adjusted to vary the stiffness desired by having the pull section appear through slots in the front of the suit for easy pull access. Once the user no longer needs the support, the straps can be released for a looser fit. The waist support provided the lower back support for the user. Just like the pull straps above it, the waist support is capable of being tightened by a pull strap located in the mid-center of the support. However, unlike the thinner straps above, the waist support has a thicker width to completely capture the lower back region, which provides the support for lifting the stretcher.

By having thick padding around the entire harness, this design provides comfort in a loose fitting, and strong stiff support when tightened. With the addition of the pull straps, this allows the paramedics to be able to set the support right away when the call goes through, and once returned to the station, they are able to release the straps for a loose fit. Throughout the design process of this project, questions and thoughts were brought up on how to further improve the current suit being used by millions of paramedics daily. One way that the group viewed this project was in the function of the human skin to the body. Just as the skin acts as a communicative, sensitive and protective organ, providing a layer against infection and irradiation (Hipler [17]), the project aims to create a suit to act as a second skin to the paramedic.

From what background information it is evident that the current suit does not offer any such protection to the user. With no sufficient qualities such as fire retardance, water resistance, puncture resistant, etc., the suit acts as a regular article of clothing with no further application. It is clear that the suit needs to serve a certain function in regards to the fabric. However, with the number of different materials that can be used, as well as the price for each material, it proves difficult to determine which fabric would work best. As well, the suit needs to serve other

functions in terms of versatility. As ideas got put together and analyzed, it became apparent that there were changes that could be made; there is no set standard suit for paramedics. Thus came the goal for the project; to design a suit that would become the standard suit used among most if not all Emergency Medical Services. By adding certain changes to current suit designs, Concepts 1 & 2 became the final design drawings for the project.

However, with the development of the drawings, the original main focus of the project, safety, played the role in a different form by offering the back support concept. With these designs, the operations of today's Emergency Medical Services groups would change forever, usher in with a new era of emergency care. This time, however, the wellbeing of both parties is being considered. Safety is the key word in medicine.

3.5: GPS Website Proof of Concept

In the background research of paramedic safety the group displays that another area where very little had been focused was the location of the paramedics. Given a scenario where paramedics have to attend a patient in a forest or at a big park, they sometimes spend more time looking for each other than the patient. This time lost is directly proportional to the effectiveness of any response effort which may lead to devastating consequences. The solution is the development of a website where the chief can view and track the position of all the paramedics on a particular shift. A website proof of concept to test a viable solution was created as part of the project.

3.5.1: Functionalities Provided With Webpage

GPS and approximate address of user

From the time the user opens the webpage, it would find and zoom into the user's location. The side pane displays the GPS coordinates and an approximate address. This functionality allows the chief to know her position relative to the paramedics and could be very useful if she is driving to the scene.

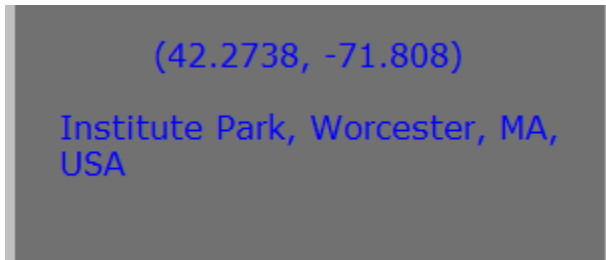


Figure 16 Approximate Location of User

Search for location

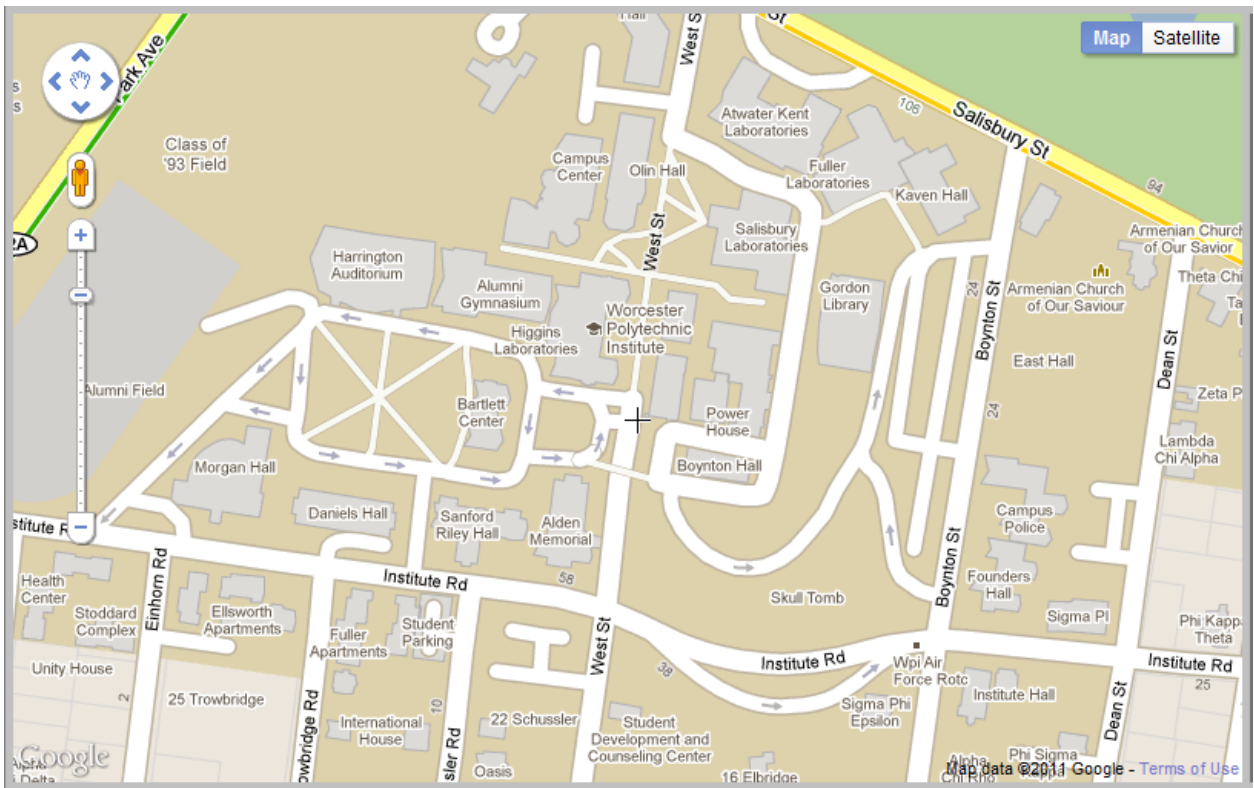


Figure 17 Map Centered At User Location

On the side panel was also found a search bar where the user can search for any address.

Center of Map

Upon loading of webpage, the user's location appears at the center of the map. Upon dragging the map to a new location, the website provides a set of new GPS coordinates and relative address for that new center location.

Features of Google Maps

The most common and useful features of Google maps are street view, terrain view, and traffic. Street view provided the user with a on the ground view of any particular location where the information is available. Terrain view provided the user with a topographical map and traffic displayed a color based system to show traffic along a main highway.

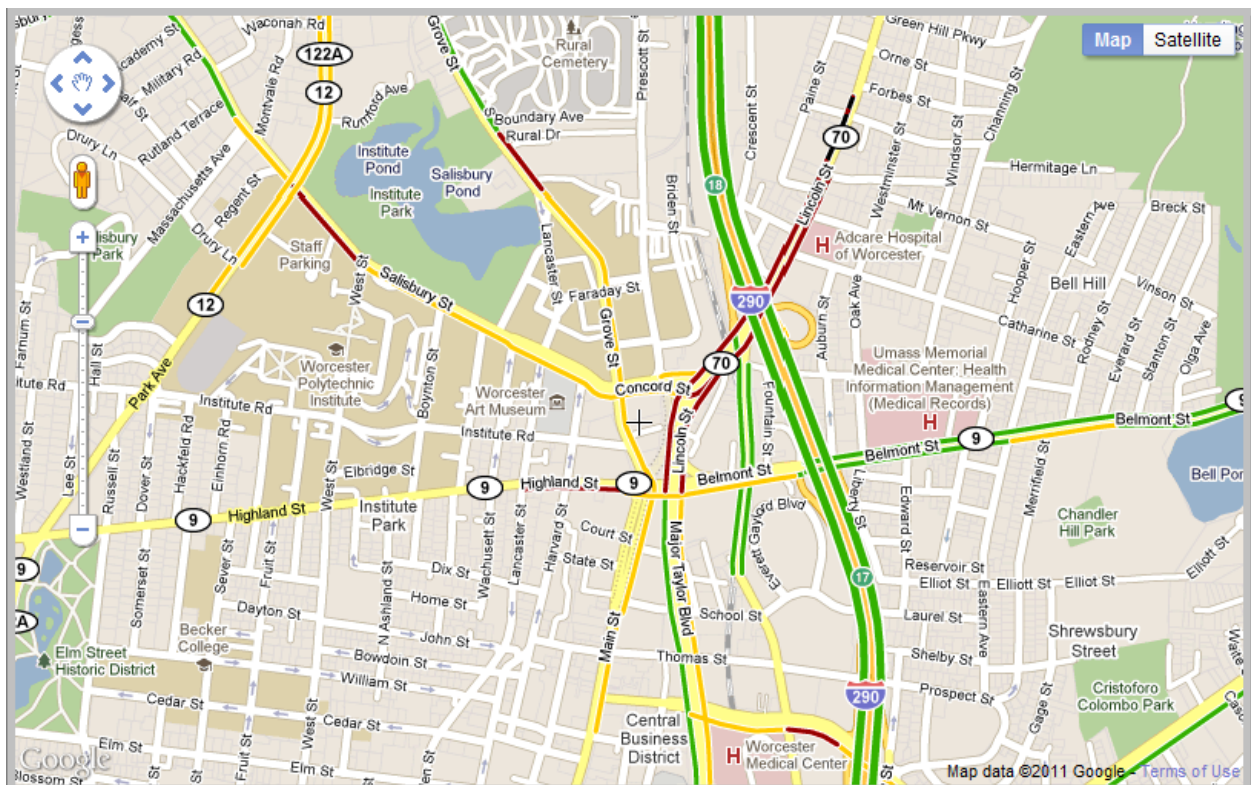


Figure 18 Example of Traffic Layer

CHAPTER 4: CONCLUSIONS

4.1: Summary of Future Work

As the world of medicine continues to advance and develop so must the protection of paramedics. Though the interventions that are incorporated into the current suit designs are meant to protect the paramedics from any harm or danger that is presented to them, it was noted that additional measurements of safety must be taken to further protect the paramedics on the job. Medicine evolves, and so must the interventions against them. What may be applicable and standard today would most certainly be irrelevant and outdated in the next year. Newer procedures, more training, and especially more devices are introduced every day in the medical field.

That was why the project understood that with the designs and ideas that are brought up and drawn out today would need to be changed in the future. The first change or modification would be fabrics. More research must be done in terms of searching for the proper material to make the paramedic suits. Certain tests such as fire retardance, water resistance, puncture testing and more would serve as guidelines as to determine what fabrics and material would serve best for the paramedic suit. Even more, testing on different combinations of fabrics and materials would lead to the advancement of finding the perfect combination to serve all three criteria.

With technology today, scientists are coming out with newer materials with more and more capabilities and functions. With this research and advancement, one day a fabric may be made to withstand biological fluids and contaminants, withstand extreme heat and cold, as well as have the strength to withstand punctures and foreign object debris (FOD). The hope was to have a suit that could hold all of these features at a low cost, made available for all paramedics

world-wide. In doing this, it would serve as the next stepping stone to creating a paramedic safety suit that would become standard all over the globe.

The next step in future research will be the adjustment of storage. Finding better ways of coordinating the storage spaces located on the suit, finding which pockets work, best, even setting a final standard layout of the pockets would become one of the main goals for future research. Finding the right combination allows for the analysis of how the placement of materials could affect or impact the job. As more materials are required for calls, more and more storage will become a demand from paramedics. For this reason, research on better storage designs and pockets would greatly benefit the paramedic in terms of having enough places to store as much supplies as possible.

Another area of research would also be the technology. The watch head and the GPS tracker are both of the two technological components of the current Concept designs. However, as with the other forms of technological advancements being made, one vision for future research is to have both devices incorporated into one single device, with more functions. The idea would have a watch head that would serve the name's purpose, to have a device to keep time for paramedics to aid in measuring vitals. On the other hand, the advancements would come into play in regards to the GPS tracking device. By having the device grow smaller to fit the size of the watch head, this would remove the necessity of having the device installed on the upper left chest region. The GPS tracker would be designed to give accurate GPS coordinates, capable of being displayed and monitored on a computer screen with a map pinpointing the location of the device. As well, the display would also show a topographical description to the reader, giving them information on the terrain, altitude, and atmospheric conditions during that time of reading. Another feature would be an emergency feature added to the GPS tracker. In

the case of an emergency where the paramedic was in danger or needed assistance, a button could be activated on the device, sending a signal to the computer which would give a notification of the emergency while reading out coordinate location as well as terrain conditions. By pressing the emergency button, the tracker would also serve as a beacon, a flashing strobe to make it easier for other paramedics to find the paramedic in need of assistance.

Finally, safety and protection of the paramedic will always be in change. The back support research would involve tests and procedures to find the right combination of comfort and protection of the paramedic. Research on materials would be the first step in changing the back support. By focusing on the main goal of providing comfort and support when needed, back support design would undergo various modifications to find the right design that would provide both. As well, this would usher in research for other protection means, including padding for neck protection, torso, as well as for the extremities. Since knee padding has been in current use already installed on the pants for paramedics, other paddings such as elbow and torso to protect the vital organs would become the next step in research for the back support.

By finding the right materials for these future functions, the suit would become more than a uniform, but the ultimate and most important piece of equipment in the EMS industry. Most certainly it is unlikely that the future suits would come to the design of the portrayed 'Iron Man' suit. However, with future research and more design and testing, it is believed that the future of the paramedic suit can change the way people view medicine, as well as the way paramedics and medical providers function and work. Emergency medicine should not just focus on the safety of the patient. The people responsible for the care, the ones that come to our aid when we call them, they too deserve to be made safe in their line of work. There is no reason for the risks to

outweigh the safety of the job. That is what this project was intended to do, and hopes to continue in the future.

4.2: Concluding Remarks

The basic principles of EMS have been established as early as Napoleon Bonaparte's era. An EMS system was created worldwide and although it only seems like a few years ago, EMS has made many changes. These changes have coincided with the era of technology but are still inadequate for the times we live in.

The advancements made in the early 1970's have remained our "bread and butter" but nothing new has been established for several years. After the terrible terrorist attacks in September 11, 2001, emergency personnel have done nothing but want to see more improvements. Rarely are they recognized for their efforts until that day, where so many emergency personnel's lost their lives and then took on the brave task of volunteering in the aftermath of that great tragedy.

Some say you have to be a little crazy to work in the field of EMS but for those who have established EMS as a career, know that the job can become quite daunting at times. There is a saying in EMS that says you will have spinal injuries when working in the field. This one issue is faced every time a patient must be put in a stretcher or carried down the stairs or you make a wrong turn while handling something heavy. Physically a medic's body endures all of these hardships on a day to day basis.

Another saying in EMS is that the first year on duty, you will be very sick. A medic is exposed to every patient we come in contact with, whether they are a trauma patient or a

medical, everything affects us. Having adequate vaccinations, gloves, equipment, and even goggles can help prevent this.

As a group we wanted something more for the medic on duty. We wanted to give them more protection while being exposed to all of the patient's sickness. We want the medic not only to be comfortable in their suit but to not have to worry about getting blood, vomit, urine, or any other bodily fluids that might come on it. Very rare does a medic have their uniform without any stains or every go without having something come on it. This suit can help prevent the exposure of the patient's bodily fluids to affect the medic.

There are two fire suits on the ambulance and although a medic will rarely have to respond to any fire emergencies, they will still be present. The ambulance will respond but be held back in any fire situation. The reason for why our team added a layer of fire protection is for the unusual cases in which the medic might be in. Such as an extrication of a car; if for some reason the medic has to be anywhere near the car or is willing to assist during the extrication, the medic will have some fire protection while working on the patient. These individuals have to treat patients while fuel leaks, endangering their lives, but with these additions to the uniform, a medic will feel more comfortable in providing assistance if allowed to.

These men and women are not seeking any recognition. Rarely are they talked about in the media or thanked by the people they save. And rarely do you hear a child say that they wish to be a medic when they grow up. These individuals are your everyday hero's who love their job and love helping those in need. People still see these invisible hero's as a means of transport, to go from their home to the hospital. Times have changed and the ambulance is now considered to be the emergency room on wheels, there are no physicians, no nurses, just a medic working on a

patient and their partner who is driving. Time is critical, a patient can go downhill at any moment and although they never went to medical school nor are they recognized, they are the ones who hold your life in their hands. The invisible hero's who want to give everyone a chance to live.

That is why we took on this project, to help those individuals who give so much and rarely get anything back, this was our way of saying "thank you" and acknowledge the work they do. The suit of the paramedics is the one item that has rarely changed throughout history and is something worn on their bodies which affect them every day. It is a small step, but these small changes to the uniform will not only help the medic but also the service they provide!

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APPENDICIES

Appendix A: Opinions of an EMT

We were very fortunate to have an EMT licensed in the state of Massachusetts working in our group. These are her opinions.

"When I was first training to become an EMT, my instructor told the class stories of what he experienced while working for EMS. He would also tell us about how we would change as not only as an employee but also as an individual. I could remember being in awe from all the stories he told us, and I doubted seeing that much in my life; both the good and the bad.

Being in EMS for several years, I can now understand what he was training us for. Although I am still a rookie in the field, the things I have seen in these past years, have impacted my life forever. And the respect that I have gathered for these medics is unlike anything out there. One of the most important things to always keep in mind is why we all do it and most importantly the oath we made when first taking the position as an EMT.

"Be it pledged as an Emergency Medical Technician, I will honor the physical and judicial laws of God and man. I will follow that regimen which, according to my ability and judgment, I consider for the benefit of patients and abstain from whatever is deleterious and mischievous, nor shall I suggest any such counsel. Into whatever homes I enter, I will go into them for the benefit of only the sick and injured, never revealing what I see or hear in the lives of men unless required by law.

I shall also share my medical knowledge with those who may benefit from what I have learned. I will serve unselfishly and continuously in order to help make a better world for all mankind.

While I continue to keep this oath unviolated, may it be granted to me to enjoy life, and the practice of the art, respected by all men, in all times. Should I trespass or violate this oath, may the reverse be my lot. So help me God”.

Written by: Charles B. Gillespie, M.D.

Adopted by the National Association of Emergency Medical Technicians, 1978

Appendix B: Journal Entries of our EMT

I spent the summer in Oxford Fire/EMS, wanting to see what ideas I could come up with in trying to improve safety in the ambulance for the medic. Every shift I walked in with a notebook, taking notes after every call and brainstorming ideas that I came up with during that shift. For several weeks I wanted to learn more about seatbelt safety in the ambulance. Since medics rarely put on a seatbelt while working in the back of the ambulance while working on patients, I decided to research the seatbelt safety aspects of EMS.

There was one specific day that really opened my eyes on safety, while working in the back of the ambulance. We were called to an elderly patient's home suffering from blindness and diabetes. On route to the hospital, the new EMT was driving quickly, slammed on the breaks forgot to stop at the stop sign and to avoid an accident from happening; she quickly turned the wheel, making myself and the other medic airborne.

The patient was secure in the stretcher but we were startled from the abrupt turn which left us with minor injuries. Although, no one was really hurt, it really opened up my eyes about the need to focus on the safety aspect of the ambulance. As time went on, the seatbelt project became rather overwhelming for the amount of time that we needed to have it finished.

The summer ended, it was time for classes to begin, and once again our team had no project. As we discussed what I experienced over the summer, our group started leaning towards a different aspect of safety; something that I had overlooked. They began to look in to the safety aspects of the uniform for the medic. As an EMT I was unsure if the idea was worth pursuing. But I asked myself, what does my EMS uniform provide for me? How does it help me while I'm treating patients?

After questioning the project idea, I looked at my uniform; it was a simple blue uniform. A navy blue shirt with EMS patches on the side, navy blue pants with some padding on the knees, heavy duty boots, and the communication devices. Most of the time, the dress shirt was not worn, and instead a simple t-shirt from the fire department is typically worn. When it's cold sometimes a jacket will be worn. A typical EMT uniform consists of boots, pants, a dress shirt, and depending on the weather a jacket. There is a wide variety of uniform colors, depending on the region and ambulance service.

Every region, every state, every ambulance service are different from one another which made a universal uniform seem almost impossible. There are a variety of calls ranging from trauma, to medical, to even assisting in advance medical treatment. All of those scenarios were a key point to designing the suit. One of the greatest goals was to see how simple we could make it, without changing too much of the original design that have been worn for decades.

Although there was no set uniform for the first EMT's years ago, the emergency personnel's adopted a simple uniform similar to law enforcements. Some of the earliest EMT class's wore dress pants, a dress shirt, shoes, and a tie. Years later some changes were made to uniform, the heavy duty boots were added to the wardrobe, the communication devices, and although no tie is worn today, the professional look is still vital to wearing a proper uniform.

Appendix C: EMS by the Numbers

U.S. Ambulance Statistics

Number of Ambulance Services: 15,276

Number of Ground Ambulance Vehicles: 48,384

Number of EMS Personnel: 840,669

Ambulance Staffing:

- Both career and volunteer personnel: 40%
- Career personnel: 38%
- Volunteer personnel: 22%

EMS Practitioner Types:

- First Responder: 11%
- EMT-B: 53%
- EMT-I: 9%
- EMT-P: 41%
- Registered Nurse: 8%

Types of Systems in the US:

- Fire Department with cross-trained EMS personnel: 38%
- Government or Third Service: 23%
- Private company: 13%
- Other: 12 %
- Hospital-based service: 7%

- Fire Department with separate EMS personnel: 4%
- Public Utility Model: 2%
- Police Department with cross-trained EMS personnel: 0.75%
- Police Department with separate EMS personnel: 0.75%

Average of calls throughout a one year period (2007)

EMS Call Volume per Week:

- 1,000 to 10,000 calls: 40%
 - 100 to 500 calls: 26%
 - 10,000 to 50,000 calls: 12%
 - 500 to 1,000 calls: 9%
 - 0 to 100 calls: 6%
- 50,000 to 100,000 calls: 5 percent
- More than 100,000 calls: 2 percent

Source: EMS Magazine's 4th Annual National EMS Systems Survey

Appendix D: Overview of Website

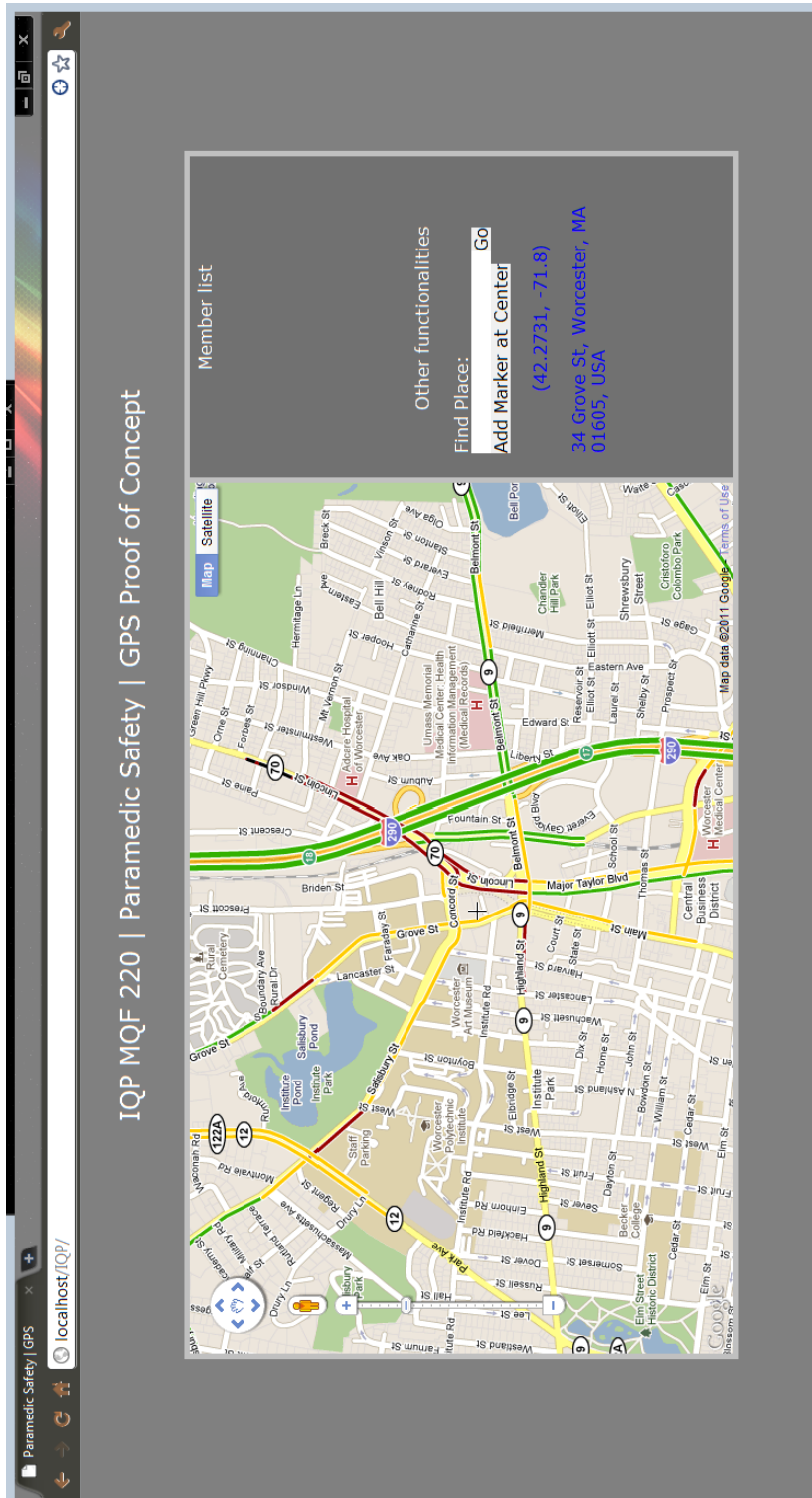


Figure 19 Overview of Website

```
<!DOCTYPE html>

<html>

<head>

<meta http-equiv="Content-Type" content="text/html; charset=iso-8859-1">

<meta name="viewport" content="initial-scale=1.0, user-scalable=no" />

<title>Paramedic Safety | GPS</title>

<link href="css/index.css" rel="stylesheet" type="text/css">

<script type="text/javascript" src="http://maps.google.com/maps/api/js?sensor=false"></script>

<script type="text/javascript">

var map;

var myOptions;

var latlng;

var geocoder;

var geocoder2;

function initialize(){

navigator.geolocation.getCurrentPosition(

    function (position) {

        Latitude = position.coords.latitude;

        Longitude =position.coords.longitude
```

```

latlng = new google.maps.LatLng(Latitude,Longitude);

myOptions = {
zoom: 12,
center: latlng,
mapTypeId: google.maps.MapTypeId.ROADMAP
};

map = new google.maps.Map(document.getElementById("mapCanvas"), myOptions );

geocoder2 = new google.maps.Geocoder();

geocoder2.geocode({'latLng': map.getCenter()}, function(results, status) {
if (status == google.maps.GeocoderStatus.OK) {
if (results[1]) {
document.getElementById('formattedAddress').innerHTML = '<br
/>'+results[1].formatted_address;
}
} else {
alert("Geocoder failed due to: " + status);
}
});

geocoder = new google.maps.Geocoder();
setupEvents();
centerChanged();

```



```

        var trafficLayer = new google.maps.TrafficLayer();
        trafficLayer.setMap(map);
    });

}

function setupEvents() {
    reverseGeocodedLast = new Date();
    centerChangedLast = new Date();

    setInterval(function() {
        if((new Date()).getSeconds() - centerChangedLast.getSeconds() > 1) {
            if(reverseGeocodedLast.getTime() < centerChangedLast.getTime())
                reverseGeocode();
        }
    }, 1000);

    google.maps.event.addListener(map, 'center_changed', centerChanged);
}

function getCenterLatLngText() {

    var lat = Math.round(map.getCenter().lat()*10000)/10000;
    var lng = Math.round(map.getCenter().lng()*10000)/10000;

    return '(' + lat + ', ' + lng +)';
}

```

```
}
```

```
function centerChanged() {  
    centerChangedLast = new Date();  
    var latlng = getCenterLatLngText();  
    document.getElementById('latlng').innerHTML = '<br /><p align="center">'+latlng+'</p>';  
    document.getElementById('formattedAddress').innerHTML = '<br /><p  
align="center">Calculating an approximate address...</p><br/>';  
    currentReverseGeocodeResponse = null;  
}
```

```
function reverseGeocode() {  
    reverseGeocodedLast = new Date();  
    geocoder.geocode({latLng:map.getCenter()},reverseGeocodeResult);  
}
```

```
function reverseGeocodeResult(results, status) {  
    currentReverseGeocodeResponse = results;  
    if(status == 'OK') {  
        if(results.length == 0) {  
            document.getElementById('formattedAddress').innerHTML = 'None';  
        } else {  
            document.getElementById('formattedAddress').innerHTML = '<br />' +  
results[0].formatted_address;  
        }  
    } else {
```

```
    document.getElementById('formattedAddress').innerHTML = 'Error';  
  }  
}
```

```
function geocode() {  
  var address = document.getElementById("address").value;  
  geocoder.geocode({  
    'address': address,  
    'partialmatch': true}, geocodeResult);  
}
```

```
function geocodeResult(results, status) {  
  if (status == 'OK' && results.length > 0) {  
    map.fitBounds(results[0].geometry.viewport);  
  } else {  
    alert("Geocode was not successful for the following reason: " + status);  
  }  
}
```

```
function addMarkerAtCenter() {  
  var marker = new google.maps.Marker({  
    position: map.getCenter(),  
    map: map  
  });
```

```

var text = 'Lat/Lng: ' + getCenterLatLngText();
if(currentReverseGeocodeResponse) {
    var addr = "";
    if(currentReverseGeocodeResponse.size == 0) {
        addr = 'None';
    } else {
        addr = currentReverseGeocodeResponse[0].formatted_address;
    }
    text = text + '<br>' + 'address: <br>' + addr;
}

var infowindow = new google.maps.InfoWindow({ content: text });

google.maps.event.addListener(marker, 'click', function() {
    infowindow.open(map,marker);
});
}
</script>
<script type="text/javascript" src="javascript/jquery.js"></script>
</head>

<body onload="initialize()">
    <div id="header">

```

```
<p align="center"> IQP MQF 220 | Paramedic Safety | GPS Proof of Concept
</p>
```

```
</div>
```

```
<div id="container">
```

```
<div id="mapCanvas">
```

```
</div>
```

```
<div id="crosshair"></div>
```

```
<div id='sideBar'>
```

```
<div id='sideContent1'>
```

```
<p align='center'>
```

```
Member list
```

```
</p>
```

```
</div>
```

```
<div id='sideContent2'>
```

```
<p align='center'>
```

```
Other functionalities
```

```
</p>
```

```
<br />
```

```
Find Place: <input type="text" id="address"/><input  
type="button" value="Go" onclick="geocode(">
```

```
<input type="button" value="Add Marker at Center"  
onclick="addMarkerAtCenter()"/>
```

```
<div id="latlng"></div>
```

```
<div id="formattedAddress"></div>
```

```
</div>
```

```
</div>
```

```
</div>
```

```
</body>
```

```
</html>
```

Appendix E: Transcript of Meeting with Oxford

Questioner: The idea that we have right now is based on the concept of a firefighter's 2 piece suit, putting the jumper and jacket over it and what that would mean is that you would be able to wear the suit both in the winter and summer. This way, we would be able to deal with both temperature change and climate effects. Now, in the suit itself, the design that we have thought about would include padding around the knees and any other locations we would deem fit along with special pockets for pens, a small area to write down the vitals and a small place for a watch.

Medic 1: Was there any discussion on it protecting against blood borne pathogens?

Kelin: Yes. We are looking into that because we also want to have some fire protection on it.

Medic 1: I was thinking more along blood borne pathogens as far as being covered in blood so that it doesn't access the skin.

Questioner: The material that we had talked about was Nomex and we were thinking about using that as a thin outer layer. Are you familiar with Nomex?

Medic 1: Yes, the fire department uses Nomex.

Questioner: Okay, so, that was one of the primary concerns that we had in order to have the body breathe and also protect from any type of fluids medics may come in contact with.

Showed Medic 1 suit design drawings.

Questioner: Another question we are wondering about is back support. I know it is a big problem in the field, but how comfortable is it to wear back support for an entire call. How would back support limit the medic's mobility and if it did limit, would they rip it off?

Medic 2: I don't see anyone wear it for any extended period of time. It seems like before the shift is even over, the medics will take the back support out.

Medic 1: We need to be able to bend, stretch, and the positions we end up being in are not common. For example, people collapse in their bathroom between the toilet and the bath tub, therefore we need a lot of mobility and while back support is a good idea and back injuries are the number one problem in this business, no one has come up with a way to make it conducive to our business. Some of the ways they have tried to go with it is to change the stretchers to make them easier to put them in and out of the ambulance because that is where a lot of the back injuries happen, but ultimately there really isn't a lot we can do because proper lifting technique doesn't work in our world. The only time you do proper lifting technique is when you are getting ready with the backboard. We move people all the time and pull them out of cars and you can't just bend at the knees. On a day to day basis, of all the lifting and pulling that we do, maybe 40% can have proper lifting techniques applied. Even if you had the back support, I don't know if it would really be conducive because those are designed to a lifting technique that is good for you. We are not doing that for a good percentage of the time.

Questioner: In that case...

Medic 1: I'm not sure it would make a difference.

Questioner: Okay. With the current suit design, is there anything that limits the medic?

Medic 1: I don't think so.

Medic 2: I can't think of any things. I know in the past people have tried to wear jumpsuit style, which is some occasions but that was not something that lasted because it did not have a big comfort factor. Once you were moving around, parts of the suit would get bunched up...

Medic 1: ...Which is why I think that a 2 piece suit is a great idea.

Questioner: From the things that we have been talking about that a medic would carry on person, it would be the gloves, pens, lights, radio...

Medic 1: We have our pagers always on us and most of us carry some sort of flashlight, bigger or smaller doesn't really matter. Mine is predominately for checking pupils or I can use it at night.

Medic 2 carries a much bigger flashlight than I do. Those are the basic things. Other than that, if I have a knife or anything else, I just put them in my pockets. A lot of the suits have zippers on the pockets which allow us to carry many tools. These things can be taken care of with pockets, but what we carry on our belts are pagers and flashlights.

Questioner: Another thing we have talked about with this project which is not necessarily related to the suit, is the location of the paramedic. Our idea was to use a GPS device to connect to a website which we are making so that you would be able know where all the paramedics are located at all times within a given radius. The way that would work would be to include the normal GPS signal from cellular phones that most people have—Most phones now are GPS enable and if they are not, they are cheaper than GPS tracking devices. That would allow you to know where everyone is and if there is a call in a forest, for example, it would allow you to spend less time looking for each other.

Medic 1: The fire service has tackled that pretty aggressively in trying to find firefighters in buildings, but that is actually a fantastic idea because as you know we are cross trained. As you

said, if we are off in the woods in a brush fire, just because medics are not acting as an EMT at that time, doesn't mean I don't have to know where he/she is. A brush fire is probably the perfect example where radio communications can be difficult and trying to figure out who is where and who is doing what, even as far as motor vehicle accidents we've had accidents where vehicles are separated from each other. Then we have crew looking for people who got ejected and it is very easy to lose track of medics. One of the directions we are moving to is having a laptop for a number of things such as accessing files on the different places we are going. Every building has a site file with hazards and stuff like that listed in it. We also use it to access hazardous material information on the internet if it is a truck roll. A laptop is at the point where in addition to getting all medical gear, a commanding officer will also have to carry a laptop. I think that is a good idea because that is pretty much where it is going. And knowing where medics are is a huge step that no one has thought about. Everyone always thinks of the guys on the fire side and a lot of the protective clothing that has been researched actually helps with that idea. As a commanding officer, you would be able to track everyone. It is a little different, because, in a fire, fire-fighters can be in a metal building, they have all that gear on but no one has ever thought about the fact if they are not in a burning building. I think that it is great that you guys have thought about that. And even something as silly as when we get multiple calls going on, to try to find out where everyone is...Are they on the way back from the hospital, are they still at the hospital, are they at the center of town at the lights when that next call comes in? There is still confusion when there are multiple trucks going around.

Questioner: In the current suit design, how much approximately are you paying for the whole outfit?

Medic 1: To completely outfit a basic set, pants would cost \$ 70 - \$ 80, patches run about \$ 70, and then you throw in the belt, the pager, the boots are almost \$200. I think overall, depending on whether you are looking at long sleeves or short-sleeves, you are looking at a minimum of \$ 500. Now, when you get a new employee, we allocate them approximately \$ 1400 to go get everything. The initial startup is very expensive.

Questioner: And what is the specialty of the belt?

Medic 1: There is nothing special about the belt other than being really heavy duty. A lot of us are using the Velcro rip-away which is actually a tactical belt that has a deployment mechanism but we wear them because the Velcro is convenient. We have used these so that we can bail out in a building if we needed them for something. And these belts are not cheap, they run about \$ 40.

Questioner: Our point is to make it have all these functionalities that we have thought about but then we have to think about cost and reality as well. What is the tipping point that would cause you to say this is something too expensive?

Medic 1: I'll tell you that the problem you are going to run into is that historically everyone cares about money but not safety. If you look at the ambulances, to make them "safe" is cost prohibitive. However, I am a firm believer in safety and I think that you will see the next generations of chiefs coming along thinking the same way. Again I will use the ambulance example. An ambulance which costs a \$ 160,000 may provide some extra safety benefits but we have an ambulance that costs \$ 100,000. Safety is costly so we need to work on that and I think that the mindset is changing. EMS is one of the biggest public services but not as much money is put into EMS. To put a dollar amount on a suit price, I don't know. But I certainly believe that

even if it costs a little more than a regular uniform, absolutely I would choose your suit. But if you are telling me that it will cost \$ 1000 per suits and if a medic needs 4 to make it through the week, then that is a different issue. You need to weigh that. What you need to comment from a selling point is that you are tackling some of the special cases as well as the blood borne pathogen which has never been tackled on the EMS side other than wearing gloves. If Medic 2 gets involved in a blood bath today, he has to throw it all away and buy a new one, so that comes into play as well. Your plan in the long run could actually save us money because we would not be throwing articles away all the time

Medic 1 leaves

Questioner: Is there anything else you would like to see in a suit design?

Medic 2: Back in the day we used to have pockets on the side and people would fill them up. It is not that we are carrying any less items now-a-days but now the pockets are hidden within pockets and hidden within seams. That seems to be very effective and popular. The radio and technology that we are carrying is getting smaller but the means of attaching them are still the same and not effective. We have tried pockets up high and I actually dropped a radio on someone one day. It is a funny story but I just can't tell you. Some of the cases we carry lean out to the side and the problem we run into is...picture yourself trying to carry a patient down the stairs and now you have the radio and it is getting hooked on doorknobs or picture how the weight of it is affecting the uniform and your hands are tied up.

Questioner: One of the other things we had talked about was having a small inside pocket for the winter because you have to keep the saline warm and from what we understand you just hold it in your jacket.

Medic 2: We carry the saline at a higher temperature in the ambulance but when it comes to treating on the scene, you are right, there is no proper way of holding it. Maybe if there was a way to hook it on but still get it to run by squeezing because if you go down lower than the patient you lose all the pressure. That is a good idea that would free up a set of hands. Another thing is that paramedics carry keys because ambulances carry compartments and you really don't want to be digging in your pocket with your bloody gloves or dirty hands and touching a wallet you use every day. Also, you don't want to have them dangle on your side because it will get stuck everywhere or some can go missing. If we have a patient who is ceasing for example, we have to unlock the narcotic cabinet. If you don't have your keys because you lost them as you dragging the patient from under the house, it becomes a big concern.

Questioner: I can see your keys. Are they attached to a lanyard?

Medic 2: My keys are not attached with lanyards because they break and if it breaks, your keys are down on the floor. The keys are important and everyone should also carry a pen.

Questioner: What is the most important functionality that we have spoken about?

Medic 2: I would prioritize having something that protects against blood borne pathogens.

Glossary

Fire Retardant (FR) viscose: viscose produced by doping the material with fire resistant fillers and additives before extrusion. Additives may include Sandoflam, polysilicic acid, or aluminum. (Horrocks, A., & Anand [11]).

Gore-Tex®: a registered trademark of W. L. Gore & Associates, Inc. is a porous Polytetrafluoroethylene which makes up a waterproof breathable layer.

Hydrophilic layer: thin layer in a waterproof breathable material which contains no holes, but allows water to pass by its hydrophilic nature. Used primarily to prevent contaminants from blocking the pores in the hydrophobic layer (Horrocks, A., & Anand [11]).

Meta aramids: Fire resistant synthetic fibers with an aromatic structure. They have high tensile strength and modulus but low elongation compared to organic fibers. Currently used in firefighting and military clothing (Horrocks, A., & Anand [11]).

Modacrylic: An inherently flame retardant material which may be blended with cotton to yield a more fire resistant material with similar degree of comfort as cotton. (Horrocks, A., & Anand [11]).

Nomex®: A fabric among the first and most popular meta aramid fabrics, Registered trademark of DuPont.

Oxidized acrylic: An inherently fire retardant material. Often blended with an aramid in a honeycomb woven form to give a stretchy fiber which may be used as a covering for irregular objects (Horrocks, A., & Anand [11]).

Panox: made by RK Textiles; see Oxidized acrylic.

Phenolic: Heat resistant material that produces little smoke or toxic gasses; however, it is precluded from the applications considered in this paper because of poor strength against abrasion unless blended with Nomex or FR viscose (Horrocks, A., & Anand [11]).

Polybenzimidazole (PBI): Organic non-combustible material. It has a similar degree of comfort as cotton. This material is currently used in some firefighter suits (Horrocks, A., & Anand [11]).

Polytetrafluoroethylene (PTFE): Material that is biocompatible, resistant to strong acid and bases and not affected by UV radiation. The material contain very small pores which allow water vapor to pass through it, however it can suffer from irregular spacing of these pores if not stabilized. (Horrocks, A., & Anand [11]).

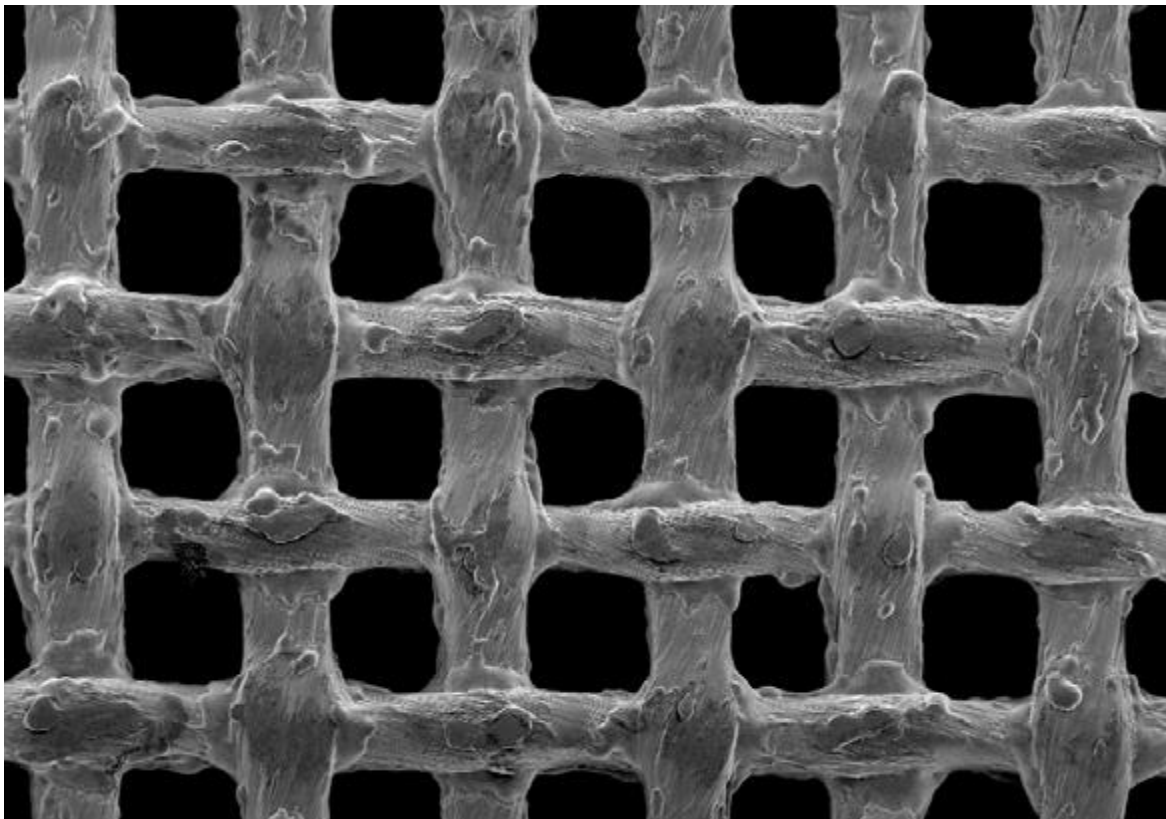


Figure 20 Tablized 100% ePTFE Fabric (Horrocks, A., & Anand [11]).

Pyrolysis: decomposition of a material at elevated temperatures without oxygen (Horrocks, A., & Anand [11]).

Sandoflam 5060: One additive that may be used to make FR viscose. Contains phosphorus and sulphur.

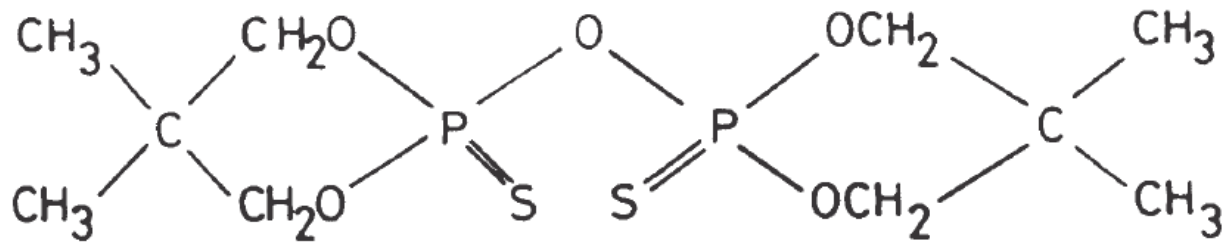


Figure 21 Structure of Sandoflam (Horrocks, A., & Anand [11]).