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Deployable Prototype Documentation

[0] (2015). *High Tech Lines*. Available: http://coverlayout.com/facebook/covers/high_tech_lines/

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I. Executive Summary

Throughout a two semester engineering senior design course, the authors sought a solution to a specific societal problem. They began this quest by first defining what that problem was. In this case, the leading causes of firefighter fatalities was investigated. Reports from the National Institute of Occupational Safety and Health (NIOSH), along with data from the Federal Emergency Management Agency, identified two leading causes of injury and death among firefighters. First, Cardiovascular Disease was found to be a major contributor to firefighter fatalities both on and off duty, while becoming lost or trapped was the leading cause of on duty fatalities. Also of interest, was that the majority of firefighters affected were volunteer. Armed with this knowledge, the authors set out to design a system capable of alleviating these threats to first responders safety. They began by exploring the technologies currently available. This research identified that the technologies exist to implement a solution, but that no current solution is currently on the market. While some devices exist, their expense make them impractical, especially for volunteer services. So, the team devised a set of features that would be required to provide a device capable of solving this perceived problem, all the while keeping in mind that it would need to be inexpensive as well. The first requirement was that the device be wearable. Firefighters would need to carry it on their already heavy gear, and weight as well as size would not to be minimized. The device would also need to provide the firefighters current location. This would help to solve the problem of being lost or trapped. The other identified problem, Cardiac Arrest, would be minimized by the device reading the heart rate of the firefighter, to identify any health problems arising on the job. Another desired feature was the ability to record this information for later review, to help with the previously mentioned NIOSH reports should an incident occur. Finally, the device would need to also send this information to the Incident Commander or supervisor on the job site, to aid in their ability to protect and manage their people, all in real time. This required a final component of the device to be an interface that this supervisor could use to track and keep an update on their assigned firefighters.

All of this was implemented successfully by the team, and tested to meet the previously determined requirements. The authors used project management tools to keep on track and avoid common pitfalls while designing the proposed device. The end result was a small wearable device under 1 pound, and about the size of a radio that can be worn by the firefighter. A small heart rate sensor provides a reading of the firefighters vital signs, while a GPS receiver provides a location. This information is stored on the device, and then sent wirelessly to the incident commander, to be displayed on a simple laptop computer or tablet. This way, the supervisor can keep track of his subordinates, and have an idea of their status, allowing him or her to more quickly be advised if something were to go wrong.

Additionally, the team performed a market review to determine the size of any potential markets for this device, and confirmed that there are twice as many volunteer fire fighters as there are fell-time salaried fire-fighters. This re-emphasized the need for a low cost and more easily obtainable solution. Research was completed into similar devices on the market, and it was discovered that no real competitor exists, and the closest solutions are more than twice the cost of this system. It is our opinion that a need and a market exists for a device such as this one, and we have proven that the technology to provide an economically viable solution is also here.

***Abstract*—First responders play a fundamental role in society, providing relief and help for those in need. This document details the authors process in implementing a heart rate and location tracking system into a firefighters uniform to help save their lives. This task is not only important for firefighters, but also for those who require the firefighters help. Current methods and technology lack an efficient means of tracking the health of first responders, their location, or the means of better interacting with their environment and have not undergone significant improvements. An analysis of these areas and of the leading causes of fatalities and injury among first responders (to include stress, personnel accountability, and situational awareness) is undertaken. All of these areas contribute to the effectiveness of disaster relief, reducing injuries, saving the lives of both first responders and the victims they assist, as well as more rapidly disseminating data for continual disaster support. Existing technology is explored and their viability is taken into consideration. The final design idea for the proposed heart rate and location tracking system that will be implemented into the firefighters uniform is discussed. A specific set of required features is agreed upon, defining the device to be a wearable, wireless device capable of measuring and recording heart rate and location accurately and reliably, while relaying that information to an interface for the Incident Commander. Furthermore, the project implementation, project time line and milestones associated with this project are reviewed. Risk assessment is undertaken, with an explanation of how those perceived risks were mitigated. A user manual and a detailed discussion about the system is also included. Hardware and software implemented is discussed, and finally a test plan that details the results of the analysis of the final product is provided, showing the ability of the device to meet the previously defined feature set metrics.**

Keywords*—Biomedical Monitoring, Cluster-based Architecture, Emergency services, Evacuation Routes, Fire Fighting Operations, First Responders, Geographic Information System (GIS), GPS, IEEE 802.11, Indoor Navigation, Inertial Sensing, Location Systems, MANet, Mapping sensors, Mobile Emergency Systems, Navigation, NMEA, Real-time Data Collection, Satellites, Session Initiation Protocol (SIP), Simultaneous localization and mapping, Terrain mapping, Tracking, Unmanned Aerial Vehicles (UAVs), Vectors, Virtual Satellite, Wearable Sensors, Wireless Sensor Networks.

II. Introduction

Firefighters play a fundamental role in society and their safety should be a high priority. This report encompasses the entire effort the authors have undertaken in the pursuit of alleviating their greatest risks through engineering design. This task is not only important for firefighters, but also for those who require the firefighters help. Current methods and technology lack an efficient means of tracking the health of first responders, their location, or the means of better interacting with their environment and have not undergone significant improvements. An analysis of these areas and of the leading causes of fatalities and injury among first responders (to include stress, personnel accountability, and situational awareness) is undertaken in order to more clearly define the problem to be addressed. All of these areas contribute to the effectiveness of disaster relief, reducing injuries, saving the lives of both first responders and the victims they assist, as well as more rapidly disseminating data for continual disaster support. This results in two primary causes of injury being identified as cardiac arrest, and becoming lost or trapped. Existing technology is explored and their viability is taken into consideration. The final design idea for the proposed heart rate and location tracking system that will be implemented into the firefighters uniform is discussed. A specific set of required features is agreed upon, defining the device to be a wearable, wireless device capable of measuring and recording heart rate and location accurately and reliably, while relaying that information to an interface for the Incident Commander. Specific metrics are identified to provide testable compliance with these features. Furthermore, the project implementation, project time line and milestones associated with this project are reviewed. Funding proposals, as well as the WBS (Work-Breakdown-Structure) are discussed to show how this system was implemented. Risk assessment is undertaken, with an explanation of how those perceived risks were mitigated. A user manual and a detailed discussion about the system is also presented, including all relevant block diagrams and flowcharts. Hardware and software implemented is discussed, and finally a test plan that details the results of the analysis of the final product is provided, showing the ability of the device to meet the previously defined feature set metrics.

III. Societal Problem

In any kind of disaster or emergency situation it is usually firefighters, emergency medical personnel or police that are first on the scene and provide relief and help for those affected by the disaster or emergency situation. Despite first responders having such a crucial role in today's society, they are chronically underfunded and lack access to state-of-the-art technology [11]. Focusing on firefighters, it turns out that 45% of firefighters death is sudden and 70% of those sudden deaths are volunteer firefighters [12]. Firefighters are under a high amounts of stress due to the nature of their occupation and it is in every ones best interest to provide them with better tools to handle emergency or disaster situations.
Considering the hectic environment involved in first response, the coordination of various types of teams and individuals, as well as the need for specialized equipment, high stress and multitasking is a daunting and difficult task for first responders, especially in collecting crucial information rapidly and efficiently [11]. The need that starts to be expressed is for any type of technology that is not bulky or cumbersome, that assists in monitoring the well-being of first responders under stress, and that can assist with interfacing with their environment in a simple and easy to use fashion [13]. The societal issues that first responders, and specifically firefighters face are discussed in detail in the following sections.

A. Disasters and Communication

Natural or man-made disasters are a common occurrence all over the world. Earthquakes, tsunamis, floods, storms, terrorist attacks and nuclear disasters can destroy the infrastructure of the affected region, cause mass fatalities, injure a large number of people and displace residents out of their homes. Depending on the severity of the disaster, having a damaged infrastructure, especially non-operational communication networks has huge implications on the rescue efforts made by either local governments or rescue and relief organizations. “Information and communication are the cornerstone of any disaster response for informed decision-making [14].” In a disaster situation, being able to communicate is of utmost importance.

If there are no communication networks available, emergency personnel, such as paramedics and rescue workers, are unable to interact with each other and carry out their work sufficiently. In addition, the organization of rescue efforts is severely impacted if national/ local governments and relief organizations can’t coordinate with each other and share their resources/ knowledge. People that are injured and/ or trapped are unable to call for help and in the worst case scenario will perish if help arrived too late. If communication networks are non-functional, people are unable to locate missing family members or friends. Even though the majority of people are in possession of a cell phone, if the communication network is non-operational or overloaded, the devices are useless.

The need for better, reliable communication for first responders definitely exists and needs to be addressed so that the first responders can carry out their work effectively and safely.

Our initial assessment, as just discussed, focused on a big picture view. We narrowed our focus onto firefighters and the issues that they are facing in certain operating environments. These include primarily wildfire environments but also suburban or rural settings. Within these settings, a fire fighting agency will have to bring their own network and will not be able to rely on existing infrastructure for communications within their team. It is this communication link that we are focusing on, as inter-agency communications are usually required for larger scale operations and not necessarily those seen on a daily operational basis.

To that end, our communications problem is defined by addressing fire team communications between an incident commander and his subordinates, while striving to provide a solution that remains robust enough to allow these communications in as many operating environments as possible. Adding to this problem are the constraints inherent in funding of these operations, as many of the fatalities and health problems we are attempting to address are coming from volunteer agencies that do not have the luxury of expensive equipment.

B. Cardiovascular Disease

First responders save lives every year, but they face the same medical challenges that many people face in today’s society. The most notable difference is that they are exposed to more hazardous conditions compared to civilians because they have devoted their lives to helping rescue other people. The healthier firefighters are, the more likely they will successfully carry out rescue operations. Firefighters have to operate in various hazardous environments, such as chemical fires, which means inhaling more smoke toxins. One would think that the number one health issue for firefighters would be respiratory illness, but surprisingly, the number one cause of mortality in firefighters is Cardio Vascular Disease (CVD).

Statistics show that 45% of mortality caused in the line of duty for firefighters is sudden CVD [12]. CVD has become the leading cause of death in firemen and consequently, there has been increasing concerns about the safety of firefighters who exhibit symptoms of CVD. Many factors contribute to CVD, especially for firefighters, since they are more frequently exposed to hazardous environments but also deal with extremely high stress and fast paced situations on a regular basis.

Another interesting factor about CVD related deaths in firefighters is that 70% of the deaths are from volunteer firefighters [12]. Volunteer firefighters undergo less rigorous training and are often in less physically fit condition compared to full time firefighters. Having a way of monitoring the vital signs of firefighters during their rescue and/ or relief operations will not only benefit the firefighters itself, it will also help those who rely on the firefighters to get them to safety.

C. Personnel Accountability

According to the U.S. Fire Administration (http://apps.usfa.fema.gov/firefighter-fatalities/), the leading cause of on-scene fire–related fatalities amongst firefighters is becoming lost, caught, or trapped while battling a blaze. Of the 130 deaths over the past 4 years, 43 were due to being caught or trapped.

A 2010 survey of first responders identified “lost inside” as a major cause of traumatic injuries to firefighters. The US National Institute for Occupational Safety and Health (NIOSH) has also reported that disorientation and failure to locate victims are contributing factors to firefighter deaths (www.cdc.gov/niosh/fire). When a first responder issues a distress call, rescue teams must be able to locate that person as soon as possible. Even when the conditions allow a full search of a building, precious time can be wasted by missing a room or even searching the same room twice. Building layouts are not always known, and plans cannot always be located in a timely fashion to coordinate a full search. The incident commander, especially, needs timely data on the location of each person under their command. Current personnel accountability systems often consist of nothing more than a Velcro board indicating where a member originally deployed to. A clear need for a better system to track the whereabouts of first responders exists, and NIOSH has issued a call to conduct research into refining existing and developing new technology to track the movement of fire fighters inside structures [15].

A 2013 report of all firefighter fatalities listed improvements to personnel accountability as a major recommendation from fire experts in after action reports for both wildland and residential fires. That year alone 29 firefighters were killed in 7 separate incidents when they became caught or trapped. In one particular incident, the infamous Yarnell Hill fire in

Arizona, nineteen firefighters died when they were caught and trapped by a fast moving wildfire that had changed direction. No one had realized that the crew left the area they were in and headed southeast. Winds had shifted causing the fire to turn south and the crew was overran [16].

This problem is not limited to the U.S., nor is it a new one. In Italy, tracking firefighters became a priority after the 1999 Roman Historical Palace fire, in which two firefighters were permanently injured after becoming lost while fighting the fire through the smoke. In the same year, six firefighters in the U.S. were killed for the same reason in the Worcester Cold Storage Warehouse fire. A few years later, after the September 11 terrorist attacks, federal leadership tasked scientists with developing technologies that could track firefighters in buildings where GPS is unavailable.

But more work is still needed. In 2012 the US Inter Agency Board listed the development of a emergency responder body worn integrated electronics system as first issue for the industry in its R&D priority report. This system should integrate enhanced communication capabilities, locations and tracking capabilities, situational awareness and environmental sensing capabilities and physiological status monitoring capabilities [17].

Operationally, personnel accountability is also useful to better coordinate fire suppression operations. The incident commander could organize and deploy forces much more effectively with real time updates. But, more importantly, a real-time status could alert a commander if an individual is behaving erratically or has moved into the path of danger. A Rapid Insertion Team (RIT) could be sent in to extract the member in danger if they could not extract themselves. Knowing a specific location would dramatically speed up the process of finding them and greatly improve the success of rescue operations, potentially saving lives [18].

Furthermore, we discovered that an added facet to our problem is the cost for volunteer agencies. We have found other solutions on the market that address this problem, but do so with expensive or impractical solutions that are out of the reach of many volunteer agencies that could benefit from these products. As such, there is still a problem to be addressed with an inexpensive and obtainable version of these products to meet the demand in a real world situation.

Additionally, we have focused primarily on wildfire fighting applications as we have learned more about the various firefighting environments. As mentioned in our communications section, a firefighting agency will need to establish their own communications network, and cannot rely on existing infrastructure. This adds to the problem of accountability and tracking in a large building or heavily developed environment, and any attempt to address this problem adds significant cost and infrastructure. Other research has shown proposed solutions in these environments, but very little attempt at what seems the more practical problem of wild-land fire fighting.

Lastly, we did learn more about our initial assessment of GPS as an impractical method of location in buildings as much of our research showed. Since then, we have found alternatives not discussed in those references used that may lessen the extent of this problem, such as GLONASS and other navigational satellite systems. Experts that had identified GPS as being unusable in buildings had not accounted for the additional satellites available from these systems, and we have found residential buildings to be conducive to geolocation with these additional systems. This impacts the problem, showing that it is not insurmountable and reduces the issue to only large commercial or industrial complexes.

D. Limitations of Current Technology

Technology such as Geographic Information Systems (GIS) and other tracking or location based applications are practical for static or fixed location use, yet don't live up to functional use in a more dynamic environment [13]. Part of the need that isn't necessarily met is that several of the currently explored aspects of applicable disaster related interface technology focus on being able to collect information, map an area, or engage with a specific process from a distanced, time consuming or complex way. The issue is that technology has been explored from the perspective of machine-to-machine, and human-to-human layers yet lack intuitive interfaces, are cumbersome, and overall not as field operational [13]. The need then, could be further explored to be a means of interfacing with the environment itself, instead of simply attempting to coordinate with other teams, individuals or systems. One of the possible means of doing so is the concept of stigmergy, the concept of interfacing with the environment and somehow coordinating information to drive an action based on environmental traces or indicators [13]. The viability of this as a possible solution to the problem relies on the fact that it removes some of the processing time it would require to coordinate different information from various groups of different types of teams, which is one of the larger difficulties in mixed team disaster relief efforts.

That's not to say that current technology does not address different aspects of the problem, however, it does not fully meet the needs previously established in the problem statement. Alternate methods include, but are not limited to mapping an area remotely, or somehow trying to coordinate multiple data inputs into a cohesive map or database to help operatives better navigate a disaster area. Various methods of remote sensing and mapping technology rely on the transfer of large amounts of information of satellite or camera imagery, which can be time consuming in processing large raw amounts of data and therefore are not practical for situation awareness applications [19]. The system abstractions and prototyping for the nature of said applications is simply not practical on a large scale [19], or in situations of immediate need of area access, such as fires. In the case of fires specifically, firefighter teams would benefit from tracking areas of particular concern or gravity with some form of live interface pin pointing system, or even a means of adding visibility in smoke ridden areas.

Another modern method of attempting to bring technology to solve the problem of mapping or otherwise better understanding a disaster environment revolves around unmanned objects, namely robots, Unmanned Aerial Vehicles (UAVs), and other remotely operated, or assistive technology. The issues that arise with some of the remotely operated and autonomous devices is the amount of data, preparation and complexity that is added by attempting to have the device navigate itself, or be remotely navigated, and be able to parse the information [20]. The term for keeping track of your own location, whilst simultaneously attempting to map your environment is called simultaneous mobilization and mapping [20]. It is a common theme for robots that are attempting to map a specific or new area. The issue in applying this technology to disaster area is twofold. On one side of the issue you have complex algorithms, sensors and parsing of separate types of data, both to maintain track of a specific location and obtaining raw data to understand the environment [20]. On the other side of the problem, there exists the issue of any remotely or self-operated device having difficulty in navigating the uneven or unexpected terrain that can be a disaster area [20]. In both of these cases you can greatly simplify the problem by introducing properly trained first responders with wearable sensors that can more passively handle smaller amounts of data and give live feedback for better functional use.

What this means is that whereas there exist various types of interfaces and technological advances that could facilitate a lot of the problems addressed thus far, there has been no significant or overly efficient means of implementing said technology in a quick access, reliable fashion. One of the considerations in terms of solving said problems could then include a device, preferably wearable, so as to reduce the use of carrying excess equipment that would have sensors and interfaces to help a first responder get data from his/her environment in some form of live and easy to use feed, and provide a simple means of tracking or marking said environment. Devices that have been explored include specialized helmets and add on sensors [13] as well as virtual reality glasses or goggle related interfaces.

The need for a wearable location tracking and heart rate monitoring device for firefighters is clearly there as we have just discussed. The following sections will showcase the design features of our product that has been developed over the last two semesters in order to solve the outlined societal issues.

IV. Design Idea and Feature Set

The communication and wearable technology industry has been growing steadily in the last decade. Our objective, based on the noted shortcomings we have found in these areas, was to find a way to improve the lives of firefighters by providing them with wearable technology that will keep track of their location and health status. A specific focus in our design idea and our resulting deliverables was that of a device that would specifically provide value and use to volunteer firefighters. In order to develop the best design, several areas of interest were explored, such as biomedical sensors, indoor and outdoor communication, location tracking and mapping, as well as the requirements and constraints of such a device. Existing monitoring systems were also researched in order to either improve upon their design or learn from their shortcomings.

A. *Initial Requirements and Constraints*

The initial constraints and requirements that this proposal laid out focused on a device that, while in some ways innovative, focuses on accessibility, ease of use, and a reasonable price range. As such, the initial constraints included the cost, weight, range, wearability/ portability, interface, reliability/ durability, as well as power. The cost for the initial design proposal was to be less than $2,000 with a weight less than five pounds. The range of the communication network was proposed to be 300 feet for indoor environments and 3-5 miles for outdoor environments. The proposed design was also to be wearable/portable which means the device has to be powered by either battery or some other portable means. The initial constraints also require that the device will withstand temperatures up to 100°F. With these requirements in mind, the team researched the current viable options from the perspective of the required deliverables, assessed their viability, and evaluated the best way to implement each feature into the full working solution.

B. *Existing Technology*

1) Bio-Monitoring Devices: Since firemen have shown an increased risk of Cardio-Vascular Disease (CVD), a vital sign monitoring system would be very beneficial to the health of firefighters worldwide. The device needs to be wearable and many considerations about firemen must be accounted for to decide on the implementation of a vital sign monitoring system. It is important to consider which vitals should be monitored, where the device will be located on the fireman, what the constraints are and how will it be implemented. It is also important to understand the reason these vital signs are important for CVD diagnosis. There are several vital signs worth monitoring in first responders such as temperature, pulse, blood pressure, pulse oxygen, respiration, EKG and EEG. These all have limitations and advantages. For the case of fireman, CVD is the primary concern, so to prevent this the most important vital signs to monitor are the pulse, blood pressure and electrocardiogram (EKG).

The vital sign monitoring system has to be placed somewhere on the body and the most obvious place to measure vital signs is at the chest. If vital signs are measured at the chest then a strong pulse, EKG and blood pressure can be obtained. The chest area is the most accurate place to measure these things and devices that wrap around the chest or patches that use adhesives have already been created to monitor these vital signs. The wrist is another place that can measure EKG, pulse and BP. The difference between the wrist and the chest is that the pulse is much weaker and much more prone to interference. Stability at the wrist is poor because people move their hands around a lot and the bone structure at the wrist prevents good placement pressure. Pulse is also weaker at the wrist because it is an extremity and the heart pushes blood to these extremities, so since this site is further from the source, the signal is weaker. In a life threatening emergency, the signals at the extremities become weak and sometimes unreadable, so although it is convenient, the accuracy level can be much worse [21]. The upper arm or upper leg are both good areas to monitor pulse, BP and EKG because these areas have arteries but it is hard to attach a wearable device to these areas compared to other areas of the body. Lastly there is the neck, head and ear. There are already wearable headphones, headbands and necklaces on the market that can measure vital signs at the head. The head is actually one of the best places to measure pulse or EEG. Pulse is very accurate at the head because it is consistent. In the event of a blood flow problem the body will always supply plenty of blood flow to the head because the brain is the most important organ in the body. Even when a wrist pulse becomes weak and unreadable the carotid pulse at the neck will be quite strong. This makes the head a good choice for accuracy and consistency but it brings some limits. Blood pressure and EKG cannot be measured from the head which rules out two very important markers for CVD. Even though it seems very beneficial to measure these vital signs in firemen, the head monitoring looks like the most viable option.

In 2012, a system was developed and implemented to track the vital signs of firefighters. The system consisted of a chest strap which read in the vitals to a portable device which was clipped on the belt. This system was capable of monitoring heart rate, EKG, pulse ox and BP. This is an amazing set of data and would certainly prevent CVD in lots of firemen, which will in turn save lots of human lives [22]. The problem is that the firemen that tested the device did not use it after some time. One important factor that the makers of the device did not consider was that the device was an extra piece of gear for the firemen. A new design made to monitor firefighter vitals should not be an additional piece of gear, but something that mounts to the uniform and is not removed. To pick a location it is important to become familiar with the firefighter's gear. The firefighter suit consists of fire-resistant boots, pants, coat, mask, helmet, neck and hair protector and gloves. Vital signs can be obtained from all of these pieces of gear but some are more practical than others. The pants and the jacket require pressure to get the sensor to press firmly against the fireman, so these pieces of equipment would possibly cause the fireman extra discomfort in order to implement them. The boots, helmet, neck garment and gloves should be more restrictive and have more pressure points, eliminating the need to add pressure. To add sensors to areas that already have pressure points against the firemen should be unnoticeable and cause minimal discomfort if any at all. For this reason these pieces of gear should be considered for monitoring and the pants and coat can be ruled out.

It's important to consider sensor stability in the monitoring of the vital signs. Since loose gear was ruled out and tighter gear is desired for monitoring pressure the stability expected from that certain area is the next determining factor. The gloves are probably the most unstable place. They will be subject to more noise and issues because the firefighters will be consistently using their hands and moving them to very different orientations throughout the mission. The boots also would be subject to noise and vibrations that could negatively interfere with the signals being measured. This leaves the mask, helmet and neck garment. These all appear to be viable places to mount sensors and get accurate readings. The head area is the most stable part of the human body and will remain in fixed positions for longer durations than any other area. The vital signs that can be obtained from this region of the body are more limited, but it would be more beneficial to monitor less vital signs in a way that works than to monitor more in a way that does not work.

Another consideration to make is whether to use individual sensors or to use a product already made to monitor vital signs in the chosen body region. If a predesigned piece of monitoring equipment could be implemented into the fireman's uniform this would be an easy way to implement a monitoring system and there are plenty of items on the market. For example there are headbands that monitor vitals that could be implemented into the helmet or the neck protector. Another interesting example are earphone heart rate monitoring systems. These are already on the market and could be a multiple use system because they can act as a radio communication device if an input is added for the fireman's voice. If something like this is used then a lot of the work has already been done so this will limit time to prove of concept. The disadvantage is that there will be less flexibility. If individual sensors are used then any desired location can be used to monitor vitals as long as there is adequate pressure because sensors are small and they can be placed almost anywhere. This makes sensors the most likely choice for altering the fire gear.

2) Indoor Communication Technology: The most dangerous thing that firefighters have to do is not saving someone on a call, but making sure their communication equipment is properly working in the environment they're responding to. Throughout our research of indoor firefighting there were incidents of firefighters losing their lives due to the communication issues within a building or structure. This is not only limited to firefighters but also disaster situations where collapsed buildings can block communication. These incidents show a lack of reliable communication equipment that the firefighters require and the continuous lack of understanding of how to properly use the equipment. Over the last decades, great strides have been made for firefighter's communication to improve during a structure fire.

One such system is called MANet (Mobile area networks) which can provide firefighters with voice and data communication. Each firefighter carries a networked radio and when two radios are in range of each other they create a network where voice and data can be sent and received. Like any network, any other radios in range will automatically connect when in range. If two radios are on the same network but are out of range then the network radio between them with relay voice and data from each other's radio until the destination has been reached[2].

Another system is called UWB (Ultra Wide Band) technology. UWB technology is able to work better through building materials and degrades less[2]. The major issues with implementation are the regulations implemented by the FCC.

The Federal Communication Commission, which relates the wireless spectrum, restricts the band and transmitted power level [2]. These restrictions severely reduce range and data transmission rates.

PLC (Power Line Communication) would help firefighters communicate when they are near power lines. There are two types, a HomePlug and Access PLC [2]. Both types use AC power lines to propagate high frequency (HF) signals. HomePlug has the ability to create a LAN network quickly. A wireless-access-point-to-HomePlug interface extends the range of the wireless network [2]. This technology combined with MANet work could provide a better range in the building. The problem with the technology is there have been no studies showing it working in a building or in home [2].

BDA (Bi-directional amplifier) systems improve n-building communication by installing cables and interior antennas to distribute the radio signals throughout the building [2]. This system is extremely cost prohibited and requires periodic maintenance to ensure the system will function when needed. There are no technical issues or regulatory issues if installed [2].

RF (radio frequency) distribution using HVAC ducts takes advantage of the existing heating and ventilation ducts in a building to distribute the radio signals throughout the building [2]. The ducts must be modified to allow for RF signals to bend around obstacles like fans and dampers. Little research has been done and commercial interest is small.

The technology solution for indoor communication involves a wide assortment of solutions but all have possible performance or regulatory hurdles to overcome. This section will go over specific systems design to provide firefighters and emergency personal in a disaster with the most reliable technology in communication.

Implementation of a mobile ad-hoc network, which is a specific type of MANet would allow for multi-conferencing for firefighters in a disaster. Firefighters use walkie-talkies to communicate to each other. The walkie-talkies have a drawback, it only allow one person to speak at a time [1]. Firefighters can interrupt each other, such as in an event of a firefighter needing to communicate Mayday. Firefighters use special codes to indicate who has priority to speak or listen [1]. However, during an emergency, there were times when the IC didn't hear a distress call by firefighters. A system like this would allow for better communication and adding video would help with providing critical information sharing to the firefighter about the condition of the structure they are in. For example, a collapsed hallway or locating a lost firefighter. The first requirement for such a system is an architecture that doesn't rely on centralization [1]. The second is a system that can accommodate nodes that will have limited resources. The third is scalability for the number of firefighters using the system [1].The fourth requirement is a hierarchical structure in order to solve problems of the flat system currently used by firefighters. The fifth requirement is to allow each team of firefighters to talk to each other privately without the other teams hearing the conversation [1]. The information that the leaders and command post have may not be necessary for the firefighters to know. The sixth is allowing audio and video conferencing and sub-conferencing. This would allow more than one firefighter to talk at the same time. The last requirement is the system to be user friendly and easy to use. The constraints of this system is no architecture for conferencing in MANet. This system architecture would have to be created to accommodate conferencing.

The firefighters would be grouped into clusters and within each cluster there would be a leader who would maintain the list of all members in the cluster. This super member would be connected to another leader in the Layer 2: leaders. The leaders would then be connected to the Layer 3: command post. Figure 1 shows the overall architecture of such a system.

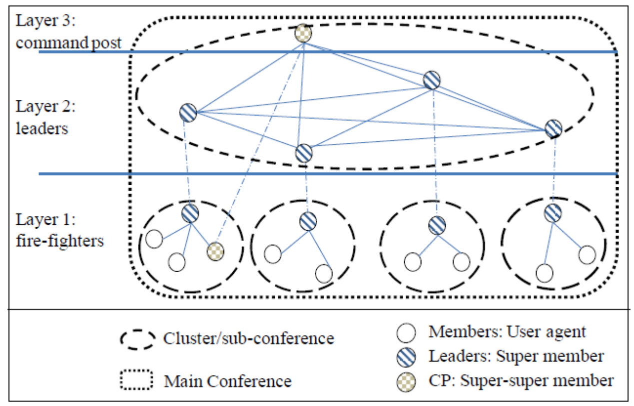


Fig. 1: Overall Architecture [1]

The tested prototype measured two things: network load and end-to-end delay. The results were calculated as the average of 10 experiments [1]. The test was done in varies configurations. It started with one command post and eight leaders. Delay varied between 145 and 216 millisecond, joining delays increase linear, a fourth leader takes more time to join than the third [1]. The research shows that it is wise to limit the maximum team members to less than eight.

Another system is called WISPER, which is a device that will allow firefighters to communicate in a collapsed building or smoked-filled houses. The need for such a system is because radios often fail in these environments [23]. Designed by the Department of Homeland Security (DHS), WISPER is a one-inch square disposable router, waterproof and heat resistant up to 500 degree Fahrenheit [23]. The system uses a two-way digital radio. The router can be used to lay "bread crumbs" to track a firefighter's location. The system would be carried around their belt [23]. The firefighter would be able to carry up to five devices, deploy them when they move behind concrete or when they are out of radio range. These routers create mesh networks that will automatically reconfigure themselves when a WISPER device is destroyed or moved [23]. The constraints for this WISPER device is that it is not available commercially. DHS is trying to find a company to manufacture the routers in volume [23].

3) Outdoor Communication Technology: Outdoor communication networks are available but every one of them faces challenges of their own. In a disaster situation, reliable, real-time communication is of utmost importance.

Several disaster relief network architectures and infrastructures were researched and the viability of such a system was also explored. Figure 2 shows the different available networking approaches that are currently being investigated. In addition, existing GPS (Global Positioning System) and radio communication devices were explored and checked for their viability for our application.

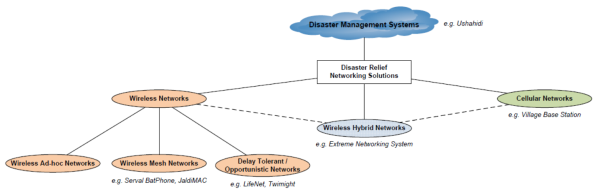


Fig. 2: Classification of disaster relief networking solutions [2]

Cellular networks are one of the options for outdoor communication. In today's society, cell/ smart phones are a very common occurrence. The "coverage and quality of service provided by these networks surpasses that of wireless ad hoc networking solutions by design" [2]. However, especially in a disaster situation, the cellular network infrastructure may be damaged/ completely destroyed or overloaded and therefore not usable. Another issue with using the cell network infrastructure is the unreliable coverage in mountainous regions. Taking wildfires as an example, cell phones are not a viable communication option since firefighters may or may not be in a region where cell phone coverage is available. Since a reliable communication network is critical, cellular networks are not an option for the purpose of our application.

Wireless networks are another option to explore. There are several classifications under the term 'wireless networks' which include wireless Ad-hoc networks, wireless mesh networks and wireless delay-tolerant opportunistic networks.

Wireless mesh networks "are characterized by a collection of fixed and stationary wireless access-points interconnected in a mesh topology acting as the infrastructure" [2]. However, this type of network requires a long deployment time, which is not ideal for a disaster situation. The range is also limited. One wireless mesh network in India spans 70x30km [2] which may or may not be adequate in a disaster/ wildfire situation. Wireless Ad-hoc networks were briefly explored but the extremely limited range of these networks quickly ruled them out as a viable option for our application. A wireless delay-tolerant opportunistic network is "a class of infrastructure-less network where wireless nodes may not always be in communication range of each other and hence no end-to-end connectivity can be assumed" [2]. This is also not a reliable and far-reaching communication solution and therefore not applicable.

Wireless hybrid networks attempt to combine wireless and cellular networks. Combining these network infrastructures would lead to greater coverage and better service [2] but several challenges have been encountered with such a network. An Extreme Networking System (ENS) was deployed in San Diego for the support of a medical emergency response [2]. The network encompassed a Wi-Fi network, wireless mesh network and several backhaul networks such as wireless and cellular. This system was tested during a Homeland Security drill and several challenges were encountered. Interference on the 2.4GHz range, communication delays as well as extensive planning were a few of the main drawbacks of this system. For our application, setting up a wireless hybrid network not only exceeds the scope of this project, it would also be very difficult, if not impossible to test. Lastly, real-time GPS communication options were explored. Systems, such as RAVTRACK and ICOM Dstar are real-time GPS tracking and communication systems. They provide VHF (very high frequency) communication between a transponder and radios. These gadgets produce a reliable communication channel and even support mobile data communication, as well as GPS tracking. Firefighters already use VHF radios, so these systems seemed like a viable option. However, these systems are very expensive. Our objective is to build a low-cost system for firefighters and unfortunately the systems that are on the market today do not qualify as low cost. After exploring the options for an outdoor communication network, it seems that the current available systems would make an implementation challenging, but not impossible.

4) Personnel Tracking: Conditions for tracking the position of firefighters can generally be broken up into three areas: outdoor with clear sky view, outdoor with obstructed view, and indoor. Each of these areas will have separate challenges to overcome.

For outdoor tracking, the GPS or similar satellite based triangulation systems are used. This system is generally very effective when a clear sky view is available, but does require the input of at least four satellites to be accurate. For most outdoor applications, this is sufficient [3]. Additional methods of tracking in an outdoor space include triangulation via cellular networks. Similar to GPS, the system can use cellular towers as reference points to determine an individual's location. While accurate within urban areas, this method suffers from latency issues, service provider fees, and is dependent upon a terrestrial network that may not provide coverage in less populated areas. A similar method that includes a larger coverage area can be used with satellite service providers. A satellite relay system can be set up that would use commercial satellites to pinpoint and triangulate a position. The positioning data would flow through service centers and incur additional latency due to the larger distances. Higher monthly service fees would be incurred as well [24]. Using external tracking services has the additional drawback of being dependent on an external agency that may not be available when emergency services are needed. To reduce cost and increase reliability, a stand-alone system can be used. These systems would operate using the GPS positioning data and then transmit this data on in-house communications networks such as HF or VHF radios. While HF radios can provide long distance communications comparable to satellite systems, the size and weight of the amplifiers and antennas needed for such distance prohibit a practical man-portable solutions that would integrate with the already heavy firefighting equipment. Therefore, VHF radios or transponders are often used that are smaller and lightweight, usually around 1 pound. The propagation of VHF frequencies allows a small amount of signal refraction, bending the transmitted wave to allow slightly greater than line-of-sight distances. In this way, systems can communicate with 10, 20, or even 30 miles between nodes depending upon local terrain/conditions. There is also little to no latency and no fees using this method [24]. To improve the accuracy of GPS locations when obstructions exist to a clear sky view, several methods have been studied. An augmentation of the GPS signal can be made with the additional tracking of other navigation systems, such as the Russian-based GLONASS. This system works in a manner similar to GPS and could provide additional satellites to track when a smaller sky view is all that is available. Additional reduction in error can be achieved with systems employing algorithms to estimate position during short periods of weak GPS signals such as a Kalman Filter. However, this adds complexity, and would only be appropriate for brief periods of intermittent signals as the errors would multiply over time. One more method to reduce errors during brief GPS signal outages includes dead reckoning. Sensors on the individual being tracked, such as accelerometers, inertial sensors, and pedometers, could read movement information and apply this to the last known position, to give an estimated updated location. Again, this would only be feasible for short time periods, as errors would accumulate [25]. For areas near terrestrial infrastructure, a solution could be to use existing transmissions from known sources (such as WLAN hotspots or other personal communications systems) as a "pseudo-satellite" to provide missing data within the GPS calculations if fewer than four satellites are available. These existing transmissions are known as signals of opportunity (SoOP). Using algorithms based on the received signal strength indication (RSSI), the time of arrival/time difference of arrival (ToA/TDoA), and the angle of arrival (AoA), these signals are combined with the known terrestrial locations and used to determine the user's location [3]. Commercial providers have already mapped many large cities, and provide the location of these signals to be used. This could be a viable method while in and around urban locations, though would require the terrestrial network and knowledge of its components, so would once again not be viable in less populated areas. This type of position locating would be more suited to an indoor environment.

Many indoor positioning systems use technology similar to that previously described above. Distance and angle measurements are used with an existing infrastructure to determine a target's coordinates. Some of these systems rely on the target transmitting the signal, with sensors located in the building providing the information used to locate the target, such as RFID sensors embedded in Exit signs. This is somewhat backwards from what was previously described. This is a complex system with a large footprint that requires a central computer connected to sensors throughout the building and the whole system must be calibrated together. This would not be feasible for our application. Fingerprinting, similar to the utilization of the signals of opportunity presented earlier, often uses Wi-Fi networks to set up a pre-determined "map" of signal strengths. The downside to this is that the map will be compromised with changes to the infrastructure to include the moving of access points or even furniture [25]. Many other solutions exist, which rely on infrared, ultrasound, radio ultra-wideband signals, IEEE 802.11, or Bluetooth signal with a system similar to those previous described. All of these systems seem to rely on a central server, known fixed locations of signals, and an infrastructure that does not change. In an emergency situation, the existing infrastructure cannot be relied upon to be in the same condition it was before. Even routine changes in the terrestrial networks would make such systems unreliable. Deploying a dedicated positioning system would require months of planning before-hand, a high cost, and would not be practical in most situations [3]. A third option would be to set up a mobile ad-hoc network specifically for the first responders. This involves deploying four or five transponders at fixed locations around a building. These nodes would transmit their position and the target could be identified from its position relative to the node. This is, in essence, a small localized version of the GPS network. Systems using this technique require the team to set up the network before entering the building. This adds complexity, deployment time, and possible errors if these hastily erected nodes are moved. It does offer the advantage of the entire system being under control of the using agency. Another similar system employs mobile nodes that drop from the user as "breadcrumbs" when the signal becomes weak enough. These portable nodes need to be hardened and be able to survive being deployed inside an environment that may catch fire. That would add a considerable expense to the equipment employed. Additionally, the same problem of errors could arise if a node is moved [25].

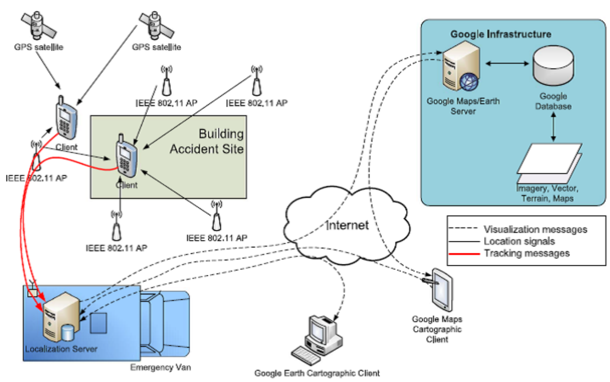


Fig. 3: Example architecture of a deployed AD-Hoc positioning network set-up around a building before entering [3]

Finally, dead reckoning can be also employed in the indoor environment. To determine location with the necessary accuracy, however, would require sensors to be placed on the actual boots of target individuals. The sensors (gyroscopes, pedometers, and accelerometers) measure as closely as possible the physical movement of the foot through space and use this to add a distance measurement to the last known location. In practice, this seems to be error prone if standard walking is not the only movements made. Carrying victims, crawling, or other activities would magnify the errors [25]. The majority of indoor based systems use one of the techniques presented above, or combine techniques to reduce errors. The more systems employed, however, add complexity, processing needs, weight, cost, and power consumption. A trade-off must be made between acceptable error and physical characteristics. Current solutions on the market and those being pursued by the Department of Homeland Security cost between $2 – 9K per unit for basic functionality, leading to a minimum overall implementation cost of over $40k per agency. This is prohibitive for many departments, especially volunteer fire departments.

5) Indoor & Outdoor Mapping: With the advent and growing market for wearable/portable devices, along with new technology such as Unmanned Air Vehicles (UAVs) advances have been made in not just portable tracking technology, but mapping implementations as well. Modern GPS and navigation systems are rapidly changing and becoming smaller and more cost accessible. This section addresses some of the current and most recent approaches to mapping in an indoor and outdoor application as it pertains to first responder use. It evaluates their functionality and feasibility from an economic, easy to use, portable and rapid use perspective.

Indoor mobile positioning has received a lot of interest in the last decade [4], and modern technology is finally at a point where it allows the viable, and more affordable option of mapping indoor and urban areas with a fair amount of accuracy. The issue with this technology, especially in terms of a viable application for first responders, stems from the fact that it has limited on the go functionality. The technologies explored in this report detail a series of complicated processing algorithms that rely on a large amount of data, either from repetitive sampling or crowd-sourcing [4], a reasonably accurate Wi-Fi based Access Point (AP) system that relies on back up and alternate wireless APs [26], and a price accessible solution that is accurate, yet somewhat cumbersome and hard to incorporate into the working field [5]. The solution suggested in [4] is actually very thorough and has multiple suggested approaches. It essentially advocates the need for not just mapping in disaster situations but what the paper calls a Personal and Mobility map (PMM) [4]. Essentially it identifies the need to keep track of individuals and their particular moving pattern on a personal level. In the case of a fire, this would be greatly advantageous since it would give the team visibility of any member who is in danger or becomes lost. It suggests to accomplish this through various approaches, including Simultaneous Location and Mapping (SLAM), Wi-Fi Received Signal Strength (RSS) technology, which relies on Wi-Fi routers and access points, as well as GPS technology and the supporting software that makes sense of it all [4]. The concept is very avant-garde in that the results turn into recognizable vector or series of vectors that essentially map the movement of an individual or series of individuals to map a specific route or a whole building/area.

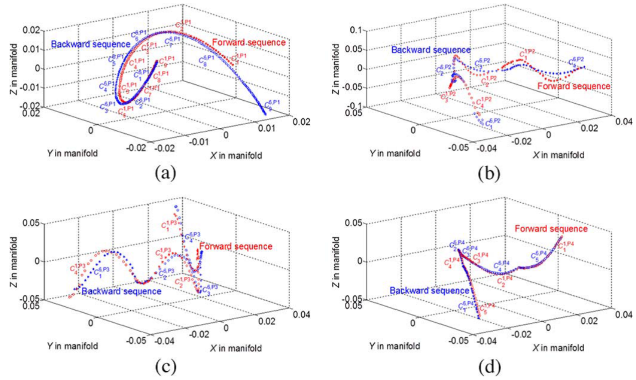


Fig. 4: Intra-Sequence clustering on each path (a)-(d) represent different methods describes in [4]

The issue with most, if not all the methods utilizing this technology for mapping purposes is that it its impractical for first response use. Mapping takes time, man-power and effort in varying quantities. Some of the methods that implement this technology talk about mapping occurring as the users "carry on with their daily lives" [4], or discuss the user of large amounts of man power in crowd-sourcing efforts [4]. Another complication is the fact that the accuracy of the system is also affected by where on the body the user wears the device, since it attempts to correlate data from multiple inputs and reference affects said data [4]. Add to that the complexity of overlaying the data, the expense and complication of the software that will process said data, as well as the training to get a rudimentary map parsed quickly, and you have a system that might be accurate and uses existing, common-use technology, but is impractical for rapid, or emergency use, and cumbersome to incorporate into a relief process. The idea of RSS Wi-Fi based mapping, however, is rather prevalent, and another study in South Korea shows an effective method of indoor mapping that relies on wireless Access Point (AP) methods, and the Extended Kalman Filter (EKF), a non-linear estimation theory [26]. This particular study is accurate within less than a meter [26] and can be increased in functionality and use by deploying more APs wherever existing signals reach their limit [26]. This approach, like many RSS Wi-Fi approaches relies on the concept that a person with a AP relatable sensor can be located and tracked based on the amount of time it takes for different access points to receive the signal [26]. By this logic, the more access points in the system, the more robust and accurate the signal, which runs into issues when you start going out of the range of the ad hoc AP network. At this point the study suggests having the user deploy another AP every time they reach the end of range of the system. Whereas this approach is more viable, and was originally studied for the effective use of first responders, it does not correlate as readily with the original approach of the research discussed in this document, mostly in that it requires first responders to be trained and learn how to use an ad hoc Wi-Fi based network, and furthermore requires the carrying of a select number of deployable APs. One other approach of note consists of readily available items that are, by comparison to some of the other approaches discussed, reasonably price accessible. Indoor mapping feasibility was tested using a Microsoft Kinect infrared sensor system, conventionally used for video games, and a Leap Motion Controller also used for human-computer interaction and found to be accurate to within 20 cm [5]. The results are a reasonably accurate real live video imaging overlay that suffers from fewer of the issues of existing methods in that it uses two separate sensors for location and for mapping, so as to produce less interference between the two signals, and a smaller stream of data that can be processed separately [5].

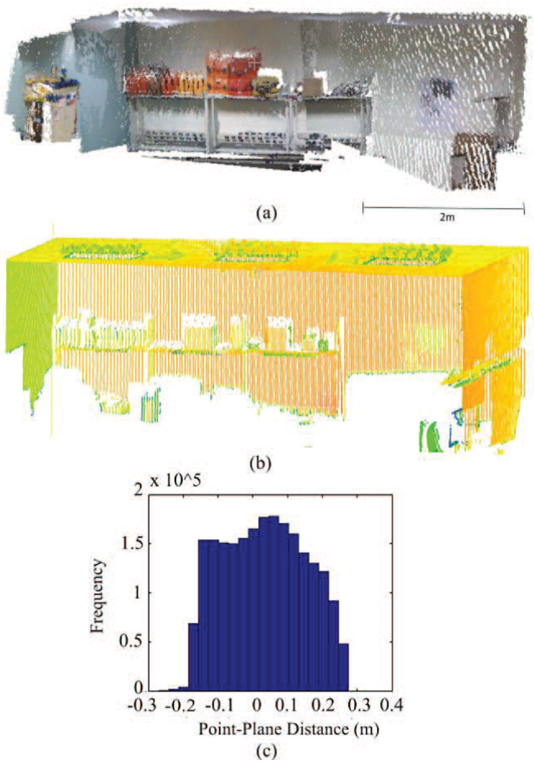


Fig. 5: (a) Output scans from fused system (b) TLS scan of same [5]

There have been more than a few techniques for exploring outdoor and topological mapping [27]. The breadth of these options, however, does not seem to be as extensive nor to be attaining as much attention as indoor mapping within the last 5 years. Most of the techniques that are currently being explored are too expensive, time consuming, or complex. They tend to rely on specific vehicles, large amount of computational, satellite, and sensor data, hybrid technologies, or robot assisted mapping. A few of the current suggested methods rely mostly on the processing of large amounts of data, and the overlaying of different types of maps with this data. Specifically, one of the approaches can be observed as Image Sequence Partitioning (ISP) which recommends alterations to existing algorithms that will make current existing data loaded maps more simple and easy to use, as well as have less repeated information [27]. From this specific article, it can be deduced that modern outdoor mapping of this type is data heavy and inefficient. Maps are dense, duplicate data is hard to get rid of, and separating data from different sensors is difficult [27]. These are all issues that would make this type of mapping simply unusable by fast paced, high stress users with a simple solution in mind. Another approach is the use of GPS, or GPS hybrid technology to map outdoor areas [6]. Whereas GPS is not as viable indoors, it relies on satellite receptors, which is designed for outside use. Taking into consideration the fact that smart phone and smart devices with said sensors are very broadly used, this technology is more viable in terms of accessibility and price. One approach considers the use of GPS, JAVA enabled devices to send a specific user's location, or track it on Google Maps [6]. But it then relies on a few factors: the user owning or buying a JAVA enabled phone, the user having cell phone reception to send an SMS message with location information, rapid battery consumption used by a smartphone constantly checking and sending location information, and also the user's ability and time constraints in navigating the phone interface to manage location data.

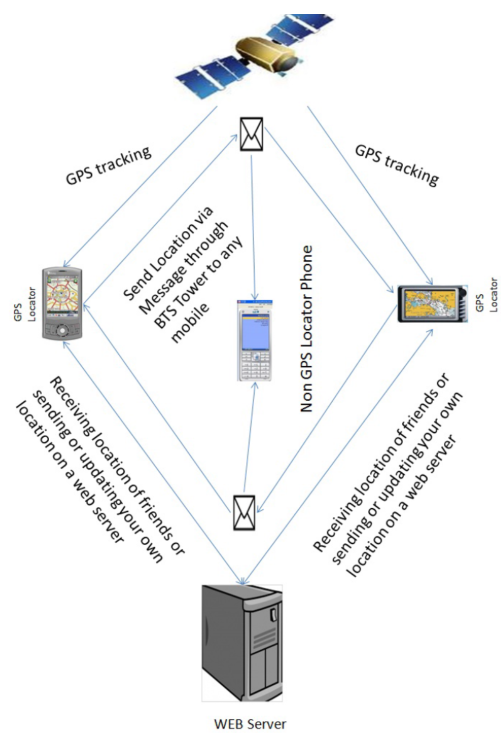


Fig. 6: GPS Location Requirements of System Described [6]

This method accomplishes a number of the goals this report sets out to provide, namely a price accessible, efficient and relatively easy to use location tracking or mapping device. However it is not a fully viable solution, as it presumes too much on the side of the responders, in terms of time, use, and

technology.
In summary, and for the practical purposes of our application, the issue with almost all the aforementioned approaches is three-fold. The main issue is expense, in striving to provide a viable, economical solution, most of the discussed options rely on expensive sensors or data managing equipment, not the least of which are smart vehicles or automated robots. The second issue arises from a lack of simplicity. The currently researched methods of outdoor mapping rely on complex algorithms involving either time, man-power, processing power, or all the above [27]. The third issue arises from the portability of the solution. An add-value device to first responders is limited in its functionality by the ability of the first responder to have it available in an accessible, un-cumbersome, and unobtrusive manner. Some of the solutions discussed are viable to the point at which the first responder would not have to carry too many or too bulky a set of adapters and sensors.

C. Our Design Idea

Having then explored the ways in which current technology provides viable solutions or aspects of the desired feature implementations, Flashpoint sought out to identify and delineate the specific, tangible metrics by which our resultant solution would be deemed to meet the desired criteria set out to address our societal problem. The following is the list of features that address the core aspects of the problem that Flashpoint set out to tackle and discuss their relation to how each one feature strives to accomplish this as part of the full solution.
1) Size: A max size of 6 inches by 6 inches is our limit, as larger items would not be practical when placed on existing gear set-ups.
2) Weight: As current firefighting gear already weighs 45-75 pounds, additional weight is not desired. The max weight of the device will be between 3 to 5 lbs. with a battery included, with a goal of less than 32 ounces for the device itself.
3) Range: The transmission range will be dependent upon the communication system used. As different fire-fighting departments operate in different areas, they use communication systems tailored for their needs. For testing purposes, we will use indoor communications interfaces using unlicensed bands having a range of approximately 300 ft., but the interface should allow adaptation to other COTS communications devices to allow for greater range (>9 miles) in a wildfire environment. The navigational range will be based off of GPS and assisted GPS, allowing a global coverage with a clear or partially obstructed sky view. A location accuracy of within 10m will be the max error we will allow.
4) Wearability/ Portability: The device will be on the body that will provide the best vital measurement. We have determined that the device will need to be wearable by firefighters, and actually used. A monitoring system incorporated into current gear is desired. We aim to provide a small, head mounted band or headphone attached to a communication device on the belt or gear.
5) Interface: The device will interface analog sensors for vitals monitoring with navigational sensors for tracking. This data will be sent through a third interface with a wireless communications device to enable reporting of the information to an Incident Commander. We will design our system to provide a simple serial data interface allowing it to be incorporated into existing communications gear. For testing purposes, we will use indoor communications interfaces using unlicensed bands, but the interface should allow adaptation to other COTS communications devices to allow for greater flexibility.
6) Reliability/ Durability/ Heat Resistance: Water resistance is an important design consideration that we will incorporate, and heat/shock resistance will be necessary for any part of the device placed outside of protective gear.
7) Power: For testing, the device will receive power when connected to a laptop or another source. When deployed in the field, a battery capable of lasting through an entire shift (8-10 hours) will be required.

D. Required Features

This section attempts to summarize an overview of the capabilities of the established design idea in terms of deliverable features, means of attaining/performing said features, as well as how they will be implemented and tested.

1) Devices: Measuring the first responder vitals would be comprised of some form or set of analog sensors. The acquisition of location would be provided by some kind of sensor/ adapter that would be able to readily provide lcocation based data to send, transfer, or transmit.
A microcontroller would be used to combine, parse, or otherwise process the data obtained from the location and vital systems sensors, in a way that is easy to interpret and/ or transmit. Also, a series of two types of wireless transceivers is needed, one to be able to obtain the parsed microprocessor data and transmit it wirelessly, the other to receive said data with manageable amounts of noise and interference.
A wireless monitor information interface would also need to be implemented. This interface would be viewed mostly from the perspective of some form of electronic device akin to a tablet or laptop PC. Essentially a device with a processor and a screen that would be able to receive the transmitted data and be able to display it on some sort of interface that is easy to use and read.
2) Software: The project would involve two major software aspects. One to parse the data and present it to the user in a readily legible and easy to understand format.
The first piece of software architecture would have to interface with the microcontroller locally (on the body) to process the sensor data that is being obtained, so as to make it easier to transmit.
The second piece of software, seemingly the more complicated of the two, would receive said transmitted data, and be able to interpret it in a meaningful interface that would provide the monitoring party with viable relative location and vitals data from the user.

E. Prototype Feature Set

Team Flashpoint, shown in figure 7 developed a laboratory prototype with the following features.

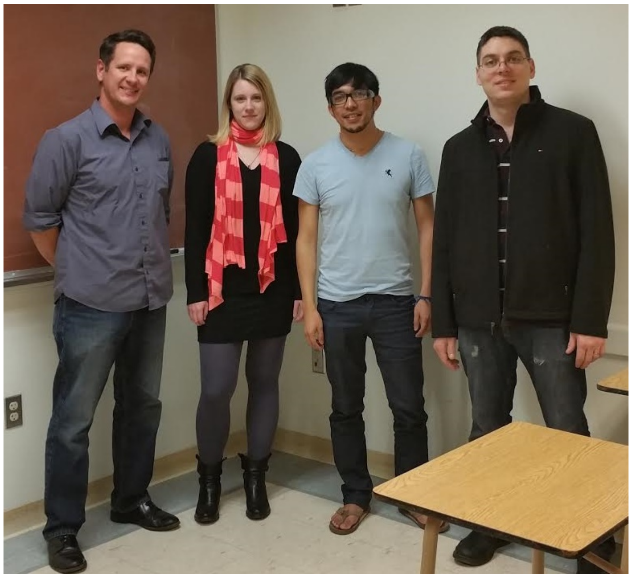


Fig. 7: Team Flashpoint [7]

1) Wearable: Max weight – 5 lbs. (microcontroller housing - not including incident commander equipment). 12 Hour minimum battery life.

2) Measure First Responder Vitals: Heart rate measured between 30 - 200 BPM Heart rate accuracy +/- 30% of resting BPM

3) Acquire GNSS location: Acquire target position to within 3m with >=25% obstructed sky view

4) Wireless Communication: Operation(display of location/HR) over wireless stand-alone network

5) Incident Commander Interface: Location and heart-rate displayed for target on commonly available interface (laptop/tablet).

6) Data Storage: Heart-rate and location history available for after incidefo.

V. Funding

A. Funding for Laboratory Prototype

Team Flashpint filled out funding applications for the Pitch competition and the UEI campus grant proposal. After discovering that UEI would want to take ownership over Flashpoint it was decided to abort this funding opportunity. The Pitch competition application was submitted on November 2nd and it made it into the final round which required the team to perform a presentation on November 19th, 2015. Due to an intense school load from midterms, the team decided to drop out of the competition and abort the prize money. Funding as of Fall 2015 has been internal only. Table I shows all of the purchases made to build Flashpoint.

Flashpoint Funding for Laboratory Prototype			
Item Description	**Price**	**Quantity**	**Used or Unused in Project**
Xbee Pro 900 modules	41.75	4	2 used, 2 for testing
Xbee Explorer breakout/USB board	24.95	1	Used for programming
900 MHZ Duck antennas(1/4 wave)	7.95	3	Used for testing
1/2 wave antennas	9.95	3	2 Used in final design, 1 backup
Gove ear clip heart rate sensor	12.9	1	Used
Xbee adapter	10	2	1 Used, 1 backup
G9 GNSS module	29	1	No, broken
G6 GNSS Module	39.49	1	Used
Xbee Explorer breakout/USB board	24.95	1	Used
Arduino Mega 2560 Rev 3	49.69	2	Used
Foxnovo Wire Jumpers (M-M, F-M, F-F)	8.99	2	Used
USB-A to USB-B Cable	4.97	1	Used
STM-32F4 Microcontroller	18.32	1	Unused
STM-32F446 Microcontroller	18.32	2	Unused
USB-A to USB Mini Cable	5.49	2	Unused
Mini-Bread Boards (6 Pieces)	5.79	1	Used
Sd card reader module	5.5	1	Used
Kingsdon micro memory flash card	4	1	Used
Swissmart micro sd storage board	8	1	Used
GPS/GNSS Location GPS module 10Hz UART 12C	28	1	Used
Pulse sensor amped	6	4	Not used, unreliable
Grove ear clip sensor	25	4	Used
Easy pulse sensor	35	1	Not used, unreliable
Sensor making materials	15	1	Not used, unreliable
TOTAL		**589.01**	

TABLE I: Funding for Fall Semester Laboratory Prototype [7]

B. Funding for Deployable Prototype

Same as for the Fall year, the team has self funded the entire project and has not taken in any external funding. Two Flashpoint units were created with this funding. A list of all of the purchases for the second semester deployable prototype is shown in table II.

Flashpoint Funding for Deployable Prototype			
Item Description	**Price**	**Quantity**	**Used or Unused**
XBee Adapter kit - v1.1	$20.00	1	Used
Lithium Ion Battery Pack - 3.7V 6600mAh	$29.50	1	Used
SparkFun Power Cell - LiPo Charger/Booster	$19.95	1	Unused
Polymer Lithium Ion Battery - 6Ah	$32.95	1	Used
Amphenol RF Connectors	$6.50	6	Unused
rp-sma bulkhead cable	$3.89	1	Used
Serpac 253 Case,BK	$9.29	1	Used
Adafruit Powerboost 1000c	$19.99	1	Used
USB Voltage Current Meter Tester - Charger Doctor	$7.50	1	Used
Bud Industries Case PT-11657-MB	$8.10	5	Unused
Bud Industries Case PT-11630	$6.40	1	Unused
Bud Industries Case HH-3550	$9.30	1	Unused
Twin Industries Case B10-8000	$15.93	2	Used
Hammond Manufacturing Case 1590BRD	$8.65	1	Unused
Bud Industries Case CU-1874-B	$3.00	1	Unused
Bud Industries Case CU-387	$7.60	1	Unused
Serpac WM052R Case,BK	$9.64	1	Unused
Serpac 151I Case,BK	$8.16	1	Unused
Serpac 153 Case,BK	$9.29	1	Unused
Arduino Mega 2560 Rev 3	$45.95	2	Used
Adafruit Powerboost 1000c	$24.99	1	Used
Sienoc USB Voltage Current Meter Tester - Charger Doctor	$5.99	1	Used
Prototype Boards (Assorted)	$27.50	1	Used
Seedstudio Grove - Ear clip Heart Rate Sensor	$14.88	2	Used
Adafruit PowerBoost 500 Basic - 5V USB Boost	$14.33	1	Used
Adafruit MicroSD card breakout board	$19.97	2	Used
Protoboard	$6.54	1	Not used
Vertical Mount PCB Board Support	$7.49	1	Not used
Hammond Project Box	$6.72	1	Not used
Kit Box+PCB board	$12.75	1	Not used
GLONASS and GPS module with GMS-G6	$39.99	1	Used
TOTAL	$462.74		

TABLE II: Funding for Fall Semester Laboratory Prototype [7]

VI. Project Schedule and Milestones

A. Task assignments per team member

The individual tasks per team member for both the laboratory prototype and the deployable prototype was planned out using Microsoft Project to create a Gantt chart. The Gantt chart has proven to be a useful tool to predict hours needed, remaining tasks, milestones and to get a general feel for what was coming in the future. The chart is shown in figure **??**.

1) Birgit Fleming: During the Fall semester, Birgit implemented the GNSS module. She was also heavily involved in creating the presentations and writing assignments. She maintained an engineering role involving the location device systems associated with Flashpoint. During the Spring semester, Birgit was involved in creating the incident commander user interface, as well as administrative tasks. She held the team leader position for the beginning of Spring and was able to guide the team through several hurdles and assignments.

2) Cole Preszler: During the Fall semester, Cole began as team leader which required a lot of planning and organizational skills. While Cole navigated the group through the creation of the project, he also implemented the stand-alone wireless communication network and assisted with the GNSS and other communications related things. Figure 8 shows him soldering components for the wireless communication network. During the Spring semester, Cole played a heavy role in testing of the communications network and GNSS implementation. He also built a secondary Flashpoint module which wound up being used to pass the demonstration phase of senior project because the original model began having malfunctions. Cole's model of Flashpoint was fully functional for the demonstration and achieved all of the feature punch list requirements.

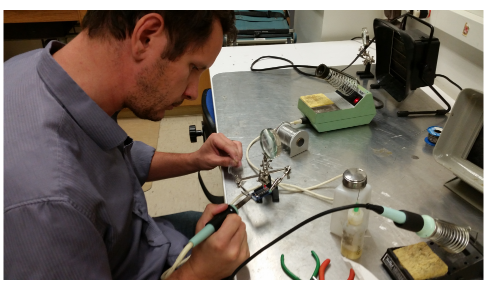


Fig. 8: Soldering of Components [7]

3) Stephen Fleming: During the Fall semester, Stephen worked on implementing the heart rate sensor and was also team leader for the second half of the semester. Stephen guided the group to bring the project from conception to completion. He took charge of the marketing and organizational aspects of the group. By learning Microsoft Project he completed a dated list of all of the tasks left to complete the project and created a Gantt Chart to help the group visualize the work. During the Spring semester, Stephen remained the point of contact for the Gantt Chart and any other resources associated with Microsoft Project. He researched many potential modifications for the pulse sensor and has many ideas to move the project forward. None of the ideas were implemented because the scope of the project would become unrealistic for the team.

4) Tony Rodriguez: During the Fall semester, Tony implemented the logic for bringing the project together. His main focus was implementing the microcontroller and getting it to properly communicate with all of the other components. After discovering that Tony was the best programmer on the team he became the lead engineer for the project. Tony got everything to work and because of him Flashpoint was a success. During the Spring semester, Tony designed the casing for the deployable prototype and helped to advance the user interface. He was also the second team leader and helped bring Flashpoint to a deployable level.

B. Hours worked/remaining per team member

Resource Name	Work in hours
Birgit Fleming (Fall)	**188.85**
Cole Preszler (Fall)	**154.38**
Stephen Fleming (Fall)	**186.38**
Tony Rodriguez (Fall)	**178.38**
Birgit Fleming (Spring)	**224.27**
Tony Rodriguez (Spring)	**225.62**
Stephen Fleming (Spring)	**242.63**
Cole Prezler (Spring)	**198.5**
TOTAL	**1599.01**

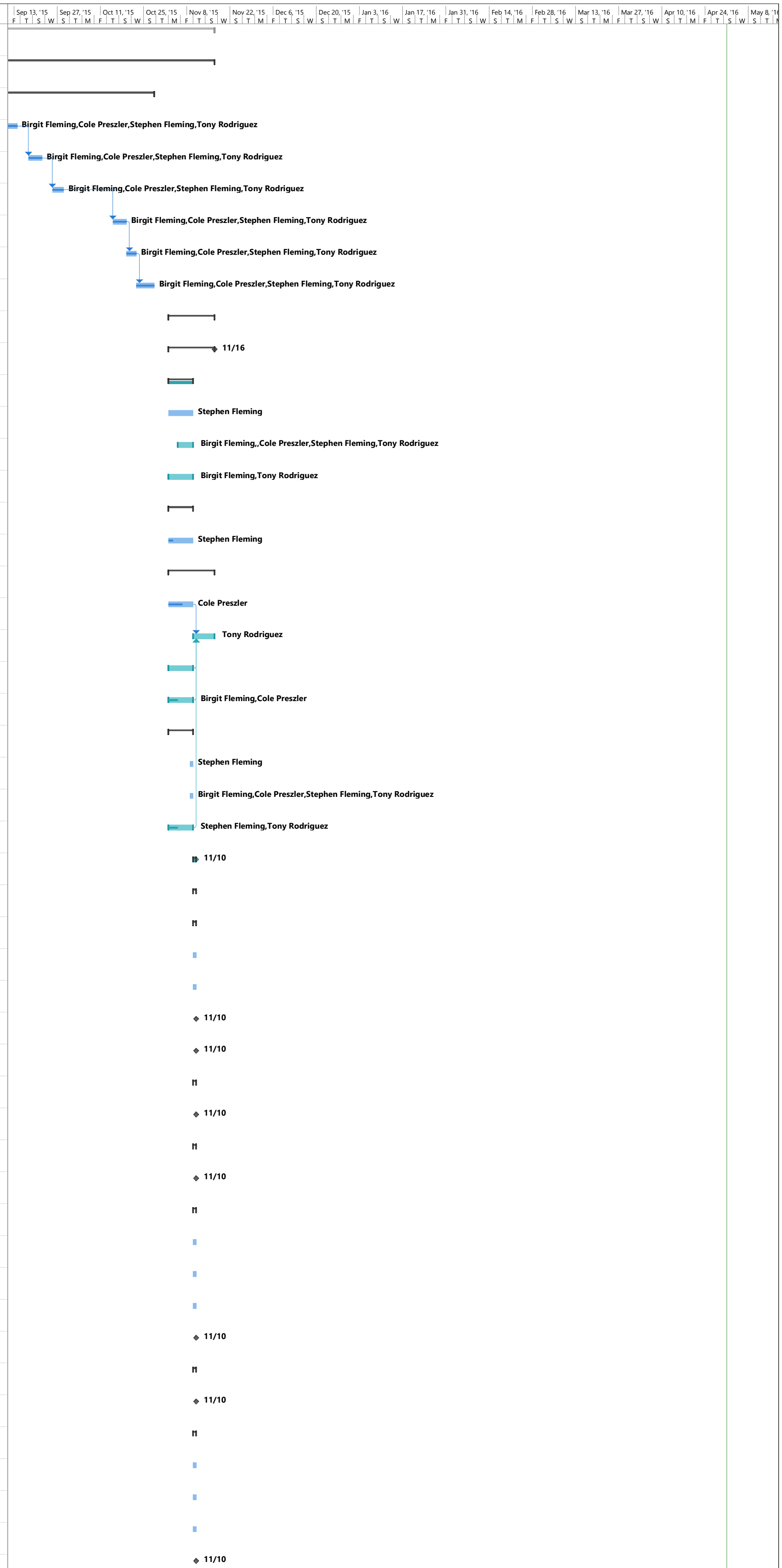
Fig. 9: Work Hours Chart for full year [7]

To calculate the total hours worked, the Gantt Chart was used. According to the Microsoft Project the team worked around 200 hours per person, per semester. Table III shows the hours per feature and the table displayed in figure 9 shows the total hours broken down by person, per semester.

Feature	Work in hours
Pulse Sensor	**107**
User Interface	**234**
Wireless Network	**132**
GNSS	**88**
Data Storage	**71**
Casing Display	**52**
Battery	**64**
Total	**748**

TABLE III: Work Hours Table per feature [7]

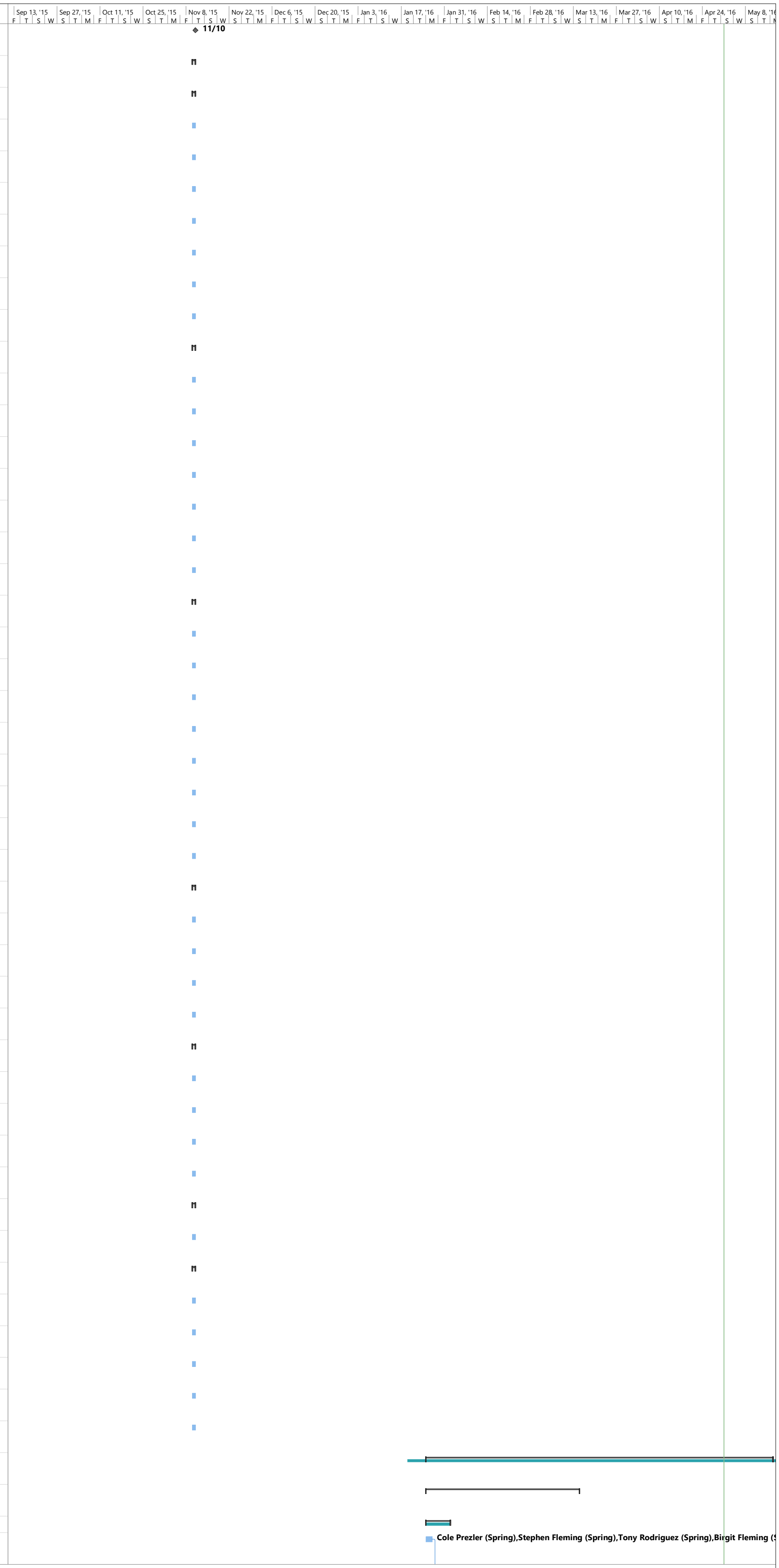
ID		Task Mode	Task Name	Duration	Start	Finish	Work	Resource Initials
1			**Team Leader Gantt Chart**	**49.58 day**	**Tue 9/8/15**	**Mon 11/16/**	**1,275....**	
1			**Fall 2015 Semester**	**49.58 days**	**Tue 9/8/15**	**Mon 11/16/1**	**1,275.2...**	
2	✓		**Coles Team Leader Position**	**35.87 days**	**Tue 9/8/15**	**Wed 10/28/1**	**537.28 ...**	
3	✓		Problem Statement Report	3.58 days	Tue 9/8/15	Sun 9/13/15	114.57 ...	B,C,S,T
4	✓		Design Idea Report	2.13 days	Thu 9/17/15	Mon 9/21/15	68.17 hrs	B,C,S,T
5	✓		Design Idea Contract	1.79 days	Fri 9/25/15	Mon 9/28/15	57.28 hrs	B,C,S,T
6	✓		Work Breakdown Structure Report	2.13 days	Thu 10/15/15	Mon 10/19/15	68.17 hrs	B,C,S,T
7	✓		Intitial Project Timeline	3.58 days	Mon 10/19/1	Thu 10/22/15	114.57 ...	B,C,S,T
8	✓		Risk Assesment Report	3.58 days	Thu 10/22/15	Wed 10/28/1	114.57 ...	B,C,S,T
9			**Stephens Team Leader Position**	**11 days?**	**Mon 11/2/15**	**Mon 11/16/1**	**738 hrs**	
10			**Midterm Technical Review**	**11 days?**	**Mon 11/2/15**	**Mon 11/16/1**	**728 hrs**	
11			**Presentation**	**6 days**	**Mon 11/2/15**	**Mon 11/9/15**	**264 hrs**	
12			Punch List Hard Copy	6 days	Mon 11/2/15	Mon 11/9/15	48 hrs	S
13			Rehearsal	3 days	Thu 11/5/15	Mon 11/9/15	120 hrs	B,,C,S,T
14			Bulletin Board	6 days	Mon 11/2/15	Mon 11/9/15	96 hrs	B,T
15			**Documentation**	**6 days**	**Mon 11/2/15**	**Mon 11/9/15**	**48 hrs**	
16			Gantt Revisions	6 days	Mon 11/2/15	Mon 11/9/15	48 hrs	S
17			**Beginning Prototype**	**11 days?**	**Mon 11/2/15**	**Mon 11/16/1**	**416 hrs**	
18			Setup Wireless Network	6 days	Mon 11/2/15	Mon 11/9/15	48 hrs	C
19			Receive and Transmit Da	5 days	Tue 11/10/15	Mon 11/16/1	40 hrs	T
20			Setup User Interface	6 days	Mon 11/2/15	Mon 11/9/15	48 hrs	
21			Get Satellite Location	6 days	Mon 11/2/15	Mon 11/9/15	96 hrs	B,C
22			**Pulse Sensor Data**	**6 days?**	**Mon 11/2/15**	**Mon 11/9/15**	**184 hrs**	
23			Create sensor protecti	1 day?	Mon 11/9/15	Mon 11/9/15	8 hrs	S
24			Testing for 30% Accura	1 day?	Mon 11/9/15	Mon 11/9/15	32 hrs	B,C,S,T
25			Program Sensor to Ou	6 days	Mon 11/2/15	Mon 11/9/15	144 hrs	S,T
26			**Laboratory Prototype**	**1 day?**	**Tue 11/10/15**	**Tue 11/10/15**	**10 hrs**	
27			**Prototype**	**1 day?**	**Tue 11/10/15**	**Tue 11/10/15**	**0 hrs**	
28			**Wearable**	**1 day?**	**Tue 11/10/15**	**Tue 11/10/15**	**0 hrs**	
29			Design wearable devic	1 day?	Tue 11/10/15	Tue 11/10/15	0 hrs	
30			Make/order device	1 day?	Tue 11/10/15	Tue 11/10/15	0 hrs	
31			Test Weight with com	1 day?	Tue 11/10/15	Tue 11/10/15	0 hrs	
32			Battery Pack lasts >= 8	1 day?	Tue 11/10/15	Tue 11/10/15	0 hrs	
33			**Data Storage**	**1 day?**	**Tue 11/10/15**	**Tue 11/10/15**	**0 hrs**	
34			Heart rate and coordir	1 day?	Tue 11/10/15	Tue 11/10/15	0 hrs	
35			**GNSS Coordinates**	**1 day?**	**Tue 11/10/15**	**Tue 11/10/15**	**0 hrs**	
36			Test Coordinate Accur	1 day?	Tue 11/10/15	Tue 11/10/15	0 hrs	
37			**User Interface**	**1 day?**	**Tue 11/10/15**	**Tue 11/10/15**	**0 hrs**	
38			Program for user inter	1 day?	Tue 11/10/15	Tue 11/10/15	0 hrs	
39			Design of user interfac	1 day?	Tue 11/10/15	Tue 11/10/15	0 hrs	
40			Improve from previou	1 day?	Tue 11/10/15	Tue 11/10/15	0 hrs	
41			Test Accurate display	1 day?	Tue 11/10/15	Tue 11/10/15	0 hrs	
42			**Networks and Communi**	**1 day?**	**Tue 11/10/15**	**Tue 11/10/15**	**0 hrs**	
43			Test Send/Receive Dat	1 day?	Tue 11/10/15	Tue 11/10/15	0 hrs	
44			**Pulse Sensor**	**1 day?**	**Tue 11/10/15**	**Tue 11/10/15**	**0 hrs**	
45			Program for Tony's Mi	1 day?	Tue 11/10/15	Tue 11/10/15	0 hrs	
46			Make secondary sensc	1 day?	Tue 11/10/15	Tue 11/10/15	0 hrs	
47			Algorithm to monitor I	1 day?	Tue 11/10/15	Tue 11/10/15	0 hrs	
48			Test for 30% Reliability	1 day?	Tue 11/10/15	Tue 11/10/15	0 hrs	



Project: Spring Gantt Chart with
Date: Sun 5/1/16

Task	Summary	Inactive Milestone	Duration-only	Start-only	External Milestone
Split	Project Summary	Inactive Summary	Manual Summary Rollup	Finish-only	Deadline
Milestone	Inactive Task	Manual Task	Manual Summary	External Tasks	Progress
Manual Progress					

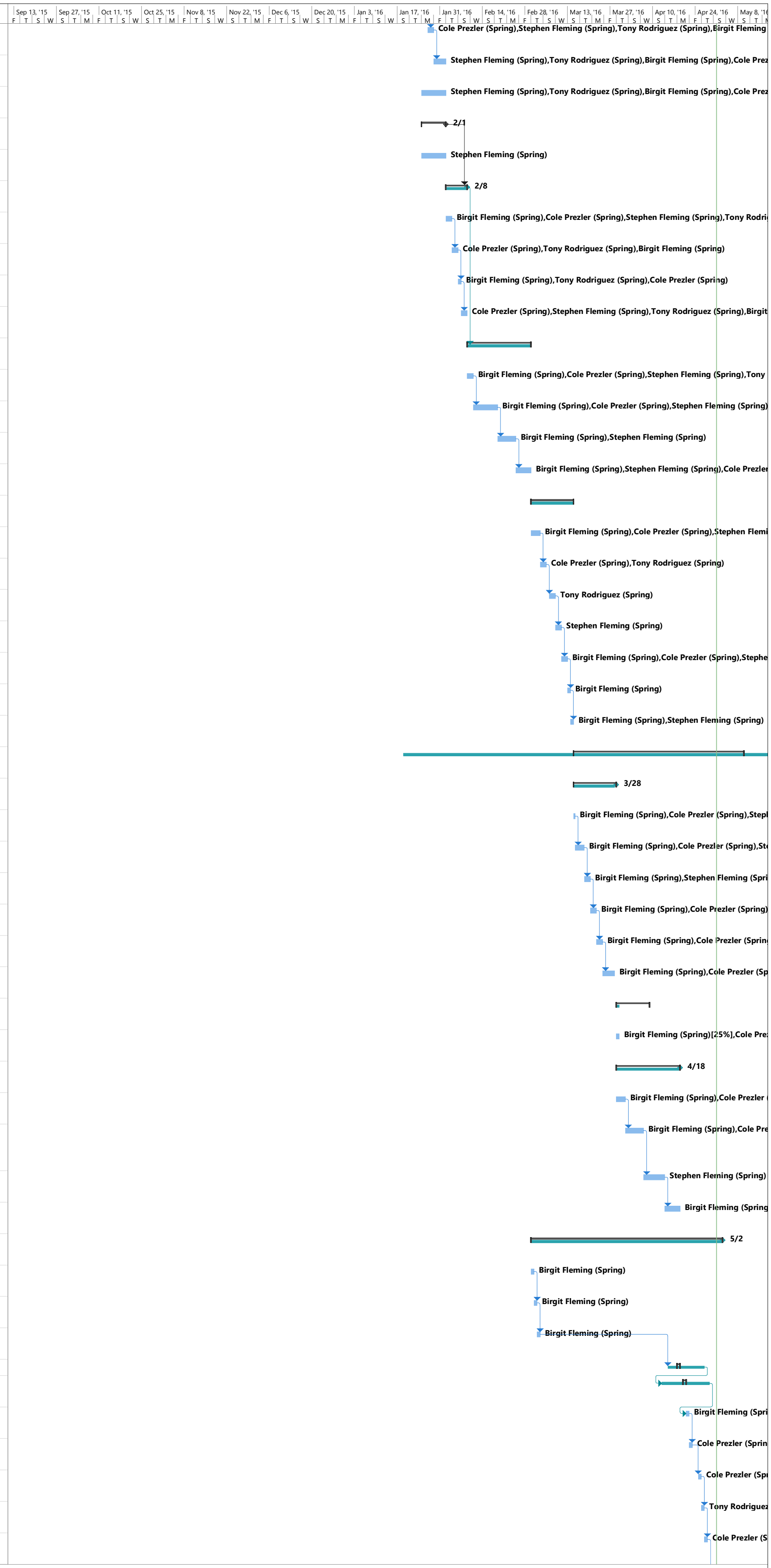
ID		Task Mode	Task Name	Duration	Start	Finish	Work	Resource Initials
49			Test HR between 30 -	1 day?	Tue 11/10/15	Tue 11/10/15	0 hrs	
50			**Documentation**	**1 day?**	**Tue 11/10/1**	**Tue 11/10/1**	**10 hrs**	
51			**Sections of Report**	**1 day?**	**Tue 11/10/1**	**Tue 11/10/1**	**0 hrs**	
52			Problem Statement	1 day?	Tue 11/10/15	Tue 11/10/15	0 hrs	
53			Feature Set	1 day?	Tue 11/10/15	Tue 11/10/15	0 hrs	
54			WBS and timeline fall	1 day?	Tue 11/10/15	Tue 11/10/15	0 hrs	
55			WBS and timeline Spri	1 day?	Tue 11/10/15	Tue 11/10/15	0 hrs	
56			Discuss Work for prot	1 day?	Tue 11/10/15	Tue 11/10/15	0 hrs	
57			photographic docume	1 day?	Tue 11/10/15	Tue 11/10/15	0 hrs	
58			Diagrams/Simulations,	1 day?	Tue 11/10/15	Tue 11/10/15	0 hrs	
59			**User Guides**	**1 day?**	**Tue 11/10/1**	**Tue 11/10/1**	**0 hrs**	
60			Getting Started	1 day?	Tue 11/10/15	Tue 11/10/15	0 hrs	
61			Pulse Sensor	1 day?	Tue 11/10/15	Tue 11/10/15	0 hrs	
62			GNSS Locator	1 day?	Tue 11/10/15	Tue 11/10/15	0 hrs	
63			User Interface	1 day?	Tue 11/10/15	Tue 11/10/15	0 hrs	
64			Wireless Network	1 day?	Tue 11/10/15	Tue 11/10/15	0 hrs	
65			Mounting/Wearing	1 day?	Tue 11/10/15	Tue 11/10/15	0 hrs	
66			Battery Replacement	1 day?	Tue 11/10/15	Tue 11/10/15	0 hrs	
67			**Testing Results**	**1 day?**	**Tue 11/10/1**	**Tue 11/10/1**	**10 hrs**	
68			Test Weight with com	1 day?	Tue 11/10/15	Tue 11/10/15	0 hrs	
69			Battery Pack lasts >= 8	1 day?	Tue 11/10/15	Tue 11/10/15	0 hrs	
70			Heart rate and coordir	1 day?	Tue 11/10/15	Tue 11/10/15	0 hrs	
71			Test Coordinate Accur	1 day?	Tue 11/10/15	Tue 11/10/15	0 hrs	
72			Test Accurate display	1 day?	Tue 11/10/15	Tue 11/10/15	0 hrs	
73			Test Send/Receive Dat	1 day?	Tue 11/10/15	Tue 11/10/15	0 hrs	
74			Test HR sensor for 30%	1 day?	Tue 11/10/15	Tue 11/10/15	0 hrs	
75			Test HR between 30 -	1 day?	Tue 11/10/15	Tue 11/10/15	0 hrs	
76			**Prototype to Deployal**	**1 day?**	**Tue 11/10/1**	**Tue 11/10/1**	**0 hrs**	
77			Add HR display for f	1 day?	Tue 11/10/15	Tue 11/10/15	0 hrs	
78			Integrate into gear	1 day?	Tue 11/10/15	Tue 11/10/15	0 hrs	
79			Re-order higher qua	1 day?	Tue 11/10/15	Tue 11/10/15	0 hrs	
80			Switch to much sma	1 day?	Tue 11/10/15	Tue 11/10/15	0 hrs	
81			**Appendix Electronic S**	**1 day?**	**Tue 11/10/1**	**Tue 11/10/1**	**0 hrs**	
82			All Data Sheets	1 day?	Tue 11/10/15	Tue 11/10/15	0 hrs	
83			Important Referenc	1 day?	Tue 11/10/15	Tue 11/10/15	0 hrs	
84			Team Resumes	1 day?	Tue 11/10/15	Tue 11/10/15	0 hrs	
85			Vendor Contacts	1 day?	Tue 11/10/15	Tue 11/10/15	0 hrs	
86			**Copies of all documen**	**1 day?**	**Tue 11/10/1**	**Tue 11/10/1**	**10 hrs**	
87			Convert all docume	1 day?	Tue 11/10/15	Tue 11/10/15	0 hrs	
88			**Presentations**	**1 day?**	**Tue 11/10/1**	**Tue 11/10/1**	**10 hrs**	
89			Hardware Block D	1 day?	Tue 11/10/15	Tue 11/10/15	2 hrs	
90			Hardware Explan	1 day?	Tue 11/10/15	Tue 11/10/15	2 hrs	
91			Software Block D	1 day?	Tue 11/10/15	Tue 11/10/15	2 hrs	
92			Software Explana	1 day?	Tue 11/10/15	Tue 11/10/15	2 hrs	
93			Gantt Chart	1 day?	Tue 11/10/15	Tue 11/10/15	2 hrs	
2			**Spring 2016 Semester**	**97 days**	**Mon 1/25/16**	**Mon 5/16/16**	**955 hrs**	
3			**Team Leader Birgit**	**46 days**	**Mon 1/25/16**	**Mon 3/14/16**	**362 hrs**	
4			**Problem Statement Revision Re**	**8 days**	**Mon 1/25/16**	**Mon 2/1/16**	**112 hrs**	
5			Research and find 4 peer reviewed Articles	2 days	Mon 1/25/16	Tue 1/26/16	16 hrs	CP,SF,TR,BF



Project: Spring Gantt Chart with
Date: Sun 5/1/16

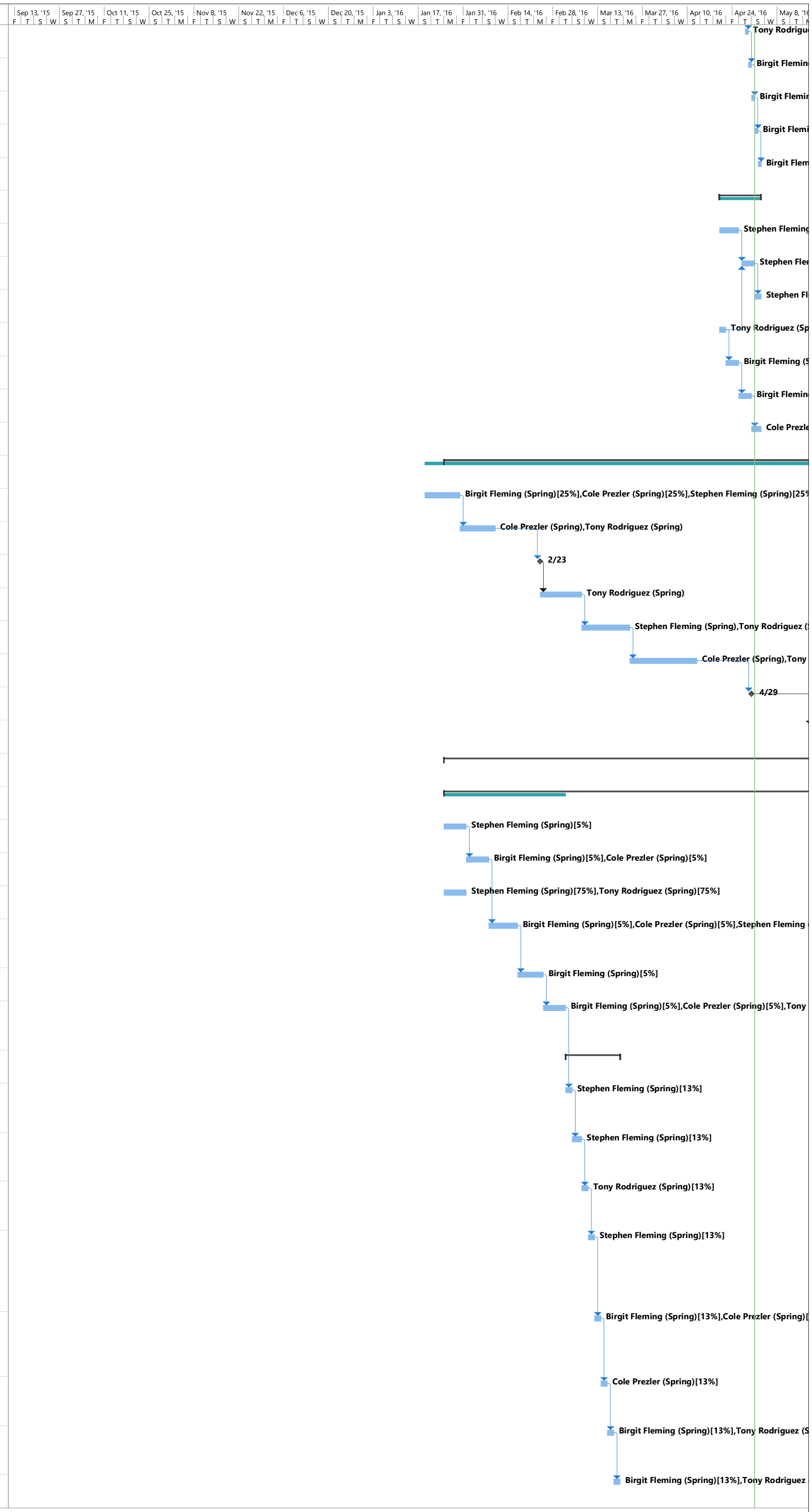
Task	Summary	Inactive Milestone	Duration-only	External Milestone	Manual Progress
Split	Project Summary	Inactive Summary	Manual Summary Rollup	Deadline	
Milestone	Inactive Task	Manual Task	Manual Summary	External Tasks	Progress
			Start-only		
			Finish-only		

ID	Task Mode	Task Name	Duration	Start	Finish	Work	Resource Initials
6		Make section of Problem statement more sophisticated	2 days	Wed 1/27/16	Thu 1/28/16	32 hrs	CP,SF,TR,BF
7		Proper Formatting	4 days	Fri 1/29/16	Mon 2/1/16	32 hrs	SF,TR,BF,CP
8		Preperation for Presentation	8 days	Mon 1/25/16	Mon 2/1/16	32 hrs	SF,TR,BF,CP
9		**Revised Project Timeline**	**8 days**	**Mon 1/25/16**	**Mon 2/1/16**	**16 hrs**	
10		Update Gantt Chart	8 days	Mon 1/25/16	Mon 2/1/16	16 hrs	SF
11		**Device Test Plan Report**	**7 days**	**Tue 2/2/16**	**Mon 2/8/16**	**42 hrs**	
12		Create Plan to test	2 days?	Tue 2/2/16	Wed 2/3/16	16 hrs	BF,CP,SF,TR
13		Perform Adequate Testing	2 days	Thu 2/4/16	Fri 2/5/16	12 hrs	CP,TR,BF
14		Document Testing	1 day?	Sat 2/6/16	Sat 2/6/16	8 hrs	BF,TR,CP
15		Write Test Plan report	2 days?	Sun 2/7/16	Mon 2/8/16	6 hrs	CP,SF,TR,BF
16		**Market Review**	**18 days**	**Tue 2/9/16**	**Mon 2/29/16**	**96 hrs**	
17		Research for market review	2 days	Tue 2/9/16	Wed 2/10/16	24 hrs	BF,CP,SF,TR
18		Write Market Review report	6 days	Thu 2/11/16	Thu 2/18/16	24 hrs	BF,CP,SF,TR
19		Prepare Presentation power point	5 days	Fri 2/19/16	Wed 2/24/16	32 hrs	BF,SF
20		Prepare for Market review presentation	5 days	Thu 2/25/16	Mon 2/29/16	16 hrs	BF,SF,CP,TR
21		**Mid-Term Review and Test Result Presentation**	**13 days**	**Tue 3/1/16**	**Mon 3/14/16**	**96 hrs**	
22		Research	3 days	Tue 3/1/16	Thu 3/3/16	32 hrs	BF,CP,SF,TR
23		Revise Test Plan	2 days	Fri 3/4/16	Sat 3/5/16	16 hrs	CP,TR
24		Report Test Results	2 days	Mon 3/7/16	Tue 3/8/16	8 hrs	TR
25		How will project be completed in next 5 weeks	2 days	Wed 3/9/16	Thu 3/10/16	8 hrs	SF
26		Product Demonstration	2 days	Fri 3/11/16	Sat 3/12/16	8 hrs	BF,CP,SF,TR
27		One page summary handout	1 day?	Sun 3/13/16	Sun 3/13/16	8 hrs	BF
28		Visual Aids	1 day?	Mon 3/14/16	Mon 3/14/16	16 hrs	BF,SF
29		**Team Leader Tony**	**46 days**	**Tue 3/15/16**	**Mon 5/9/16**	**593 hrs**	
30		**Featue Set Presentation and rep**	**12 days**	**Tue 3/15/16**	**Mon 3/28/16**	**104 hrs**	
31		Research for report	0.5 days?	Tue 3/15/16	Tue 3/15/16	16 hrs	BF,CP,SF,TR
32		Write Section of Report	3 days?	Tue 3/15/16	Fri 3/18/16	32 hrs	BF,CP,SF,TR
33		Powerpoint for presentation	2 days?	Fri 3/18/16	Sun 3/20/16	16 hrs	BF,SF
34		Prepare for presentation	2 days	Sun 3/20/16	Tue 3/22/16	24 hrs	BF,CP,SF,TR
35		Component knowledge	2 days	Tue 3/22/16	Thu 3/24/16	8 hrs	BF,CP,SF,TR
36		Interdependence and integration knowledge of component	2 days	Thu 3/24/16	Mon 3/28/16	8 hrs	BF,CP,SF,TR
37		**Team member evaluations**	**9 days**	**Tue 3/29/16**	**Fri 4/8/16**	**8 hrs**	
38		Fill out evaluation forms	1 day?	Tue 3/29/16	Tue 3/29/16	8 hrs	BF,CP,SF,TR
39		**Deployable Prototype Review**	**17 days**	**Tue 3/29/16**	**Mon 4/18/16**	**72 hrs**	
40		Prepare to present prototype almost complete	3 days	Tue 3/29/16	Thu 3/31/16	32 hrs	BF,CP,SF,TR
41		Discuss Pending Tasks before working prototype demonstration	4 days	Fri 4/1/16	Wed 4/6/16	8 hrs	BF,CP,SF,TR
42		Revise Gantt Chart	5 days	Thu 4/7/16	Wed 4/13/16	16 hrs	SF
43		Prepare visual presentation	5 days	Thu 4/14/16	Mon 4/18/16	16 hrs	BF,SF
44		**End of Project Documentation**	**54 days**	**Tue 3/1/16**	**Mon 5/2/16**	**166 hrs**	
45		Full Problem Statement	1 day	Tue 3/1/16	Tue 3/1/16	8 hrs	BF
46		Design Idea Fall Version	1 day	Wed 3/2/16	Wed 3/2/16	8 hrs	BF
47		Design Idea Spring Revision	1 day	Thu 3/3/16	Thu 3/3/16	8 hrs	BF
48		Creating Fall Prototype	1 day	Mon 4/18/16	Mon 4/18/16	12 hrs	
53		Creating Spring Deployble Prototype	1 day	Wed 4/20/16	Wed 4/20/16	18 hrs	
58		Market Review	1 day	Thu 4/21/16	Thu 4/21/16	4 hrs	BF
59		User Manuel for End User	1 day	Fri 4/22/16	Fri 4/22/16	16 hrs	CP
60		Hardware Documentation	1 day	Mon 4/25/16	Mon 4/25/16	16 hrs	CP,TR
61		Software Documentation	1 day	Tue 4/26/16	Tue 4/26/16	8 hrs	TR
62		Test Plan for deployable prototype hardware	1 day	Wed 4/27/16	Wed 4/27/16	8 hrs	CP



Project: Spring Gantt Chart with Date: Sun 5/1/16	Task	Summary	Inactive Milestone	Duration-only	Start-only	External Milestone	Manual Progress
	Split	Project Summary	Inactive Summary	Manual Summary Rollup	Finish-only	Deadline	
	Milestone	Inactive Task	Manual Task	Manual Summary	External Tasks	Progress	

ID		Task Mode	Task Name	Duration	Start	Finish	Work	Resource Initials
63			Test Plan for deployable prototype software	1 day	Thu 4/28/16	Thu 4/28/16	16 hrs	TR
64			Pictures and Graphs	1 day	Fri 4/29/16	Fri 4/29/16	16 hrs	BF,TR
65			Formatting	1 day	Sat 4/30/16	Sat 4/30/16	16 hrs	BF
66			Spelling and Grammer	1 day	Sun 5/1/16	Sun 5/1/16	8 hrs	BF
67			Electronic Submissions Compl	1 day	Mon 5/2/16	Mon 5/2/16	4 hrs	BF,SF
68			**End of Project Presentation**	**11 days**	**Wed 4/20/1**	**Mon 5/2/16**	**88 hrs**	
69			Introduction	4 days	Wed 4/20/16	Mon 4/25/16	8 hrs	SF
70			Overview of Project	4 days	Wed 4/27/16	Sat 4/30/16	8 hrs	SF
71			Include significant milestones	2 days?	Sun 5/1/16	Mon 5/2/16	16 hrs	SF
72			Summarize Technical Aspects	2 days	Wed 4/20/16	Thu 4/21/16	16 hrs	TR,CP
73			One page handout	2 days	Fri 4/22/16	Mon 4/25/16	16 hrs	BF,CP,TR
74			Prepare Poster	4 days	Tue 4/26/16	Fri 4/29/16	16 hrs	BF,TR
75			Demonstrate to End User	3 days	Sat 4/30/16	Mon 5/2/16	8 hrs	CP
76			**Project "FLASHPOINT"**	**100 days**	**Mon 1/25/1**	**Thu 5/19/16**	**155 hrs**	
77			Discuss Modifications to proje	11 days	Tue 1/19/16	Fri 1/29/16	16 hrs	BF,CP,SF,TR
78			Order new parts now to avoid late shipping times	11 days	Sat 1/30/16	Tue 2/9/16	8 hrs	CP,TR
79			Begin Working on Prototype to avoid possible issues	11 days	Wed 2/10/16	Tue 2/23/16	16 hrs	CP,TR
80			Software and signal processing in final stage to limit risk of error	12 days	Wed 2/24/16	Mon 3/7/16	8 hrs	TR
81			Decide if wiring is a problem to change early and reduce problems	15 days	Tue 3/8/16	Tue 3/22/16	18 hrs	SF,TR,CP
82			Progress Deployable Prototype	15 days	Wed 3/23/16	Tue 4/12/16	16 hrs	CP,TR
83			Make protective casing to protect hardware from damage	15 days	Wed 4/13/16	Fri 4/29/16	24 hrs	BF,CP,TR
84			Demonstrate Prototype	15 days	Sat 4/30/16	Wed 5/18/16	12 hrs	BF,CP,SF,TR
85			**Testing**	**100 days**	**Mon 1/25/1**	**Thu 5/19/16**	**37 hrs**	
86			**Testing Plan for Flashpoint**	**100 days**	**Mon 1/25/1**	**Thu 5/19/16**	**21 hrs**	
87			Order pulse monitor with accurate pulse reading	7 days	Mon 1/25/16	Sun 1/31/16	3 hrs	SF
88			Decide on and precure device to test GNSS location	7 days	Mon 2/1/16	Sun 2/7/16	3 hrs	BF,CP
89			Order Casing	7 days	Mon 1/25/16	Sun 1/31/16	6 hrs	SF,TR
90			Order and decide on any other testing devices needed to test project.	7 days	Mon 2/8/16	Tue 2/16/16	3 hrs	BF,CP,SF,TR
91			Devise a testing plan for project	7 days	Wed 2/17/16	Wed 2/24/16	3 hrs	BF
92			Establish a plan to fix problems if testing results are not withnin feature set	7 days	Thu 2/25/16	Wed 3/2/16	3 hrs	BF,CP,TR
93			**Testing Flashpoint**	**16 days**	**Thu 3/3/16**	**Sat 3/19/16**	**16 hrs**	
94			Test Pulse sensor reads pulse between 30 and 200 BPM	2 days	Thu 3/3/16	Fri 3/4/16	2 hrs	SF
95			Test pulse sensor has an accuracy of +/- 30% of resting BPM.	2 days	Sat 3/5/16	Mon 3/7/16	2 hrs	SF
96			Weigh casing with entire project to be under 5 pounds.	2 days	Tue 3/8/16	Wed 3/9/16	2 hrs	TR
97			Test battery life to be less greater than 12 hours by hooking up system to battery power and running until the battery dies.	2 days	Thu 3/10/16	Fri 3/11/16	2 hrs	SF
98			Test GNSS location to be within 3m of actual location with >=25% obstructed sky view	2 days	Sat 3/12/16	Sun 3/13/16	2 hrs	BF,CP
99			Test stand alone wireless network is properly communicating data.	2 days	Mon 3/14/16	Tue 3/15/16	2 hrs	CP
100			Test UI to display proper data from pulse sensor and GNSS module	2 days	Wed 3/16/16	Thu 3/17/16	2 hrs	BF,TR
101			Test data is properly stored on SD card.	2 days	Fri 3/18/16	Sat 3/19/16	2 hrs	BF,TR



Project: Spring Gantt Chart with
Date: Sun 5/1/16

Task	Summary	Inactive Milestone	Duration-only	Start-only	External Milestone	Manual Progress
Split	Project Summary	Inactive Summary	Manual Summary Rollup	Finish-only	Deadline	
Milestone	Inactive Task	Manual Task	Manual Summary	External Tasks	Progress	

Fig. 10: Gantt Chart Work Breakdown Structure [7]

C. Project Work-Breakdown Structure, Milestones and Schedule

The Gantt Chart shown in figure 10 shows the breakdown of work amongst the team, the project schedule and all of the milestones. It provides information about the goals, tasks, hours required to complete task, person responsible for task and beginning and ending dates for both the Fall and Spring semesters. Each task that needed to be completed was broken down and had resources assigned to it. Some of the more significant milestones to mention were completing the hardware build, completing the software, completing the testing and completing all of the modifications. Many more milestones are displayed in the list of tasks created by Microsoft project. The most important milestone we completed was the software. We had lots of issues with getting the software to work and the project could not move forward for some time because it was not working. Since the team was well organized, this milestone was completed because there was adequate time to diagnose and solve the problem. Another important milestone that was completed was the testing phase. This allowed the team to make proper modifications to get better test results before the project became deployable.

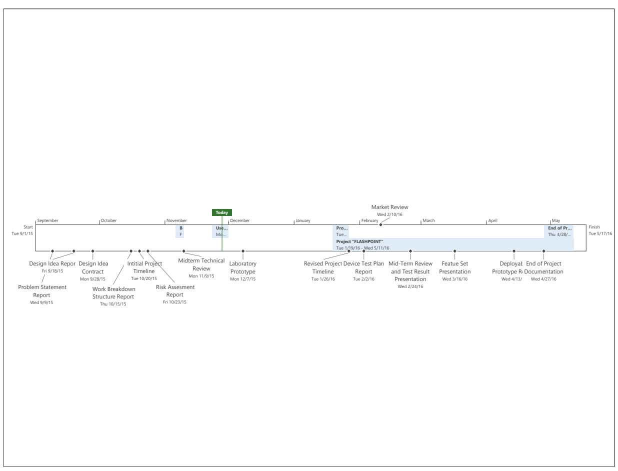


Fig. 11: Full Senior Project Timeline with Milestones [7]

VII. Risk Assessment and Mitigation

Every project comes with its own unique risk factors. Team Flashpoint developed a Risk Assessment Matrix shown in figure 12 that outlines the risk associated with the development of this project.

Near Certainty					
Highly Likely			Sweat/moisture sensitive		
Likely		Wiring/ Funding	Power Drain/ Shipping Time	Link Failure/ Accuracy/ Time Management/ Collaboration Tools downtime	No GNSS data/ Hardware Damage
Low Likelihood		Illegal Transmissions	Data Errors/ Reliability/ Not waterproof	Battery life too low/ Personnel Issues	Sensor Failure/ No signal/ UI Software not operational
Not Likely					Software Incompatible
	Minimum	Can Be Tolerated	Limited	May Jeopardize Project	Catastrophic

Fig. 12: Risk Assessment Matrix [7]

The risks and the corresponding risk mitigation for each component of the project will be discussed.

A. Communication Risks and Mitigation

This project depends upon a link of communication between the firefighter and the Incident Commander. As firefighters operate in many various environments, a reliable long range link is essential. So, the communications link is of vital importance, and the need for long range communications introduces many risks.

1) Illegal Transmissions Risks: Very High Impact, Low Probability

Firefighters generally use the Public Safety communications spectrum. As we are not licensed to use these frequencies, testing a new system in these bands poses a great risk; not only due to possible FCC violation, but also due to possible interference with active public safety activities. Operations on unlicensed bands requires the use of equipment already licensed to operate in said spectrum. Amateur radio bands are a possibility, but require an amateur license, and leave the final product with the possibility of not being usable by the firefighters if they do not have a similar license. An Educational FCC license is available to pursue, but adds time and cost by waiting on the FCC to approve such a license.

2) Illegal Transmissions Risk Mitigation:

To reduce the possibility of illegal transmissions, we will use a device with FCC certification in a band separate from the Public Safety frequencies. Our chosen device is an XBee Pro 900 module. This system is certified to operate from 902-928 MHz in the ISM(Industrial, Scientific, Medical) bands. Recommendations from the FCC that Public Safety personnel utilize more devices in other emerging bands [28] serve to solidify this as our choice of mitigation.

3) Link Failure Risks: High Impact, Medium Probability

An unusable link would make our system into an expensive paperweight. The link will need to be usable over a large range of environments and terrain in order to operate at all. A link failure would prevent any information from being obtained by the Incident Commander and put the project in jeopardy.

Short range communications will not be sufficient to achieve a successful design.

4) Link Failure Risk Mitigation:
To reach the distances required, the usual Zigbee 2.4 GHz ranges are not sufficient. These high frequencies are easily defeated over rough terrain; lower, more robust frequencies are required. The 900 MHz range will present a signal capable of traveling further distances. Additionally, this device uses a proprietary "Digi-Mesh" protocol. Normal Zigbee units have three types of network members: a central device, a router, and an end unit. The routers can pass data on from end units, but require more power use than we would allow. The end units can only send their data, and cannot pass on data from other units. The Digi-Mesh protocol allows each battery operated end unit to act as a repeater for other units in range. In this way, a firefighter that is out of range of the Incident Commander but still in ranger of another firefighter could still maintain a link to pass location and vital data. This method of networking could greatly increase our range during fire-line operations.

5) Power Drain Risks: Medium Impact, Medium Probability
Rf transmission systems can consume a large amount of power. A high power system would present a more reliable link to mitigate the risk presented above, but have the negative impact of quickly draining any battery connected. As this device needs to be mobile and last through an entire shift, power drain needs to be minimized.

6) Power Drain Risk Mitigation:
To mitigate power issued, we require a reduced transmit cycle. This device we have chosen is capable of a sleep mode. This allows the unit to reduce power consumption during normal operations and only transmit and pre-determined intervals. Additionally, the power level is able to be reduces as well, and we will experiment with optimal minimal power required. This combination will give us the ability to maintain a reliable link while minimizing drain power drain.

7) Data Errors Risks: Medium Impact, Low Probability
Erroneous data could lead to incorrect readings, or no readings at all. The reliability of the system would be in question, making it an unusable tool.

8) Data Errors Risk Mitigation:
A reliable connection will be maintained by using a low data rate signal of 9600 baud. This will allow a usable connection over longer distances than those required for a high data rate system. Additionally, if the stated specs of the system cannot be met, our choice of a commercial product will allow us to communicate with the manufacturing company to obtain support if necessary.

B. Navigation Risks and Mitigation

In order to provide the location of a firefighter a device has to be purchased that has the capability of providing said data. Several GNSS modules, which support GPS as well as GLONASS were purchased. There are plenty of risks associated with implementing or operating a GNSS module, some of which will be discussed.

1) Sensor Failure Risks: Very High Impact, Low Probability
If the sensor completely fails, it will have a detrimental effect on the project's outcome. However, the likelihood of this occurring is rather slim.

2) Sensor Failure Risk Mitigation:
If the module completely fails, the only thing that can be done is to get a replacement or order a new module. Having a vendor with expedited shipping available is crucial.

3) Location Accuracy Risks: High Impact, Medium Probability
The acquisition of accurate location data is also crucial to the project's outcome. If the firefighters location cannot be accurately pinpointed, it can have severe consequences in a disaster situation. The accuracy of the acquired location data has therefore a high impact on the project's outcome and the likelihood of this occurring is not negligible.

4) Location Accuracy Mitigation:
If the location data is not accurate enough, adding an antenna might be a solution. If that doesn't work, a more accurate module has to be purchased. Vendor support is also crucial in this matte since they can provide insight into the different modules that suit our needs.

5) No Data Acquisition Risks: Very High Impact, Medium Probability
If there is no data acquisition at all, the project cannot be completed. The impact of such a scenario is very high and the chance of this occurring cannot be ignored.

6) No Data Acquisition Risk Mitigation:
If there is no data acquisition at all, the vendor needs to be contacted to figure out if the module is faulty or something was done wrong during the implementation.

7) Reliability Risks: Medium Impact, Low Probability
Having a device that will work time and time again is very important, especially in the conditions the firefighters are working in. Since we are developing a breadboard prototype at the moment, rather than deploying it in the field, the reliability of the device only slightly impacts the project with a low likelihood of occurrence.

8) Reliability Risk Mitigation:
Having multiple items on hand is important if one of them suddenly breaks, as well as being able to contact the vendor for support.

C. Biomedical Sensors Risks and Mitigation

In order to monitor the health of the firefighters there needs to be sensors that can give us data about their heart rate and possibly some other vital signs. The risks associated with implementing these sensors will be discussed.

1) Sensor Failure Risks: Very high impact, low probability
Sensor failure is possible due to bad equipment, improper power, external conditions and low quality sensors.

2) Sensor Failure Risk Mitigation:
To reduce the risk of sensor failure, sensors are being purchased from quality sources like Mouser and Digi to avoid using cheap components.

3) Signal Accuracy Risks: High impact, High probability
Accuracy can be affected by factors such as too much movement, improper pressure, moisture or bad programming algorithms.

4) Signal Accuracy Risk Mitigation:
Sensor accuracy can be calibrated by finding the proper amount of pressure that the sensor applies to the contact point.
5) Environmental Risks: High probability, medium impact
Since the sensors will be on firemen that will be running around and maintaining a high physical level then the chance of sweat causing moisture around the sensor is pretty much guaranteed.
6) Environmental Risk Mitigation:
To mitigate sweat and moisture issues Lifebeam sensors will be used. Since Lifebeam sensors have been on the market and used for athletes, they are not sensitive to moisture.
7) Wiring Risks: Medium probability, low impact
Wiring can sometimes get in the way and since the sensors may be located in the firemens helmets the wiring may become an issue and will need to be dealt with.
8) Wiring Risk Mitigation:
If the wiring becomes an issue then bluetooth will be used to avoid any discomfort or inconvenience associated with wiring.

D. Wearable Technology Risks and Mitigation

A very important part of the deliverable end product of the project revolves around the component that will be worn by the end user him/herself. The main wearable component in question is the on-body micro-controller device, which will also manage all the physical and software signal interfacing and processing. Various factors come into play on this device, from the physical connections incoming from the various sensors, to the software signal processing before a single stream of data is output through the wireless communication interface. Additionally, some of the main considerations include the weight, shape, size, water resistance of the outer casing, the signal and software processing and capabilities of the micro-controller itself as well as the weight and lifetime limitations of the battery powering the device. As important components of this deliverable the corresponding risks and risk countermeasures are outline below.
1) Software Incompatible Risks: Catastrophic Impact, Very Low Probability One of the main roles of the wearable component is its ability to provide a center for interfacing for all the sensor signal inputs, as well as a processed single output that the communications interface can use. If the software were to somehow not be able to perform this function, it would greatly, and adversely, affect the progress of the project as a whole, since the project relies on signal processing to provide its delivered results.
2) Software Incompatible Risk Mitigation:
Noting the importance of this particular risk, various methods are used in mitigating it. The micro-controller in use, the STM32 Nucleo 64, was selected for its flexibility of use, the variety of connection types it can handle, as well as the fact that it uses open source software, has multiple IDE options, and a variety of ways of handling information in general. Pairing all this knowledge with research into how best to handle the different signal options, having researched proper vendor support of the working components, and having a backup micro-controller all contribute to help mitigate this risk.
3) No Signal Risks: Very High Impact, Low Probability Similar to the ability of the component to be able to process all the signal inputs from a software perspective, if the component were to receive a noise, unusable, or otherwise unviable signal, it would impair the ability of the system to deliver any viable results.
4) No Signal Risk Mitigation:
Whereas the lack of a viable signal would be a significant problem, the steps taking in its mitigation make it a less present threat. Each one of the signal outputs is being tested, and researched by a specific group member and verified by the micro-controller charged team member as well, thus disseminating the responsibility and effort involved in ensuring a proper signal can be routed to the micro-controller. Proper research in terms of the signal and the components will allow the team to pre-order spare components and be aware of existing areas of difficulty in integration.
5) Battery Life Risks: High Impact, Low Probability One of the indicated deliverables of the project is the ability of the device to provide its features for the duration of a standard firefighter shift. A battery dying premature or early into the shift defeats the original intent of the rest of the project deliverables, and is therefore of significant note and importance
6) Battery Life Risk Mitigation:
Two main methods of mitigation are being employed in delivering this feature. The first being proper research to find the longest lasting battery technology that still meets proper weight specifications. The second revolves around the undesirable, but fallback option, of having a hot-swapping capability that would essentially mean the user would have a spare battery on hand, and easily be able to replace it in the component without too long of a loss of service or any other adverse interaction.
7) Not Waterproof Risks: Medium Impact, Low Probability The device casing is also an important component with room for project affecting risks. It must be able to securely house the micro-controller unit and its incoming wiring, offer water protection, and not be overtly bulky or heavy. The lighter, more unobtrusive it can be, all while retaining elements of protection and water resistance, the more functional it can be. Whereas this item is an important component, the impact is not considered as strongly as the previously mentioned items due to easier access to alternate designs and replacement options.
8) Not Waterproof Risk Mitigation:
To mitigate any risks of the casing and wire input to the micro-controller itself a few different avenues are being explored. Research is being made to see if a company makes a compatible product or can custom make a case. Additionally, the on-campus resource, the 3D printing club is being consulted with to see the viability of printing a case for the project. The micro-controller and components were already selected for heat and water resistance, but additional research and backup options are being prepared so as not to rely on a single point solution.

E. User Interface

The user interface is the connection between the firefighters and their incident commander. The user interface will display the heart rate and location data of the firefighters and a stable, reliable interface is therefore crucial to effectively monitor a team. The user interface will run on a Windows-based platform (laptop or tablet) with a XBee communication module attached to it. The user interface itself will depend on several components to run and function properly and there are certain risks involved which will be outlined below. Furthermore, the possible steps for risk mitigation will also be explored.

1) Software Non-Operational Risks: Very High Impact, Low Probability

The software could not start properly for various reasons, such as automatic Windows updates that would create a compatibility issue.

2) Software Non-Operational Risk Mitigation:

Thorough testing of the software on different Windows versions (such as Windows 7, 8, 10) will ensure that the user interface executable runs on various Windows versions. Automatic updates should also be disabled on the designated target laptop or tablet to guarantee a functioning user interface.

3) No Signal Risks: Very High Impact, Medium Probability

It is possible the wireless connection stops working and the communication module stops receiving data. The incident commander would stop receiving the heart rate and location data of his team.

4) No signal Risk Mitigation:

Thorough testing of the device will ensure that there will be no wiring issues that could contribute to a signal loss. However, if the situation should arise, the heart rate and location data will be stored locally. When the connection is restored, the data will start transmitting again to the incident commander interface.

F. Miscellaneous Risks

Other risk factors that could jeopardize a project include poor time management, funding, personnel issues or collaboration tools downtime. These risks and their corresponding mitigation will be discussed.

1) Funding Risks: Low Impact, Medium Probability

All the sensors, the casing, the micro-controller and cabling need to be purchased. Safe costs estimates land the project in the hundreds of dollars at the very least. This needs to be considered in terms of risks for the possibility of not having enough funding. Whereas the lack of ability to purchase the necessary products is indeed a concern, it is not high in terms of priority simply because the team has assessed the costs and can offset them out of pocket.

2) Funding Risk Mitigation:

Various options are being researched and pursued in terms of grants, scholarships, and other types of funding. Business clubs on campus looking for a viable product to fund, as well as companies such as Intel looking to invest in wearable technology are all relevant to the project at hand, and usually require documentation the project is already producing. With those options being stated, whereas funding is a consideration and the money availability is a risk, it is not a big driving concern for a few reasons. At the safest estimates, including replacement parts the team has addressed the need and availability of funds for the project to the conclusion that the team can single-handily fund the entire project. The avenues of funding will still be pursued, but any funding would be an added bonus to a project that does not need to rely on it.

3) Time Management Risks: High Impact, Medium Probability

As with any project, many factors can delay completion. In this case, each team member is undertaking a full load of college courses. Many members are also juggling work, family, and other responsibilities. Many opportunities exist for these other responsibilities to derail a section of the project, which in turn could delay the entire design.

4) Time Management Risk Mitigation:

Communication is the largest tool we have to mitigate time management issues. We will need to remain in contact with each other so that a possible problem can be dealt with quickly. Organization is also vital to ensure we are not overlooking any facets of the project. Additionally, we will each keep one other member in the loop on our sections, so they could take over if need be. To this end, documentation is of great importance. We have established shared folders where all reports, data-sheets, guides, and documentation is kept and all members have access to this information.

5) Hardware Damage Risks: Very High Impact, Medium Probability

There is always a chance that something will break, either due to faulty wiring, spilling something on it or dropping it. The possibilities of how a device can be accidentally broken are endless. It doesn't have to be the fault of the implementer either. Sometimes devices just give out. If a device is damaged to the point of being non-functional, that will have a very high impact on the project's outcome. The likelihood of this occurring is definitely not negligible.

6) Hardware Damage Risk Mitigation:

If possible, backup devices should be on hand. If the devices are rather expensive it is crucial to have a vendor available that provides expedited shipping so that we can get a replacement in a timely fashion without jeopardizing the project.

7) Shipping Time Risks: Medium Impact, Medium Probability

As we have already experienced, time can be a make-or-break issue with many aspects of this project. We are using a large number of vendors as we are integrating systems from many disciplines. Some of the parts ordered previously (especially for GNSS items that are primarily produced overseas) have taken a month or more to arrive. This can put a section far behind schedule and must be managed.

8) Shipping Time Risk Mitigation:

Redundancy is key in this area. We have established multiple options for all areas of the project, in order to avoid problems here. We have already ordered items that we knew would take more time to arrive. Additionally, vendors with faster shipping times will be our preferred choice for future orders.

9) Collaboration Tools Downtime Risks: High Impact, Medium Probability

The school server could be overloaded or not functioning properly and therefore interfere with our due dates for assignments.

10) Collaboration Tools Downtime Risk Mitigation:

Turning in assignments prior to their due date, rather than last minute will ensure that a server outage won't affect the team's assignment grades.

11) Personnel Issues Risks: High Impact, Low Probability
This particular consideration lands in the territory of circumstances that are hard to control. It revolves around the idea that whether its due to stress, or an unforeseen circumstance, a team member would either no longer be able to contribute to the project, or be able to do so on a limited capacity. This needs to be considered carefully, since every one of the team members is fulfilling a very specific role and any such loss would have a high impact on the project, even if we don't expect it to be an issue. The biggest concern for this risk is that this type of scenario is hard to predict.
12) Personnel Issues Risk Mitigation:
Personal circumstances are hard to predict as well as hard to navigate. However, the team has taken a few pre-cautionary steps to mitigate the risks. Each team member has one other person who is at least partially involved in the mechanics of their project, creating at least some level of redundancy in the form of a back up to the knowledge of any specific task. This along with a pre-established plan to document the work being done is meant to be a resource to provide guidance for any other individual that needs to step in and fulfill a specific aspect of any one of the roles.

VIII. Other Design Documentation

A. Potential Markets

In the research and development of our wearable location and heart rate monitoring device, the main focus was put on firefighters. However, other demographics may benefit from this product as well. Several potential markets will be discussed, among them other first responders, military and recreational users.
1) First Responders: First responders include firefighters, police, EMT (emergency medical technician) and paramedics. Researching first responders revealed some interesting facts that could potentially open up a different market for our product.
Focusing on police, a Harvard School of Public Health study has been shown that police officers have a "roughly 30 to 70 times higher risk of sudden cardiac death (SCD) when they're involved in stressful situation [29]." This is a significant number that is hard to ignore. The location tracking aspect of our device could also prove to be a significant benefit for police officers, especially when in high risk situations, such as pursuits of potentially violent suspects. Police officers aren't the only ones who have to deal with these types of situations, however. Federal agents could also benefit from heart rate and location tracking if not already provided. According to the FBI, there are 1,001,984 total full time law enforcement employees in the United States [30]. This would be a rather large potential market for our product.
EMTs and paramedics face equally stressful situations and could potentially benefit from a heart rate monitoring device. The location tracking wouldn't be as applicable, but since our system is highly adaptable, providing different sensors might prove beneficial.
However, the main focus would be put on police officers, since they are most often involved in high-stress and possibly dangerous situations in which a heart rate and location tracking device would be of value.
2) Military: Members of the military, especially when deployed, are under huge amounts of stress. A study published in Circulation showed that "military deployments may increase the risk for coronary heart disease among U.S. service members and veterans [31]." Aside from the risk of heart disease, a location tracking device, especially for soldiers who are deployed and/ or on missions could be a life-saver.
The number of active frontline personnel is approximately 1,400,000 and the number of active reserve personnel is approximately 1,100,000 [32], indicating a very large potential market for our device.
3) Recreational: Our device could also potentially apply for the recreational user, for example hikers. The heart rate monitoring could possibly protect hikers (especially long distance) from over-exertion and at the same time provide location monitoring. If the hikers are out of range, the location and heart rate data would still be saved onto a SD card which can be utilized for later analysis. However, there are already several products, such as smart-watches, that are aimed at recreational users, so it would be hard to penetrate that market and compete with big names such as Garmin.

B. Size of primary target market

The primary target market is directed at firefighters. When designing a product it is important to consider the size of the market because it will allow one to understand the potential the product has for profit or use. For business people money is important, so to have a sizable target market is important. If you want to help save firefighters, then the size of target market shows the amount of impact that the product will make. With any mindset the market size is an invaluable piece of information about a product.
In 2013 the National Fire Protection Association put out a report showing that there was a total of 1,140,750 firefighters on duty in the United States. Out of the total number of firefighters listed in this report 354,600 of them actually work for the fire department, while the other 786,150 are volunteers[33]. Since two-thirds of the firefighter population don't get a paycheck it might be best to reduce costs as much as possible so we can reach the entire market.
The firefighter market is relatively large because with over one-million firefighters it can be assumed that each has at least 5 people that care about each firefighter that Flashpoint can appeal to. This makes our target market approach 6 million. The target market for firefighters with the families included is rather large and presents a great opportunity to market Flashpoint and expect some results.

C. Existing Products/ Competitive Analysis

As our focus for this project has been wild-land fire fighting, an analysis of existing products in this market is warranted. Not many products exist, and fire departments have no official solution. In fact, in a 2014 Wildfire Today article, Mike Ferris of the National Incident Management Organization in Portland states "At the present time there is no technology in use that enables real-time tracking of ground resources assigned to wildland fires. There is also no standard for such tracking or the technology that would support it that has been accepted on an interagency basis." [34]

Searching for commercial solutions that would meet this need, we have found 3 possible contenders. They are the Ravtrack system by Raveon technologies, the Waspmote developer sensor platform by Libelium, and the Garmin Astro 320 tracking system.

The Ravtrack system is designed for many applications, and is marketed as for firefighter and public safety use. For this purpose, it has an Atlas PT system that would be used to track personnel. It is a very capable system, and provide real time tracking, an emergency alert button, and a man-down sensor in a water resistant package. The capability exists to integrate outside sensors as well, though this is not provided by the company. The downside to this system is reduced location acquisition due to no GNSS support, and cost. The worn device retails for over two thousand dollars each, and the incident commander interface would be another thousand, as would as the software license. This makes a simple one person tracker start at four thousand dollars for the minimum kit, making it impractical for volunteer fire departments.

The Waspmote is a developer platform that combines various sensors and communications devices that would allow the creation of a similar system. It is, however, marketed to developers and not to end users as it still requires engineering to create a custom solution. The cost for a discounted starter kit in around 220 dollars, with only the controller, battery, and communication link. This is more than we have spent for similar parts for our project. Sensors would need to be acquired, coded, and the entire project refined, similar to what we are doing. As such, this is not really a competitive product, but another platform that we could use to develop a version of our system.

The Garmin Astro 320 is a tracking system designed for and marketed to sporting dogs. So far, this is the closest practical solution we have found. It is composed of a handheld display, and one or more dog collars with tracking that utilizes GPS and GLONASS. Additionally, it is relatively inexpensive at around six hundred dollars for a tracking collar and display. The downside is that it does not support biometric sensors, and that it is mounted on a dog collar, so would require modification to use with a fire fighter. But, this is the most practical item we have found thus far, even though it is not marketed to use for our purpose. In fact, I have read reports of firefighters actually purchasing these collars themselves and using them successfully. A similar product for a comparable price, marketed to fire fighters, could do very well.

D. Cost Analysis

One of the goals of the Flashpoint project was to provide a device that was not just functional and portable, but also price accessible. With competitive products offering similar features at the $4000 mark, the approach Flashpoint has taken is to have our price point be one of the marketing selling points.

A growing consideration as the project was better researched was its functional use as it pertains to volunteer firefighters. Noting that they are at higher risk of cardiac arrest [12], and don't always have access to the best equipment, Flashpoint seeks to deliver a device that would stay within purchaseable access to individuals funding their own tools and equipment. The $4000.00 is a tough sell to small county and city funded fire departments that employ volunteers. With Flashpoint's original goal of staying under the $2000 mark, the team has since striven to keep it even more price accessible if possible.

1) Cost of Development: A cost analysis of the team's investment and funding, noted in the Team Funding Table below, can be roughly summarized, at about $350 for a full functioning prototype system with a single wearable unit. This is taking into consideration some of the pricier components, cabling and adapters, as well as the casing/wearable components and looking at the project in its rough development stage. From an standalone perspective the cost of all these components can be reduced to accommodate more streamlined/cost efficient option, including an alternate microcontroller and a pcb design that could forgo the wiring, and simplify casing.

An evaluation of prototype development costs for the current Flashpoint team could reduce the price of the hardware to under $300. However this does not include development time, including troubleshooting, testing, and software development which is not an insignificant amount of labor.

2) Cost of Production: Cost of production can greatly vary depending on the way that it is implemented. From a preliminary standpoint having a PCB design and starting a small company that is operated by the current Flashpoint team would be a labor intensive process, however, the price point of the system itself can be reduced in producing it in larger quantities. There are, however, a series of start-up costs that would be involved with marketing a new product.

The fact that the Flashpoint project uses wireless communication would require for the device to be FFC certified as an intentional radiator [35], a fee that can range as high as $10,000-$12,000. There are additional certifications that would be required for plugging into an AC outlet, Underwriter's Laboratory (UL) certification, as well as a lead-free certification to be used in California, and overseas (RoHS Certification)[35]. These are large sunk costs, that don't provide any profit but are required to start producing and marketing a new type of electronic product and add up rather quickly.

Certification costs aside, however, the first step in a budding electronics company would consist of creating a PCB design and have it mass produced, a handful of PCB boards with anywhere from 30 to 50 components can cost in the vicinity of $750 to $1000 to produce, and the cost could be further reduced with a 3D printer to help produce the main wearable component. However, this would require the investment in a 3D printer, which can widely range from a couple hundred dollars to industrial options costing starting at $50,000.

Ultimately any of these options can prove profitable for a company, depending on the size of the market approached and the demand for the product. If the demand is in producing the systems in volumes of under 100 units a month, a PCB design is implemented and the work force remains relatively small, it would take months for profits to overcome the initial invested costs with a great deal of labor hours. This is assuming the user interface software costs a couple hundred dollars and standard Engineering wages at the national average of 125$/hr [36].

If a larger workforce can be implemented, however, including a good quality 3D printer, and some form of standardized manufacturing process, the initial costs would be greater in starting a bigger company, however, if the demand were to exist, the profits would also be larger. The costs could be reduced by producing the device overseas, but this would require a contract with an Original Equipment Manufacturer (OEM) with its own set of costs and restrictions. Additionally, the average cost of starting a small factory in the US ranges in the order of $300,000 to $700,000. However, with these implementations the cost point of each system could be greatly reduced from the $250- $300 range to under $200 in larger volumes, but the process would also require for the units to be in demand, and sell well, in order for such a production to be successful.

3) Cost to the Consumer: Ultimately the cost point for the consumer could vary a significant depending on the approach taken to produce the product. If Flashpoint were to stay a small venture with the goal of producing few units using a small team with a modest profit margin the original goal of a price under $2000 is more than reasonable. Assuming a competitive cost of anywhere between $300-$500 for software, and a price point that allows for production costs in the form of a profit margin of about 50% then individual wearable sensors could cost in the vicinity of $600 (with the additional functionality of being able to add multiple wearables to a single receiving/software system), and receiving modules $300. This would result in a final price point of approximately $1,200 assuming consistent sales of at least 100 units a month to overcome initial costs in the first 5 to 6 months of production. At this price range, and for the range of features the Flashpoint system would be very price competitive and could probably still stand to charge more.

If Flashpoint were to have more funding, however, and a large stable capital, the price of all the units could be slightly reduced, meaning a higher profit margin. The noted price above is noted as competitive, however, if the need arose, or the competition improved their products, a better implementation of a manufacturing process could help reduce the price of the overall system to the $800 range. Due to the large increase in manufacturing costs, this option would only be profitable if there were a higher demand for the products and the price reduction in production was big enough to justify retaining a reasonable profit margin, and if the goal were to continue to provide a low-cost option. Another approach could consist of varying features/hardware being added/removed, that could be easily implemented in the production/manufacturing process and that could provide different price tiers.

TABLE IV: Team Funding [7]

FUNDING				
Cole Prezler Purchased				
Item Description	Price	Qty	Total	Used or Unused in Project
Xbee Pro 900 modules	41.75	4	167	2 used, 2 for testing
900 MHZ Duck antennas(1/4 wave)	7.95	3	23.85	Used for testing
1/2 wave antennas	9.95	3	29.85	2 Used in final design, 1 backup
Gove ear clip heart rate sensor	12.9	1	12.9	Used
Xbee adapter	10	2	20	1 Used, 1 backup
G9 GNSS module	29	1	29	No, broken
G6 GNSS Module	39.49	1	39.49	Used
Brandon Hopkins Purchased				
Xbee Explorer breakout/USB board	24.95	1	24.95	Used for programming
Birgit Fleming Purchased				
Sd card reader module	5.5	1	5.5	Used
Kingston micro memory flash card	4	1	4	Used
Sainsmart micro sd storage board	8	1	8	Used
GPS/GNSS Location GPS Module 10Hz UART I2C	28	1	28	Used
Stephen Fleming Purchased				
Pulse Sensor Amped 1.1	6	4	24	Not Used, Unreliable
Easy Pulse Sensor	35	1	35	Not Used, Other sensor preferred.
Materials to make sensor	15	1	15	Not used in project.
Tony Rodriguez Purchased				
Arduino Mega 2560 Rev 3	49.69	2	99.38	Used
Foxnovo Wire Jumpers (M-M, F-M, F-F)	8.99	2	17.98	Used
USB-A to USB-B Cable	4.97	1	4.97	Used
STM-32F4 Microcontroller	18.32	1	18.32	Unused
STM-32F446 Microcontroller	18.32	2	36.64	Unused
USB-A to USB Mini Cable	5.49	2	10.98	Unused
Mini-Bread Boards (6 Pieces)	5.79	1	5.79	Used

E. Market Research

To gain an understanding of the market a survey was created that will help flush out some of the potential problems associated with Flashpoint. The survey will help us gain the participants opinion about the product, the value it is worth to them, anything they like or dislike and some personal information about the person providing the opinion.

Flashpoint - Health and location monitoring for firefighters

Survey to help Firefighters

This survey is intended to establish a customer perspective about the operation, production, market and value of the product. Since Flashpoint is being designed to help firefighters avoid getting lost or exerting themselves past what their hearts can handle, so it is important to get a wide variety of opinions about the design and feasibility of the product. During these early stages there remains the chance to correct any mistakes with very minimal cost. Surveys can aid in revealing these mistakes.

Pick whatever best applies.

How much is Flashpoint worth to a firefighter?

	Less than $200	Less than $400	Less than $700	Less than $1000	More than $1000	Nothing
Entire system	○	○	○	○	○	○
Heart Rate Monitor Only	○	○	○	○	○	○
GNSS Location Tracker Only	○	○	○	○	○	○
Cost to Manufacture	○	○	○	○	○	○
Cost to customer	○	○	○	○	○	○

Will Flashpoint help:

	Extremely	A lot	A little	Maybe	Not at all	Have bad impact
Firefighters	○	○	○	○	○	○
Paramedics	○	○	○	○	○	○
Military	○	○	○	○	○	○
Average Person	○	○	○	○	○	○
Children	○	○	○	○	○	○

Pick whatever best applies.

Tell us about yourself:

Occupation	
Education level	
Age	
Gender	
Relationship to First responder	

Fig. 13: Firefighter Survey [7]

What do you like about Flashpoint and its features?

	System Advantages
Flashpoint	
GNSS Location	
Pulse Monitor	
Stand Alone Wifi Network	
Processing Hardware	
Processing Software	
Security	

What do you dislike about Flashpoint?

	System Disadvantages
Flashpoint	
GNSS Location	
Pulse Monitor	
Stand Alone Wifi Network	
Processing Hardware	
Processing Software	
Security	

What is it that interests you about Flashpoint?

What would you change about Flashpoint?

Thank you for completing the Survey. We greatly value your feedback. Please leave any relevant comments that were not addressed in the survey below.

Fig. 14: Firefighter Survey [7]

F. *SWOT analysis*

SWOT is commonly used as part of strategic planning and looks at the strengths, weaknesses, opportunities, threats of and to a product. Internal factors are strengths and weaknesses, while external factors are opportunities and threats.

The main strength of our product is cost. We are much less expensive than the closest product marketed for this use. We also have a very adaptable system that provides more features (especially with the biometric sensor) than any other product out there. If we were to also add our optional mesh network, we would be much more feature rich than the Garmin, while much less expensive than the Ravtrack.

Our weaknesses include durability and name recognition. Our product is not as robust as the Ravtrack, and we would not have a name that is as recognizable as Garmin. Our lack of marketing and manufacturing expertise is also a weakness.

Threats to our product include the economy of scale that other manufacturers can provide. They have established experienced marketing teams that we do not have. They have better name recognition, and they provide similar services.

Opportunities include the high price of competitive products, and the underserved market that we are in. The closest threat is not even marketed for this purpose, which turns this threat into an opportunity. We could actually provide a very similar product with marketing to fire fighters, and have an immediate advantage.

Looking at the above analysis, we could minimize our weaknesses by robustness testing and increasing the durability of our product, while striving to remain inexpensive. Also, by keeping or even adding features, we maximize our strengths. Finally, by marketing specifically to fire fighters with an inexpensive product, we have a market share opportunity that we can capitalize on.

G. *Testing Tasks and Results*

1) User Interface:

This part of the feature set is the connection between the firefighter and the incident commander. The user interface will be utilized to display the heart rate and location data of the firefighters that are out in the field. The user interface is being developed in C# and will run on Windows platforms.

Feature Punchlist Requirement: Location and Heart Rate displayed on laptop/ tablet

One of the main parts of our project is the ability for an incident commander to track the firefighters out in the field. In order to do so, a reliable display of the heart rate and location data needs to be developed.

Feature Testplan:

In order to test this feature set, the user interface will be installed on a tablet. We will then connect the XBee module to the tablet to see if we can receive data from the corresponding XBee module that is connected to the wearable device to be worn by the firefighter. If the heart rate and location data will be displayed on the user interface, the feature set will be met.

Modifications:
Developing the user interface as a windows form in Visual Studio (written in C#) is proving to be a challenge. The lack of flexibility makes it difficult to achieve the goals we have set out to do in order to develop a user interface that is robust, as well as aesthetically pleasing. We will probably continue to develop it as a Windows Form application because of the time constraint, but in hindsight, we should have used a different platform.
As far as the testing goes, instead of installing the user interface on a tablet, it was run from a laptop. This made the testing process and troubleshooting easier and more time efficient.

2) Data Storage:
This section deals with the ability to store the heart rate and location data for review. It is important for incident commanders and investigators to be able to access past data in order to figure out what has happened, in case something goes wrong.

Feature Punchlist Requirement: Heart rate and location history
The storage of heart rate and location data of the firefighters onto an SD card for after incident review.

Feature Testplan:
The system will be set up and heart rate and location data will be collected. Once the data collection is done, the SD card will be unmounted and plugged into a computer in order to see if the data has been recorded. The accuracy can be determined by the date and time of the recorded data.

Modifications:
The data storage aspect of our device is straight-forward. We purchased a few SD card modules which kept crashing our system, which is obviously not what we wanted. After some more research, we found a SD card module that is not only smaller than the other ones, but is also very reliable and doesn't cause any issues in our system like the previous ones. As far as the testing goes, our GNSS module has some issues with the date and time. We have a new one on the way which should resolve those issues. As soon as we have the new GNSS module, we can verify the date and time as well. For now, we will check to see if the heart rate and location data was written onto the SD card module. Since we know the location and heart rate of the user for our testing process, we can verify the accuracy of our data by visual inspection of the contents of the SD card.

3) Battery Life:
Since we are developing a wearable device, the battery life is a crucial factor in this project.

Feature Punchlist Requirement: 12 hour minimum battery life
The battery for our system will have to last a minimum of twelve hours since the recommendations for the length of a firefighters shift are twelve hours [37].

Feature Testplan:
In order to test this feature, the system will be turned on and left on for at least twelve hours, collecting data. If the system remains powered on after the specified time period, the feature set will be met.

Modifications:
We purchased a few different sets of batteries and we chose the battery with the smallest form factor. No modifications had to be done to the testing plan. The system was left running for over 12 hours.

4) GNSS Location:
This section encompasses verifying the ability of the device to obtain an accurate location under realistic conditions. A major goal of this product is to establish personnel accountability by tracking this device. This section will center around the device's ability to provide this feature.

Feature Punchlist Requirement: Acquire target position to within 3m with >=25obstructed sky view.
The specific metrics that need to be met are an accuracy of 3 meters. Within this range, fire fighters can be found by sight or sound, especially if a PASS (Personal Alert Safety System) is used. Additionally, this location acquisition will need to be completed without a full sky view of all GPS satellites, such as would be encountered on rough terrain. Trees, buildings, rock outcroppings, etc., could all block some view of the sky in a real world environment, so the device will need to remain accurate under these conditions.

Feature Testplan:
Location data will need to be read from the sensor into the micro-controller and stored on the SD card. This same data will need to be transmitted from the device to the Incident Commander interface, and displayed on the map. White box testing will verify data within this signal flow, but the metric will be finalized with a black box test at the User Interface. The device will be placed at a specific distance from a real world reference point, such as a building corner. This same reference will be located on the map, and the distance from the point indicated will be measured using the map scale. A pass/fail indication will be obtained if these distances are within 3 meters. Additionally, the test will be completed with a building tall enough to obstruct more than 25 percent of the sky view that would otherwise be available. This percentage will be estimated as closely as possible by two or more testers viewing the sky from the point of view of the device. Using a protractor to measure the angle of the edges of the obstructing building, a calculation of the total observed obstruction will be made. Additional optional testing will be pursued to determine the maximum obstruction possible while maintaining location acquisition.

Modifications:
We learned through this test that even commercial devices

promising 3 meter accuracy are usually not able to deliver on this promise, as multi-path interference often results in errors of 10 meters or more. Just because a device is technically capable of such accuracy does not mean it can be realized reliably in operation. It would require a use of Differential GPS(DGPS) systems to obtain an error corrected signal to go below 3 meters, and most likely to even hit the 3 meter mark reliably. We modified our test to add a comparison with a commercial device that also uses GNSS systems, and advertises a 3 meter accuracy as well. The easiest way to do this was to examine our personal electronics, and we found a GPS/GLONASS receiver in the Nexus 6 Smartphone, which was used to compare to our device.
Additionally, we researched the local Sacramento City Survey to determine local markers with more accurate GPS coordinates with which to compare our device. A nearby marker with a published coordinate was found, and we tested against this standard. The varied, but was usually around 3m from the marker. Interestingly, the imagery obtained from online maps split the difference and was approximately 1 meter off from the our device, but 2 meters off from the markers. As we will be using the imagery to pull a map for the incident commander to display, it is more important that the device be accurate to the imagery, than the surveyed markers. This gives us a much higher accuracy(approximately 1 meter) than we had anticipated.

5) Wireless Communication: This section tests the ability of the device to perform the primary function of transmitting sensor data from the device micro-controller to the user interface hardware. The standard we are using for this section is to conform to guidelines for Fireground operations for voice communications (NFPA Voice Radio Communications Guide for the Fire Service-Oct 2008). "1.2 On-Scene Incident Operations (Fireground) 1.2.1 Provides immediate critical, uninterrupted, predominately local (simplex or direct channel), crew-to-IC communication."[38]

Feature Punchlist Requirement: Operation(display of location/HR) over wireless stand-alone network
The specific metric required for this section is to operate on a stand-alone network. This means the device must not need to rely on outside networks for communications. This way, a fire department has complete control in an emergency situation, and is not dependent upon networks operated by outside agencies that may not have service in all areas, or may be unavailable in an emergency situation. To meet the direct channel recommendation, we will use a LOS (Line of Sight) network.

Feature Testplan:
Operation of the device will be tested by transmitting the appropriate data (location/HR) from the device hardware to the user interface hardware over a direct LOS (Line of Sight) network. No outside networks (GSM, Internet) or wired interfaces will be used to assist the transmission. An update will need to be provided on the current location/status at least every 5 minutes to meet a minimum reliability metric at the maximum usable distance. A pass/fail indication will be obtained by a black box test, and comments on the range available will be made. Further optional testing will be pursued in an attempt to optimize the practical range.

Modifications:
The test was performed as discussed, but additional range tests were undertaken indoors and outdoors. An indoor test was performed through 3 levels of a concrete building, using several different antennas to determine which was higher performing. Additionally, an outdoor test was used to simulate environmental factors such as trees, brush, and rain or smoke. This test was found to vary greatly based on terrain, so repeated tests were necessary. A second round of tests was later conducted to increase confidence in the results.

Optional Desired Feature Add-On: Operation(display of location/HR) over wireless Mesh Network.
Not included in the original feature set, but a desirable capability, is the operation of a mesh network. This would allow an additional range extension based on each device being used as a repeater for other devices. If successful, the range of the system could be extended with each additional user.

Feature Testplan:
This test will require additional configuration, and possible change of the communication interface currently being employed. Time permitting, this change will be pursued, and previous range and functionality tests will be repeated. Additionally, a second device will need to be constructed to perform the repeater function. If this test is accomplished, a passing indication will be achieved if the device can transmit the appropriate information to the User Interface while it is BLOS (Beyond Line of Sight). This will be tested by turning off the repeater device, establishing that there is no communication between the DUT(Device Under Test) and the User Interface and a long distance, and then turning on the repeater device and establishing communications at this same distance. If the display of current position/HR data can be made outside of the previously established LOS range, this optional test will be successful.

Modifications:
The optional test was not completed at this time due to time constraints, but the performance of the outdoor range test resulted in a desire to pursue this optional test at a later date. While not necessary to meet our metric, research into the programming of this function will be undertaken.

6) Wearable:
This particular feature set focuses on the wearable component that will be sported on-body by the firefighters themselves. It is comprised of the microcontroller unit, an attached heart rate sensor, GPS module, memory reader/writer, and communication module with an attached antenna in some form of enclosure. The goals of the feature set are to provide a wearable component that will be as unobtrusive as possible in terms of size, weight, and ergonomics.

Feature Punchlist Requirement: Max weight of 5 pounds.
One of the bigger considerations for this particular deliverable is that it will not hinder the firefighters in their everyday mechanics. Weight plays a big role in light of all the other equipment that the firefighters already carry with them. The feature indicates the desired deliverable of making the wearable as light as possible, but certainly within less than a 5 pound mark.

Feature Testplan:
To test this particular feature the full set of hardware that the firefighter would be asked to wear was be weighed, including: casing, wiring, battery pack, and attachments, with a scale that can measure up to 100ths of a pound. Overall components were found to not exceed the 5 pound mark to consider this feature properly tested. Additionally, any replacement of parts or adjustments to the casing will be reevaluated at every step of the design process to ensure adherence to this feature.

Modifications:
This particular feature, along with the majority of the wearable related punchlist deliverables, did not require too much in the way of altering the process of testing itself, but rather on careful planning and back up options. An array of cases were ordered ahead of time to ensure multiple options in terms of not just weight, but also dimension. The result was an array of cases that varied noticeably in terms of weight. The options ranged from light plastic cases in the 40 gram range (0.088 lbs) to metal enclosures in the 230 g (0.51 lb) range. The variety was selected with regards to durability, practicality, ease of alteration, and functionality. The only alteration that was needed was the need to change the weight on the case based on some of its other features, detailed further in the sections below.

Feature Punchlist Desired add-on: Max size 6" x 6"
Another important aspect of making the wearable design more manageable in the field is limiting its size. Whereas this is not a specific deliverable in the feature punchlist, the team will strive to deliver a device that is as compact as possible, with the self-set limitation of 6" by 6".

Feature Testplan:
The wearable component(excluding the protruding antenna or attached heart rate sensor) will be measured using a measuring tool that can accurately measure to the 10th of an inch. Once again, any changes made to the casing or overall main wearable design will cause a reassessment of this measurement.

Modifications:
No real alterations were necessary for this particular aspect of the test plan. Whereas the cases were not kept in an ás iścondition, the alterations needed to the cases resulted in having material removed, or holes made in the cases under test. This resulted in dimensions that were virtually unchanged, if slightly smaller than the expected test measurements where the goal continues to be to make the resultant full case solution as small as possible. As was the case with weight, many cases were ordered ahead of time so as to have a wide selection of dimensions to work with, with the idea being that options were needed to figure out how best to set all the components inside a case, and maintain functionality, even while striving to make the case small and unobtrusive.

7) Overall Component Testing:
While the individual testing of each component is crucial to the overall project, as well as in being able to meet the established contract/punchlist, ultimately the goal of testing is to test the overall functionality of the device. This section denotes how the testers will attempt to test overall system functionality and the integration of all the individually tested features.

Feature Punchlist Requirement: Overall Component Testing.
After having had white box testing for each of the individual components, this particular part of the testing plan will focus on two aspects of testing: overall component white-box testing, and overall component black-box testing. White box-testing would allow for redesign and inner rework of essential components as overall integration and functionality is tested. Black box testing would consist of testing from a more consumer or external engineering level, where adjustments can still be made, albeit more superficially, to ensure full functionality for the end user.

Feature Testplan:
The first part of testing will focus on ensuring that the individually tested features all work as expected when put together, essentially testing overall functionality and integration with corresponding troubleshooting steps to adjust any feature as necessary while ensuring that each feature still meets its individual testing criteria. White box testing will be considered completed when each of the features meets its corresponding criteria while being tested as part of the overall component. Weight, power, and measurement restrictions would have to be met, while simultaneously being able to track location and heart rate monitoring, all of this would have to be stored locally in memory, and properly communicated and displayed at the incident commander interface. Troubleshooting in this white-box step would allow for rewiring, recoding, and or component replacement (only if strictly necessary), which would in turn require retesting of affected features (weight, size, etc).
Once white box testing is complete, the device will be left operating for a full run of operation with intervention from the testers if needed. However, black box testing would imply that while components can be plugged/unplugged, power-cycled and run through troubleshooting, this troubleshooting would be more on part with an external engineer testing the device. This would restrict the ability of the tester to rewire, recode, or replace inner components. The test would be considered complete when the device can be successfully tested while only troubleshooting in this fashion, if necessary.

Modifications:
As a whole, the overall testing of the wearable aspects of the device was the most involved of all the physical testing procedures, and still requires some further work to be done. Finding different cases that fit the dimension and weight restrictions was not as difficult as it was to figure out how best to implement all the components as seamlessly as possible into a self-contained solution that was reliable. Part of the difficulty arose from the various options that were available, as well as the lack of experience in what the most successful designs in terms of a wearable electronic device happened to be. An insight, that though mitigated with research, will still require further debugging and extended testing. Restrictions in terms of overheating, unintentional shorts, insulation, padding, spacing, lining up connections, and ensuring reliable ports to the outside of the device were all issues that arose from this testing. Other considerations included a functional way to add an on/off switch, a programming and a charging connection. One other interesting issue that arose from full integration white box testing was the realization that having the wireless communication module too close to the heart rate monitoring incurred noticeable Electromagnetic Interference and heart beat noise. To reduce this the team had to relocate the heart rate sensor connection, as well as establish better grounding and some shielding for both the cable and the module itself. Additionally, any alterations had to be tracked with relation to the overall weight and dimension of the component, as well as an effort to retain a sealed, water and fire resistant device that could still be mounted comfortably and in an unobstructive fashion.

8) Pulse Sensor:
This part of the feature set is to measure the heart rate using a Grove ear clip pulse monitoring sensor. The fireman's heart rate will be read into the micro-controller and transmitted to the user interface using a wireless stand alone network.

Feature Punchlist Requirement: The heart rate that is being read into the user interface must be within 30 percent of the actual value. The heart rate is to be measured while at rest. Also the heart rate must be between 30 and 200 beats per minute.
Feature Testplan:
In order to test this feature set the person under test will have the heart rate sensor clipped to their ear and the system will read the measured heart rate into the user interface. The value on the user interface will be the value under test. In order to verify the accuracy of the value the 2 methods which will be used are the pulse oximetery finger reader or a manual pulse will be taken at the wrist or carotid artery. A CMS 50-DL pulse oximetery reader was purchased and will display an accurate pulse to within +/- 2 percent. If this method is not successful a manual pulse can be taken and compared to the pulse on the user interface.

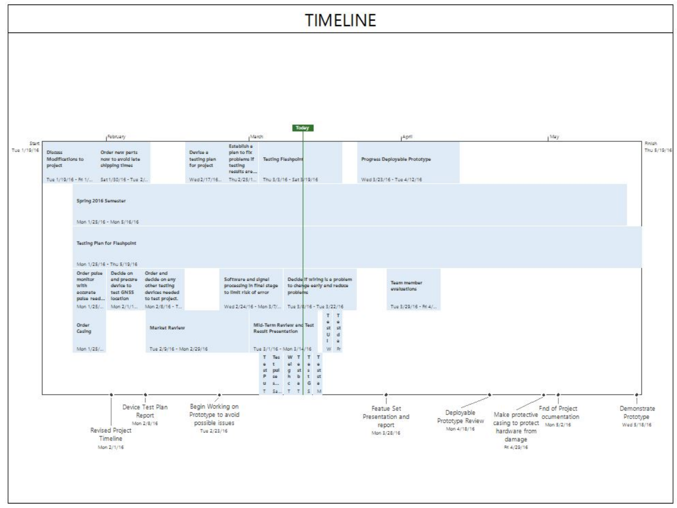


Fig. 15: Timeline with Testing Plan [7]

Modifications:
The purchased pulse reader was used to compare the heart rate, which worked fine. No modifications had to be done to the testing plan.

H. Test Timeline

The timeline shown in figure 15 has been updated with the tasks necessary to test Flashpoint. The timeline has been setup in the most efficient way possible. For instance the testing equipment was ordered early so that the testing results could be aquired in a timely manner. By following the time-line team 7 was able to test the project without problems and to an accuracy level that is sufficient for this particular product and the feature set.

I. Testing Results

1) User Interface: The user interface was tested on a laptop as laid out in the modified test plan. The first test we performed was inside Riverside Hall. The data was read into the user interface. In order to verify whether or not we are getting the correct data, we also placed a different pulse sensor onto the team member who had the components. We knew his location, which was insisde Riverside Hall. We didn't have any transmission issues and the data that was read in was accurate. The second test that was performed took place outside. We took a laptop and placed in on a fixed spot. A team member then clipped the heart rate sensor onto his ear, took the prototype and walked around campus. A snapshot of the results that were read in can be seen in figure 47.

Fig. 16: User Interface [7]

The test was successful. The main goal was to display the location and heart rate data, which was accomplished.

2) Data Storage: The SD card was unmounted and plugged into a computer after we tested the user interface. The collected data was written to the SD card as desired and the test was deemed successful.

3) Battery Life: The battery was tested on March 12th overnight. The user interface was running and the unit was receiving GNSS and pulse sensor data for the entire time. After 12 hours the battery was disconnected and the test was declared a success for 12 hours minimum battery life. Furthermore, the battery was sized to be able to supply 400mA but our system was pulling less than 300mA.

4) GNSS Location: As per the original test plan, we chose a large building corner to test at, that would provide a point of reference. We used Sequoia Hall on the CSUS campus, and this 5 story concrete building provided more than 25 percent obstructed sky view (with additional trees, the obstruction was estimated to be 35 percent). Holding the device directly at the corner, a location was sent to the user interface. Immediately next to the device, a commercial GNSS receiver displaying an advertised accuracy of 3 meters was read as well. The Flashpoint device reported coordinates of 38.561815, -121.42229. The commercial device displayed 38.561807, -121.422324. Using Google Maps (as this is where our display is derived from) to zoom in on the building corner, a distance measurement was made to each waypoint. The commercial device showed a distance of 3.72 meters from the building corner, while the Flashpoint distance was only 2.98 meters as seen in Figure 17. Surprisingly, our device was more accurate than the commercial device. After some research we concluded that this could be due to additional multipath interference seen by antennas in some consumer electronics. The Flashpoint reading was within specifications, but close enough that it may not be so reliably. This tests warrants us to check the validity of our requirements, and re-determine if 3 meter accuracy is really necessary. If so, our device could provide this, but we may want to pursue additional DGPS support to ensure reliability.

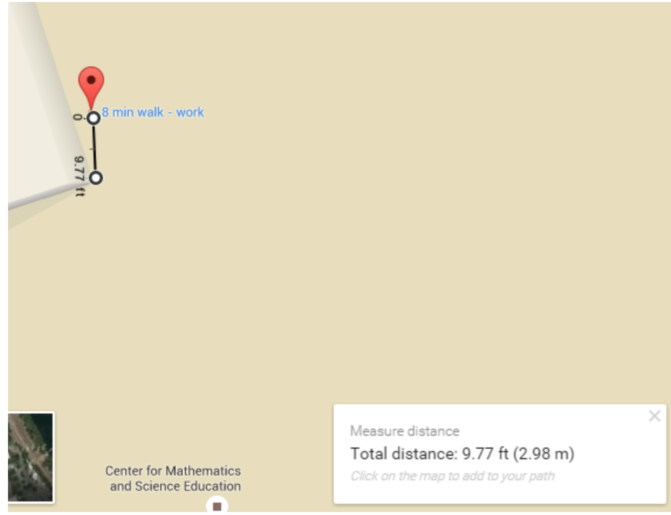


Fig. 17: GNSS Location Accuracy measurement [7]

5) Wireless Communication: While testing both the heart rate and GNSS accuracy, the device provided sufficient wireless connectivity to meet our metric. Additional tests helped to paint a better picture of our capabilities, however. First, an indoor test in Riverside Hall at the CSUS campus allowed us to examine performance in an indoor environment with very poor propagation characteristics. The concrete construction hampered transmissions much more than residential building would do. The test consisted of a packet based range test using the Digi X-CTU software for the XBee Pro RF modules. The modules were programmed for maximum power output of 250 mW. Leaving the User Interface on the 3rd floor, the device was taken from one end of the building to the other, down the outside stairwell to the 1st floor, back across the building, and up the opposite stairwell to return to the user interface. The results are illustrated in Figure 18. The graph clearly shows a decline in packets received as I was walking down the stairwell. On the first floor, the reception is weak, and bottoms out around -80 dBm. As the noise floor was observed to be around -90 dBm, this only gives a 10 dB SNR, which is barely usable for voice applications, but will create data loss. The graph shows a sharp increase as I made my way up the opposite stairwell. This test shows a usable but hampered signal when being operated in an extreme condition such as a large concrete building. The test was then repeated using various antennas to determine which may be more suitable. Using a 1/4 wave antenna with the mag mount base station antenna and making the same loop, a packet success rate of only 57.35 percent. Changing from the base station to a 1/2 wave antenna strangely provided an improvement to 60.29 percent, possibly from the antennas being more similar in size. The best transmission rate was seen with the 1/2 wave antenna and the base station mag mount antenna, at 64.71 percent.

Fig. 18: Indoor Range Test [7]

The outdoor test was also undertaken in extreme conditions. An area with numerous trees and bushes was chosen, and the mag mount antenna placed on a car to simulate the lowest vehicle that may be used. The device was carried at chest level while walking away from the user interface. The test was accomplished under heavy rain to simulate poor environmental conditions such as thick smoke, fog, rain, or other interference. For the first test, the device lost packet transmission at around 325 meters with very heavy rain. A residential test was done under lighter rain, in a residential area. In the case, the device was able to go approximately 520 meters before losing transmission. This area had more buildings providing obstruction than the first test, but less rain. A third residential test with a different, even more obstructed route provided a distance of around 480 meters. This lead us to the conclusion that the range is very environmentally dependent. An additional finding was that the X-CTU software range test had a problem with reestablishing packet transmission after a loss, and the devices would need to be much closer than the previous range to obtain a transmission again. This could account for the much shorter distance with the first test, even though fewer obstacles were in the way. If an anomaly had caused a transmission break, the range would have seemed shorter. So, the test was repeated to ensure accuracy, and a 2nd run showed greater than 420 meter range. Another test was completed with fewer trees and obstructions, and primarily rolling terrain being the only limiting factor. These tests revealed approximately 830 meter range and was more consistent. The residential tests were also more consistent, and show a very usable range for fire fighting operations in a residential area. In either case, the manufacturer's advertised range would only be achievable with higher gain antennas placed at a much more elevated position. While we were close to the advertised indoor/urban range of 600 meters, for our uses, and to be practical in a wearable device, we would not expect to see anything close to the 14 km ranges advertised for outdoor use, though over open land we may approach 1 km or more. These higher ranges clearly require much more elevated antennas than a firefighting team would practically employ, though the use of a telescoping mast for the Incident Commander could be examined. For wildland fire fighting, much greater distances than we currently see may be required, so a future effort to pursue optional mesh networking may be pursued. If not sufficient, a higher power 1 watt rf module is available, though this would add size, cost, and power drain to the final product.

6) Wearable: Two big considerations of the wearable component consisted of the weight and size restrictions. The deliverables have the end result wearable component at under 6 inches by 6 inches (excluding the antenna and heart-rate wiring), as well as weighing less than 5 pounds. An approach to this particular part of the testing consisted of ordering various case options so as to have flexibility in terms of fitting all the different components together. During the process of trying to organize the various components into one case, the weight and dimensions of the various options were tracked.

TABLE V: Flashpoint Wearable Weight Specifications [7]

	Weight	
Component	**grams**	**lbs**
Deep Short Case	52	0.115
Wide Flat Case	114	0.251
Red Metal Case	230	0.507
Wide Square Case	137	0.302
Wide Tall Case	162	0.357
Wide Narrow Case	115	0.254
Large Case	150	0.331
Flashpoint V 0.15	345	0.761
Flashpoint V 0.25	260	0.5732
Flashpoint V 0.50	410	0.904

Table V below summarizes the weight of the various involved components, as well as the weight of some of the more promising cases. Flashpoint V 0.15 summarizes the overall weight of one of the first full contained solutions, with Flashpoint V 0.25 being the latest and slightly more refined current solution. With the original goal of having the full solution be less than 5 lbs, the current working solution being less than 1 lb is actually a huge success in the way of weight restrictions, and means that if the need arose we could consider heavier materials or even bigger cases if the space or functionality were needed. Additionally, all the attempted plastic solutions were well within less than a pound, with the heavier solutions, the metal cases, being the only ones that crossed the pound mark. Even with the use of metal casing, however, the enclosure would certainly meet the design specification of being well under 5 pounds.

Besides the weight, having a compact and unobtrusive solution was the other big wearable consideration. Similar to the weight, the various dimensions of the components were taken into account, with an emphasis on the dimensions of the case itself being made. Table VI below summarizes some of the better case options, in terms of size, that still allowed for the proper housing of all necessary components. It also illustrates the variety of size options that were assessed with regards to a solution. The current Flashpoint V 0.25 solution (highlighted in the indicated table) measures L: 4.558" by W: 2.402" by H: 1.339", and falls well within the 6" by 6" specifications

TABLE VI: Flashpoint Wearable Dimension Specifications [7]

	Weight		Dimensions		
Component	grams	lbs	L (in)	W (in)	H (in)
Deep Short Case	52	0.115	4.558	2.402	1.339
Wide Flat Case	114	0.251	4.000	2.062	1.140
Red Metal Case	230	0.507	4.409	2.382	1.220
Wide Square Case	137	0.302	4.500	4.500	1.510
Wide Tall Case	162	0.357	5.594	4.344	1.840
Wide Narrow Case	115	0.254	5.308	2.942	1.959
Large Case	150	0.331	5.500	3.130	2.500

established in the feature punchlist.

7) Overall Component Testing: Overall component testing is the resultant and last thing to test in a fully working and functional project. With this in mind, it is also the longer lasting and more involved testing. The goal of this particular test is to ensure the original working prototype was able to be altered into a more polished state that is wearable, light weight, retains functionality, and is self-contained, all while lasting its designated more than 12 hour range. The greatest difficulties in testing arose from not just having all the separate components work together, but work together in a finalized state. As such, preliminary test of the overall functionality are running well, but still need to be further explored.

Some considerations of which the particulars were not as easy to predict were the lining up of all the different components inside an enclosure not just in a functional manner, but an efficient one. The various case options were tested individually, alterations were made in the way of holes being drilled, components being lined up and measured, and mountain options being revisited. Some of the mounting attempts involved anything from specialized double sided tape and velcro, to epoxy and Room Temperature Vulcanization silicone (RTV). Troubleshooting aspects that arose during testing included contact isolation (assisted by epoxy and RTV), spacing, padding, mounting, and case alterations. Various holes had to be measured, remeasured, drilled and sealed to allow for outer programming and charging mounts, as well as room for wireless antennas and heart rate sensor wiring.

The latest design, depicted in figures 36 and 37, includes all necessary components in a pre-measured design, with corresponding ports. Further full solution testing still needs to be conducted after all the components can be more carefully realigned.

Moving forward, and after a preliminary round of tests, a few extra sets of casing and components were ordered so as to more efficiently and cleanly line them up inside the case for better functionality. Slightly bigger casing was also ordered to accommodate better alignment, and more padding/isolation. Additionally, a few extra buttons needed to be implemented into the design. Finally, the casing and straps that attaches to firefighter arms and belt need to be mounted permanently and further tested.

If time and resources were not an issue, all the wiring would be outsourced into a pre-designed PCB solution that would be more compact and light weight, additionally, instead of a pre-designed stock box, a specially designed case would be designed and printed on a high end 3D printer, or outsourced as well. Along with this, it was hard to find a full enclosure solution that also contained the wearable aspect, this would be streamlined and combined in the case design. Which in turn produced two variations of an enclosed solution, as noted in the dimension and weight tables. The working prototypes took the form of a compact working solution with tightly fit components in Figure 19 and one with slightly larger dimensions that allowed for a better layout that was better organized and easier to isolate components in, noted in Figure 20.

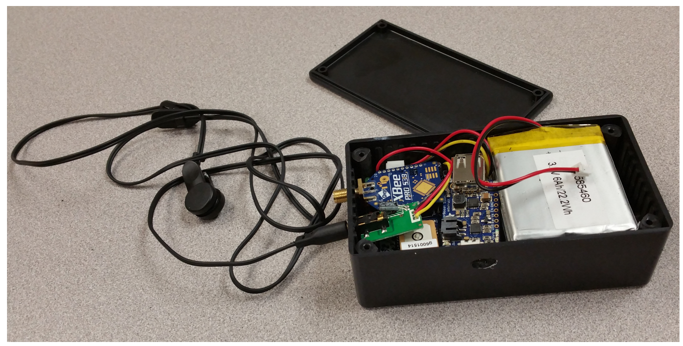


Fig. 19: Flashpoint V 0.25 Wearable Solution [7]

Fig. 20: Flashpoint V 0.50 Wearable Closed Solution [7]

TABLE VII: Pulse Sensor Test

Test	Flashpoint	Pulse-Ox
Test 1	85	86
Test 2	79	81
Test 3	77	78
Test 4	84	84
Test 5	76	78
Test 6	84	85

8) Pulse Sensor: Pulse sensor data was monitored over a 12 hour period checking the pulse received through the Flashpoint system against the pulse reading from a Pulse Oximeter with 2% accuracy every 2 hours. The pulse oximeter was a cheaper model and this caused some difficulty in gaining adequate testing results. The pulse oximeter takes about 10 seconds to register a reading and if the person being tested moves or bends fingers in a way that restricts blood flow the pulse sensor did not get an accurate reading. It also has difficulty updating the pulse when it changes. It appeared to be accurate every time it was reset based on comparison to manual readings and the data from the Flashpoint pulse sensor. The results showed that the pulse is within +/- 30 percent of the actual pulse so this meets the feature set requirements. Additional testing after complete construction of the device resulted in errors while transmitting. It was found that the wireless module induced EMI into the heart rate sensor, and each transmission resulted in numerous additional heart beats. A solution was found to mount the sensor cable perpendicular to the antenna to reduce the additional interference. This resulted in the actual heart beat readings being much stronger than the interference. Another solution is to reduce the frequency of transmission, to reduce the amount of interference, allowing erroneous readings to be averaged out. This also reduces power consumption. The next incarnation of this device would need RF shielding around the heart rate sensor board and cable to minimize interference.

IX. Conclusion

Noting the impact and the importance of the role that firefighters carry out, the goal of this report was to seek, through engineering design, a solution that would provide value, mitigate their greatest risks, and do so in a practical, reliable and inexpensive fashion. Through research and evaluation of valuable data such as that from reports from the National Institute of Occupational Safety and Health (NIOSH), the authors of this report were able to identify some of the major risks (including stress, personnel accountability, and situational awareness) and main causes of fatalities for firefighters, and were able to single out two particular areas of risk that were sought to be addressed. The two main causes of injury were identified as cardiac arrest, and becoming lost, trapped, or separated from their team. With this in mind the idea is explored of a device that can track user heart rates and location, store, process and adequately display this information as well as transmit it wirelessly. As such, the team explores current existing solutions, as well as related aspects of technology to better address this particular societal need. From said research the team devised a design idea to solve the problem in the form of a wearable, wireless device that is reliable, unobtrusive, easy to use, lightweight, compact, and inexpensive. To compliment this design idea, the team also puts forth a specific set of deliverables in the form of a feature punchlist with delineated metrics to ensure that a resultant battery operated device, less than 6" by 6", under 5 pounds, which can acquire accurate location to within 3 meters of accuracy, with 25% obstructed sky view, and communicates wirelessly to a centralized and user friendly user interface, while simultaneously storing the data locally was formed. In the specification of these features the team also followed a thorough planning process, including hourly accounts of work performed in the way of a Work Breakdown Structure (WBS) with specific milestones and a project timeline to flesh out and help guide the work distribution and schedule. Additionally, funding proposals and risk mitigation were addressed with a noted risk matrix to account for reducing known and unexpected risks. The result was a project that stayed on schedule in terms of providing the expected deliverables and meeting the necessary milestones well within each expected established delivery date.

The two semester long process itself was a learning one, and while there are still various aspect of the resultant deployable prototype that the team would purport to improve, the team was able to deliver a neatly packaged wearable device that adequately meets or exceeds all the expected features. The first half of the project focused on providing a workable laboratory prototype to ensure the deliverables were deployable as listed, and that changes or alterations were able to be addressed. The team demonstrated that a rough working laboratory prototype was able to meet all the necessary features, and that some changes were needed in terms of a more efficient and reliable heart rate sensor, as well as a more consistent micro-SD memory card reader. With these implemented changes the device was demonstrated to provide the desired capabilities. Venturing into a more functional solution, and having the reaffirmation that the original proposed solution was viable, the team sought to explore the possible market and applications of the noted solution even while working to implement a full and more thorough round of testing of each individual feature, all while ensuring the testing was conducted on a wearable and fully integrated cleaned version of the design. The tests results helped identify areas of improvement, including some troubleshooting to identify Electromagnetic Interference (EMI) between the wireless communication module and the heart rate sensor, which led to some additional grounded shielding and relocation of the heart rate sensor connection on the deployable device. Beyond this, field testing in the form of white box testing, which led the the rearrangement of the wiring and internal mounting of the device, eventually led to the full black-box testing of the finalized component. From this final round of testing both the internal microcontroller integrating code and the user interface code were adjusted and improved so as to provide a reliable set of data flow. The user interface specifically was approached from an easy to read and use perspective with a cached set of maps obtained from Google maps for offline use.

The end result of this whole process was a device that was ensured to be wearable in a few ways, the battery was tested to last much longer than the ideal 12 hours for a full shift and was noted as lasting more than 20 hours. The device was found to also be well within weight and size restrictions at under 0.9 pounds and under 5.5" by 3.2", and with an accuracy of under 3 meters as compared to Google Map tracking, with more than 50% obstructed sky view, while continuously storing data on a local micro-SD card with a time stamp, and sending the same data wirelessly to a clean and easy to use user interface that is able to be launched via a simple executable file on any windows compatible device. Not only did the design meet the criteria of attempting to be light weight, reliable and easy to use, but the resultant cost of the individual components, after some market and cost evaluations was noted to be able to be implemented well under the $2000 mark, which is more than competitive when compared to similar products that don't provide the same small form-factor or the same type of on the go functionality for human use. Additional areas to explore that the team would still desire to pursue are varied and include the design of an even smaller device or one with altered functionality to extend the use of the wearable to help in tracking other types of activities such as outdoor use, hiking, or even in special needs and care facilities. Additional functionality could also see the software support of a wireless phone app to integrate into the system. Beyond that there were hardware alterations that the team would like to implement in the full working solution in the form of replacing the current wired heart rate monitor solution with a wireless alternative, considering but not limited to bluetooth technology. One other very interesting rising consideration is being able to alter the software, and the logged data specifically, to help not just identify a live feed of firefighter current locations and heart rates, but trends in terms of overall patterns in specific users or sets of users and correlating them with areas, or actions of higher stress as well as movement patterns/vectors. All in all the team demonstrates that technology is available to deliver a solution that could have great viable use from the perspective of First Response and on the field use. This solution can be made to be practical, easy to use, accurate, and less expensive than limited alternatives, and therefore provides an add value technology that could help save the lives of not just firefighters, but the lives of those they seek to help as well.

References

[1] M. Aloqaily, F. Belqasmi, R. Glitho, and A. Hammad, "Multi-party/multimedia conferencing in mobile ad hoc networks for improving communications between firefighters," *Computer Systems and Applications (AICCSA)*, pp. 1–7, 2013.

[2] C. of Disease Control and Prevention. (2003) Niosh firefighter radio communication. [Online]. Available: http://www.cdc.gov/niosh/fire/pdfs/FFRCSsum.pdf

[3] M. Femminella and G. Reali, "A zero-configuration tracking system for first responder networks," *Systems Journal, IEEE*, no. 99, pp. 1–12. [Online]. Available: http://ieeexplore.ieee.org/stamp/stamp.jsp?tp=&arnumber=7210149&isnumber=4357939

[4] A. M. Zhou, T. Z. Wong, L. Xin, X. Kunjie, and S. Ruikang, "Personal mobility map construction for crowd-sourced wi-fi based indoor mapping," *Communications Letters, IEEE*, vol. 18, pp. 1427–1430, 2014.

[5] A. Kusari, P. Zhigang, and C. Glennie, "Real-time indoor mapping by fusion of structured light sensors," *Ubiquitous Positioning Indoor Navigation and Location Based Service (UPINLBS)*, pp. 213–219, 2014.

[6] A. Chandra, S. Jain, and M. Qadeer, "Gps locator: An application for location tracking and sharing using gps for java enabled handhelds," *Computational Intelligence and Communication Networks (CICN)*, pp. 406–410, 2012.

[7] T. R. S. F. Birgit Fleming, Cole Preszler. (2016) Team flashpoint.

[8] Digi. (2015) Xbee-pro® 900hp and xsc rf modules s3 and s3b user guide. [Online]. Available: http://ftp1.digi.com/support/documentation/90002173_R.pdf

[9] Sparkfun. (2014) Xbee explorer datasheet. [Online]. Available: https://cdn.sparkfun.com/datasheets/Wireless/Zigbee/XBee-Explorer-v21b.pdf

[10] Adafruit. (2015) Adafruit xbee guide. [Online]. Available: https://learn.adafruit.com/xbee-radios?view=all

[11] P. T. Virgona, "First responders to superstorm sandy; an information technology assessment," *IOSR Journal of Nursing and Health Science (IOSR-JNHS)*, vol. 2, pp. 51–56, 2013.

[12] D. B. Smith and S. Kales, "Extreme sacrifice: sudden cardiac death in the us fire service," *Extrem Physiol Med*, vol. 2, no. 1, p. 6, 2013.

[13] R. G. Aldunate, K. N. Schmidt, and O. Herrera, "Enabling communication in emergency response environments," *Sensors*, vol. 12, no. 12, pp. 6380–6394, 2012.

[14] F. Legendre, "30 years of ad hoc networking research: What about humanitarian and disaster relief solutions? what are we still missing?" *Proceedings of the 1st International Conference on Wireless Technologies for Humanitarian Relief*, p. 217, 2011.

[15] H. Gellersen and C. Fisher, "Location and navigation support for emergency responders: A survey," *Pervasive Computing*, pp. 38–47, 2010.

[16] U. F. Administration, "Firefighter fatalities in the united states in 2013," *FEMA*, 2014.

[17] L. Faramondi, F. Inderst, R. Setola, and U. Delprato, "An enhanced indoor positioning system for first responders," *2013 International Conference on Indoor Positioning and Indoor Navigation*, 2013.

[18] J. Rantakokko, P. Haendel, M. Fredholm, and F. Marsen-Ekloef, "User requirements for localization and tracking technology: A survey of mission-specific needs and constraints," *International Conference on Indoor Positioning and Indoor Navigation (IPIN)*, 2010.

[19] U. Ramaachandran, K. Hong, L. Iftode, R. Jain, R. Kumar, J. S. K. Rothermel, and R. Sivakumar, "Large-scale situation awareness with camera networks and multimodal sensing," *Proceedings of the IEEE*, vol. 100, pp. 878–892, 2014.

[20] A. Milstein, M. McGill, T. Wiley, R. Salleh, and C. Sammut, "A method for fast encoder-free mapping in unstructured environments," *Journal of Field Robotics*, vol. 28, pp. 817–831, 2011.

[21] G. Patancheru, *Wearable Heart Rate Measuring Unit*, ser. 1st edition, 2014.

[22] R. Brown. (2015) Wearable biosensors for firefighters:wasp. [Online]. Available: http://www.ele.uri.edu/Courses/bme281/F14/1_RyanB.pdf

[23] N. Ungerleider. (2011) Tracking and rescuing firefighters with disposable bread crumb routers. [Online]. Available: http://www.fastcompany.com/1762656/tracking-and-rescuing-firefighters-disposable-bread-crumb-routers

[24] L. Topp, "Interview of director of sales raveon technologies," 2015.

[25] C. Fischer, "Location and navigation support for emergency responders: A survey," *IEEE*, vol. 9, no. 1, pp. 38–47. [Online]. Available: http://ieeexplore.ieee.org/stamp/stamp.jsp?tp=&arnumber=5342406&isnumber=5370796

[26] M. B. Gong, H. B. Moon, and J. Gyu-In, "An indoor positioning system

for a first responder in an emergency environment," *Control, Automation and Systems (ICCAS)*, pp. 1368–1372, 2014.

[27] H. Korrapati, J. Courbon, Y. Mezouar, and P. Martinet, "Image sequence partitioning for outdoor mapping," *Robotics and Automation (ICRA)*, pp. 1650–1655, 2012.

[28] (2015) Public safety tech topic 22 - application of emerging wireless broadband technology for public safety communications. [Online]. Available: https://www.fcc.gov/help/public-safety-tech-topic-22-application-emerging-wireless-broadband-\hfilltechnology-public-safety-co

[29] T. Datz. Police face higher risk of sudden cardiac death during stressful duties. [Online]. Available: http://www.hsph.harvard.edu/news/press/releases/policefacehigherriskofsuddencardiacdeathduringstressfulduties//

[30] C. J. I. S. Division. Full time law enforcement employees. [Online]. Available: https://www.fbi.gov/about-us/cjis/ucrcrimeintheu.s/2011/crimeintheu.s./2011/tables/table_74_full-time_law_enforcement_employees_by_population_\hfillgroup_percent_male_and_female_2011.xls

[31] K. Carollo. Combat exposure may increase risk of heart disease. [Online]. Available: http://www.cardiovascularbusiness.com/topics/prevention/combatexposuremayincreaseriskheartdisease

[32] G. Firepower. United states of america military strength. [Online]. Available: http://www.globalfirepower.com/country-military-strength-detail.asp?country_id=united-states-of-america

[33] H. J. G. Haynes and G. P. Stein. (2014, nov) U.s. fire department profile. [Online]. Available: http://www.nfpa.org/research/reports-and-statistics/the-fire-service/administration/us-fire-department-profile

[34] B. Gabbert. What is the forest service doing about tracking firefighters and fires in real time? [Online]. Available: http://wildfiretoday.com/2014/07/12/what\hfill-is-the-forest-service-doing-about-tracking-firefighters-and-fires\hfill-in-real-time/

[35] J. Teel. The 4 big costs of bringing a new electronic product to market. [Online]. Available: http://predictabledesigns.com/the4bigcostsofbringinganewelectronicproductto-market/

[36] ——. How much will my prototype cost. [Online]. Available: http://predictabledesigns.com/how-much-will-a-prototype-cost/

[37] M. Technology and D. Center. Wildland firefighter health safety report. [Online]. Available: http://www.fs.fed.us/t-d/pubs/pdfpubs/pdf02512815/pdf02512815dpi72.pdf

[38] FEMA. U.s. fire administration voice radio communications guide for the fire service. [Online]. Available: https://www.usfa.fema.gov/downloads/pdf/publications/voice_radio_\hfillcommunications_guide_for_the_fire_service.pdf

[39] I. Aedo, S. Yu, P. Diaz, P. Acuna, and T. Onorati, "Personalized alert notifications and evacuation routes in indoor environments," *Sensors (Basel, Switzerland)*, vol. 12, pp. 7804–7827, 2012.

[40] M. K. Akella, "First responders and crisis map symbols: Clarifying communication," *Cartography and Geographic Information Science*, vol. 36, pp. 19–28, 2015.

[41] R. Wettach and et al. (2015) Fritzing: Electronics made easy. [Online]. Available: http://fritzing.org/

[42] (2015) Arduino mega 2560. [Online]. Available: https://www.arduino.cc/en/Main/ArduinoBoardMega2560

[43] M. Hart. (2015) Tinygps: A compact arduino gps/nmea parser. [Online]. Available: http://arduiniana.org/libraries/tinygps/

[44] (2015) Sd library. [Online]. Available: https://www.arduino.cc/en/Reference/SD

[45] (2016) Serco mold 153-black standard enclosure. high impact abs w/ scratch resistant grain finish. 3hx5.25lx2.25h. black. [Online]. Available: http://www.frys.com/product/138188#detailed

X. Glossary

BDS - BeiDou Navigation Satellite System (a particular GNSS owned and operated by China
BLOS - Beyond Line Of Sight
BPM- Beats per Minute
COTS - Commercial Off The Shelf
DUT - Device Under Test
EMI - Electromagnetic Interference, noise or unexpected readings arising from unexpected or unnacounted for electromagnetic fields, or the electric fields they can induce.
Galileo - A particular GNSS owned and operated by the European Union.
GLONASS - Globalnaya Navigazionnaya Sputnikovaya Sistema, or Global Navigation Satellite System
GNSS - Global Navigation Satellite System
GPS - Global Positioning System
HR - Heart Rate
IC - Incident Commander
ISM - Industrial Scientific Medical
LMR - Land Mobile Radio
LOS - Line Of Sight
PASS - Personal Alert Safety System
SoC - System on a Chip. An integrated circuit (IC) that integrates all components of an electronic system into a single chip.
UAV = Unmanned Aerial Vehicle, an automated electronic flying device often used for reconnaissance.
UI - User Interface - The means by which a user and a computer system interact.

Appendix A
User Manual

For the following section, which details an overview of how to connect the various components together, to have a functional system the diagram in Figure 21 is referenced (created using the open source program Fritzing [41]). The figure represents the laboratory prototype wearable implementation of the project as it would exist when worn by the firefighter. Note that it does not represent the receiving aspect of the system. The various color codings are implemented to help better track the different connections in the system and will be referenced by said color, as well as the pin number and connection. Additionally, the full working prototype is depicted below, Figure 22. This represents simply the unmounted wearable component that is designed to be worn on the firefighter's body, and it represents a tested wearable design to be mounted on an armband or belt carrier. It should be noted that to operate the module one must simply verify that the heart rate monitor is safely secured and centered on the earlobe, that the antenna is attached, and that the power switch is set to on.

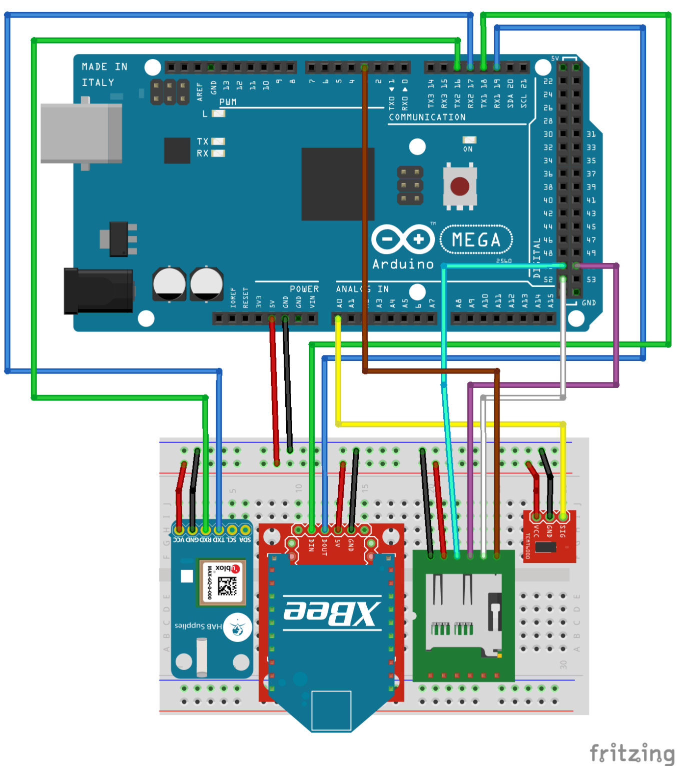


Fig. 21: Simplified Wiring Diagram of Laboratory Prototype [7]

Fig. 22: Flashpoint V 0.50 Wearable Closed Solution [7]

A. Memory Card

Before powering the device on, the SD card must be firmly inserted into the SD card module which is attached to the microcontroller. The Adafruit MicroSD card breakout board communicates with the microcontroller via an SPI connection. The connection relies on a synchronized clock signal (SCK - Pin 52 (White)) and separate transimit receive cables labeled MISO(Master In Slave Out - Pin 50 - Teal) and MOSI (Master Out Slave In - Pin 51 - Purple). It operates off of the microcontroller 5V output, and uses the noted pins 50 through 52 for clock synchronization and data transmission, as well as pin 3 (Brown) to wake up and direct the device to send and receive data (Refer to the microcontroller Section for specific overall pinout information). Insert or remove the SD card only if the device is powered off in order to avoid data loss or data corruption. In the case of data corruption, verify the card information by loading it into a separate micro-SD card reader (or SD card reader with appropriate adapter) and formatting the card if needed (note that formatting erases all data). The module makes use of both the SPI and SD libraries already built into the Arduino IDE [44].

B. GNSS Module

The GNSS module used for this design is the GlobalTop Titan-2 GMS-G6. The module is mounted on a breakout board which requires an input voltage of 5V. The GNSS module outputs the data in NMEA (National Marine Electronics Association) format, which gets processed in the software. The module should be connected to a backup power source so that it can retain the last known location. If the module is fully powered off, a cold start will take about 35 seconds until valid location data can be gathered. If the backup power source is connected, a valid signal can be obtained within 1 second (hot start). The module is wired into the microcontroller's UART Serial Port Pin set 2 (pins 15-green and 16-blue), and powered using its 5 Volt output. This module makes use of an open source library available at: http://arduiniana.org/libraries/tinygps/. The library can be easily integrated into the Arduino IDE by selecting the options Sketch>Include Library>Add .ZIP Library and selecting the downloaded .zip file.

C. Heart Rate Monitor

Another sensor being used in Flashpoint is the heart rate sensor. This sensor is necessary to monitor the health of the firefighters that are on misions. The sensor is comprised of a simple ear clip design, is powered by the microcontroller 5 Volt connection and has a simple analog output, being used by the microcontroller A0(yellow) pin.

1) Connecting the Heart Rate Sensor: This sensor consists of 3 wires which are all connected to the microcontroller. The color of the wires can change depending on the sensor model, but there will be a ground, power and signal wire. The ground is normally black, power is usually red and the signal wire is green or blue. If in doubt, there are small labels near the solderpoints of the wires. Once the orientation of the wires is achieved then these wires need to be connected the Arduino Mega Microcontroller. The power wire should be plugged into the +5V output terminal, the ground wire should be plugged into thr ground terminal and the signal wire should be plugged into the Analog 0 (A0) pin.

2) Sensor Placement: The sensor is setup to either be placed on the finger or on the ear. The person who is having their pulse measured should slip the sensor over their finger and tighten the Velcro so that the sensor pressure is moderate. The person must remain quite still and calm. With the proper pressure and mood the sensor should be very accurate.

3) Sensor Readings: If the sensor is properly hooked up and the pressure is correct the user interface should display an accurate reading for beats per minute (BPM). This shows how many time the users heart beats in a minute.

D. Communications

The communications link between the fire fighter and the Incident Commander will be handled via a stand-alone wireless network based on the Digi XBee platform.

1) Communications Hardware: Hardware consists of the 900 MHZ SB3 Digi Pro XBee module on each end of the link. The modules are ordered with an RP-SMA connector to allow connection to manufactured antennas. A 900-928 MHz antenna is required, and at least a 1/2 wave size is needed to eliminate the need for an additional ground plane. On the Fire fighter side, the interface consists of an XBee adapter module or breakout board. The particular device used is an XBee adapter from Adafruit. A tutorial is available on the Adafruit website on soldering and component placement, but we have omitted unnecessary components and only included the power and RSSI indicator. The RSSI will glow brighter with a greater received signal strength. Voltage from the micro-controller is 3.3 VDC connected directly to the module through filter capacitors, eliminating the need for an additional 5V voltage regulator. The hardware connection is a cimple UART interface using the pinout below:

UART Pins	Module Pin Number
DOUT	2
DIN / $\overline{\text{CONFIG}}$	3
$\overline{\text{CTS}}$ / DIO7	12
$\overline{\text{RTS}}$ / DIO6	16

Fig. 23: XBee UART pinout [8]

On the Incident Commander side, we are using an XBee explorer from Sparkfun to adapt the XBee module to a USB connection. This setup is plug and play, and only requires the antenna connection previously mentioned. We are using a Mag-mount antenna to allow vehicular adaptation, with the vehicle body acting as a ground plane. This also gives us a 3 dBi gain.

2) Communications Software: Programming the communications modules is made easier by the use of Digi X-CTU software. This will need to be downloaded from their website (http://www.digi.com/products/xbee-rf-solutions/xctu-software/xctu#resources) and installed. The software is very user friendly, but keep in mind that programmable XBee modules will need to be setup using the manual setup function, not the automatic. Once setup, each module can be connected using the XBee Explorer, or using the Xbee adapter and additional FTDI interface to convert to USB. The module should be checked for current firmware version and settings through the "read module" function. Data rates are changed through firmware. There are 200k and 10k data rates available. We are utilizing the 10k data rate to increase range, so this firmware will need to be selected from the tool and installed. Software defaults are sufficient to establish basic communications, but a Network ID can be programmed to reduce interference with other networks, and software AES encryption is also another option to make the network more secure. These are selected through the drop down menus in the X-CTU command mode options, and flashed to the device. The modules operate in transparent mode, providing a simple serial data link between devices. Interface speeds can also be selected for various devices, and we are keeping everything at 9600 baud rate, 8 bits, 1 stop bit, no parity. Power levels range between 0-4. This gives a power range of 0.1 microwatt to 250 milliwatts. For testing, PL 0 is used, but PL 3 will be used in the field to provide higher range without too much power drain. Additional advanced options are available to add mesh networking and coordinated sleep cycles. All settings are read from the attached device using the "read" button next to the appropriate parameter, and written using the "write" button. The communications layer structure is included in the figure below:

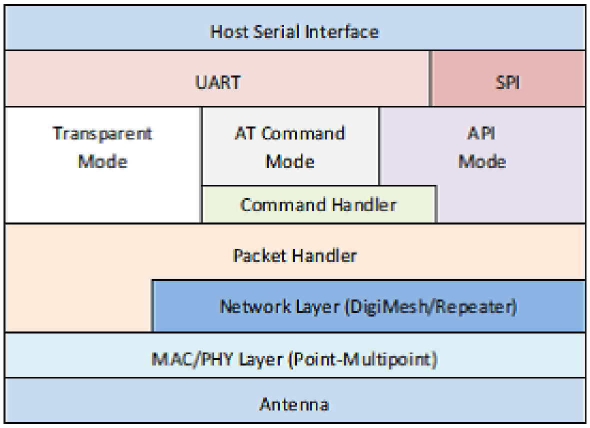


Fig. 24: XBee Communications Layers [8]

E. User Interface

The user interface provides a way for the incident commander to visually track his team. It relies on a series of incoming data and proper means of connection through a provided receiving communication module, noted in Figure **??**, that is connected via a simple USB-miniUSB cable, and offerse plug-and-play functionality. The user interface will be a stand-alone application, however, the source code can be altered if necessary. The steps on how to modify the source code, as well as running the application are discussed below.

Fig. 25: Flashpoint V 0.50 Receiver Hardware [7]

1) Software Requirement: In order to modify the source code of the user interface, a integrated development environment (IDE) is required. Our team decided to utilize Microsoft Visual Studio Enterprise 2015 for development. The software is readily available online but is not the only IDE that can be used. The user interface was developed as a Windows Form written in C#. If the user attempts to modify the source code of the user interface a basic understanding of the IDE and Windows Forms, as well as programming skills, especially in C# are required.

2) Installation: In order to run the user interface, a executable file (flashpoint.exe) will be provided. After double-clicking the executable file, the user interface will start and the incident commander will be able to monitor his team.

The user has to make sure that the XBee communication module is connected to a USB port on the tablet or laptop that will run the user interface. If the module is not connected, no data will be transmitted.

F. Microcontroller

The microcontroller used for this project is the Arduino Mega 2560 Rev 3. Specifications for this device can be found attached in the appendix as well as at the Arduino website [42]. Similarly the Arduino IDE can be found at the same listed website and consists of simple C-based code. Whereas other C-enabled IDEs can be used to edit or load the code, the Arduino IDE allows for simple plug and play functionality through drop down menus that allow you to select your Arduino model under Tools>Boards, and your currently used port under Tools>Port. The board can be plugged into any computer running the Arduino IDE through a simple USB-B cable. The code itself running this project consists of a serial UART input from the the GPS module using the Serial2 connection, and an Analog input from the heart rate monitor. The heart rate is sampled using an interrupt and a timing based algorithm that averages a heart rate every 10 heart beats. The data, which consists of a latitude, longitude, signal age, date and time is then combined into a comma delimited string before being output through Serial1 to the Xbee communication module. All incoming and outgoing signals are processed at a baud rate of 9600. Of it's various available connections 1 SPI Connection is used with the SD Card module, an analog input pin is used for the heart rate sensor, and 2 UART Serial connections are used in this project listed as Serial1 in use with the XBee communication module and Serial2 for use with the GNSS GPS module. Uploading a sketch onto the board is as simple as clicking a compile and load button on the IDE, and further detailings of the software can be found in the software section of this report. The wiring diagram can be observed in Figure 21. They are configured as follows:

1) Analog Heart Rate Sensor: Comprised of a simple Analog output, the sensor simply makes uses of one analog pin on the microcontroller.

- Vcc - 5 V pinout
- Grnd - Common Ground
- Analog Signal Out - Pin A0 (Yellow)

2) GPS Module: This module communicates with the microcontroller via a UART using Serial2 on the microcontroller board.

- RX on Module(TX on Board) Pin 16 (Green)
- TX on Module(RX on Board) Pin 17 (Blue)
- Vcc - 5 V
- Grnd - Common Ground

3) Adafruit MicroSD card breakout board: This module utilizes SPI communication, which relies on the microcontroller, acting as the master, to wake up and request information from the module, referred to as the slave, through a shared clock connection for synchronization. The device will use on of two chip select pins, Pin 3, or Pin 22.

- CS (Chip Select) - Pin 3 /Pin 22 (Brown)
- SCK (Serial Clock) - Pin 52 (White)
- MOSI (Master Out Slave In) - Pin 51 (Purple)
- MISO (Master In Slave Out) - Pin 50 (Teal)
- Vcc - 5V
- Grnd - Common Ground

4) Xbee Communication Module: This module communicates with the microcontroller via a UART using Serial1 on the microcontroller board.

- RX on Module(TX on Board) Pin 18 (Green)
- TX on Module(RX on Board) Pin 19 (Blue)
- Vcc - 5 V
- Grnd - Common Ground

Appendix B
Hardware

A. Communication

1) Block Diagram:

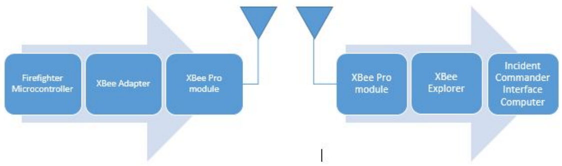


Fig. 26: Communications simplified block diagram [7]

The communications signal flow is only required to have a simplex link from the fire fighter to the Incident Commander using the hardware identified above.

2) Schematics: For the User Interface portion, an XBee Explorer serial to USB interface card is employed. The XBee module is connected to a breakout board as seen below:

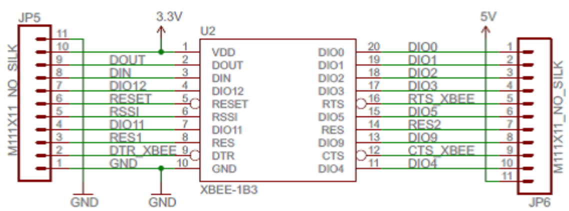


Fig. 27: XBee explorer schematic [9]

The board uses an FTDI chip to convert to USB format:

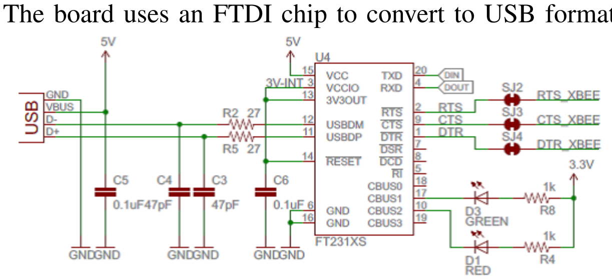


Fig. 28: XBee explorer ftdi schematic [9]

An additional linear voltage regulator is used to enable 5v input, as well as simple LED indications for power and received signal strength, and a reset button.

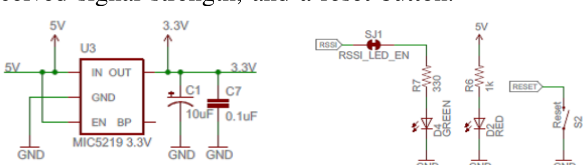


Fig. 29: XBee explorer voltage/indicators [9]

On the Microcontroller side, a simple adapter is used. We chose an XBEE adapter from Adafruit, as it is inexpensive, and provides a 5v powering option using a linear voltage regulator. The schematic is below:

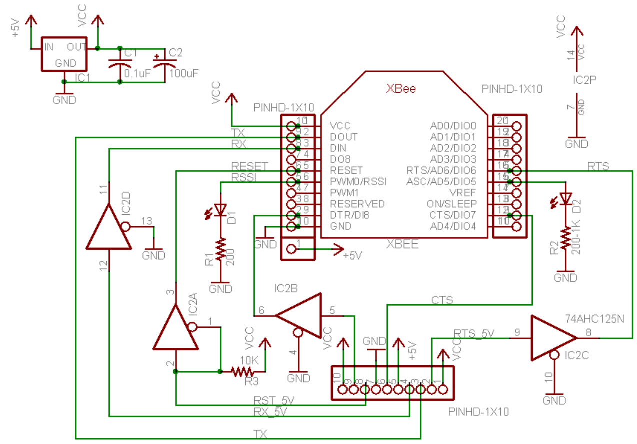


Fig. 30: XBee adapter schematic [10]

Feature Punchlist Requirement: Operation(display of location/HR) over wireless stand-alone network
The specific metric required for this section is to operate on a stand-alone network. This means the device must not need to rely on outside networks for communications. This way, a fire department has complete control in an emergency situation, and is not dependent upon networks operated by outside agencies that may not have service in all areas, or may be unavailable in an emergency situation. To meet the direct channel recommendation, we will use a LOS (Line of Sight) network.

Feature Testplan:
Operation of the device will be tested by transmitting the appropriate data (location/HR) from the device hardware to the user interface hardware over a direct LOS (Line of Sight) network. No outside networks (GSM, Internet) or wired interfaces will be used to assist the transmission. An update will need to be provided on the current location/status at least every 5 minutes to meet a minimum reliability metric at the maximum usable distance. A pass/fail indication will be obtained by a black box test, and comments on the range available will be made. Further optional testing will be pursued in an attempt to optimize the practical range.

Modifications:
The test was performed as discussed, but additional range tests were undertaken indoors and outdoors. An indoor test was performed through 3 levels of a concrete building, using several different antennas to determine which was higher performing. Additionally, an outdoor test was used to simulate environmental factors such as trees, brush, and rain or smoke. This test was found to vary greatly based on terrain, so repeated tests were necessary. A second round of tests was later conducted to increase confidence in the results.

Optional Desired Feature Add-On: Operation(display of location/HR) over wireless Mesh Network.
Not included in the original feature set, but a desirable capability, is the operation of a mesh network. This would allow an additional range extension based on each device

being used as a repeater for other devices. If successful, the range of the system could be extended with each additional user.

Feature Testplan:

This test will require additional configuration, and possible change of the communication interface currently being employed. Time permitting, this change will be pursued, and previous range and functionality tests will be repeated. Additionally, a second device will need to be constructed to perform the repeater function. If this test is accomplished, a passing indication will be achieved if the device can transmit the appropriate information to the User Interface while it is BLOS (Beyond Line of Sight). This will be tested by turning off the repeater device, establishing that there is no communication between the DUT(Device Under Test) and the User Interface and a long distance, and then turning on the repeater device and establishing communications at this same distance. If the display of current position/HR data can be made outside of the previously established LOS range, this optional test will be successful.

Modifications:

The optional test was not completed at this time due to time constraints, but the performance of the outdoor range test resulted in a desire to pursue this optional test at a later date. While not necessary to meet our metric, research into the programming of this function will be undertaken.

3) Wireless Communication Testing Results: While testing both the heart rate and GNSS accuracy, the device provided sufficient wireless connectivity to meet our metric. Additional tests helped to paint a better picture of our capabilities, however. First, an indoor test in Riverside Hall at the CSUS campus allowed us to examine performance in an indoor environment with very poor propagation characteristics. The concrete construction hampered transmissions much more than residential building would do. The test consisted of a packet based range test using the Digi X-CTU software for the XBee Pro RF modules. The modules were programmed for maximum power output of 250 mW. Leaving the User Interface on the 3rd floor, the device was taken from one end of the building to the other, down the outside stairwell to the 1st floor, back across the building, and up the opposite stairwell to return to the user interface. The results are illustrated in Figure 31. The graph clearly shows a decline in packets received as I was walking down the stairwell. On the first floor, the reception is weak, and bottoms out around -80 dBm. As the noise floor was observed to be around -90 dBm, this only gives a 10 dB SNR, which is barely usable for voice applications, but will create data loss. The graph shows a sharp increase as I made my way up the opposite stairwell. This test shows a usable but hampered signal when being operated in an extreme condition such as a large concrete building. The test was then repeated using various antennas to determine which may be more suitable. Using a 1/4 wave antenna with the mag mount base station antenna and making the same loop, a packet success rate of only 57.35 percent. Changing from the base station to a 1/2 wave antenna strangely provided an improvement to 60.29 percent, possibly from the antennas being more similar in size. The best transmission rate was seen with the 1/2 wave antenna and the base station mag mount antenna, at 64.71 percent.

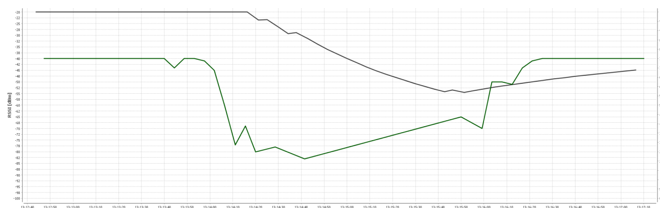


Fig. 31: Indoor Range Test [7]

The outdoor test was also undertaken in extreme conditions. An area with numerous trees and bushes was chosen, and the mag mount antenna placed on a car to simulate the lowest vehicle that may be used. The device was carried at chest level while walking away from the user interface. The test was accomplished under heavy rain to simulate poor environmental conditions such as thick smoke, fog, rain, or other interference. For the first test, the device lost packet transmission at around 325 meters with very heavy rain. A residential test was done under lighter rain, in a residential area. In the case, the device was able to go approximately 520 meters before losing transmission. This area had more buildings providing obstruction than the first test, but less rain. A third residential test with a different, even more obstructed route provided a distance of around 480 meters. This lead us to the conclusion that the range is very environmentally dependent. An additional finding was that the X-CTU software range test had a problem with reestablishing packet transmission after a loss, and the devices would need to be much closer than the previous range to obtain a transmission again. This could account for the much shorter distance with the first test, even though fewer obstacles were in the way. If an anomaly had caused a transmission break, the range would have seemed shorter. So, the test was repeated to ensure accuracy, and a 2nd run showed greater than 420 meter range. Another test was completed with fewer trees and obstructions, and primarily rolling terrain being the only limiting factor. These tests revealed approximately 830 meter range and was more consistent. The residential tests were also more consistent, and show a very usable range for fire fighting operations in a residential area. In either case, the manufacturer's advertised range would only be achievable with higher gain antennas placed at a much more elevated position. While we were close to the advertised indoor/urban range of 600 meters, for our uses, and to be practical in a wearable device, we would not expect to see anything close to the 14 km ranges advertised for outdoor use, though over open land we may approach 1 km or more. These higher ranges clearly require much more elevated antennas than a firefighting team would practically employ, though the use of a telescoping mast for the Incident Commander could be examined. For wild-land fire fighting, much greater distances than we currently see may be required, so a future effort to pursue optional mesh networking may be pursued. If not sufficient, a higher power 1 watt rf module is available, though this would add size, cost, and power drain to the final product.

B. *Wearable Technology*

In terms of physical components, the project can loosely be broken down into two sections. The bigger of these two is the wearable component that the firefighter would carry on their body, with the smaller one being the receiving module that is focused on the user interface software. This section provides an overview of how the various components comprising the wearable section are connected, as well as how the information is handled, and processed.

1) Block Diagram: The data and physical connections for the wearable component of the project center around and are routed by the microcontroller. Figure 32 below details the physical connection between the various devices that comprise the wearable component, as well as the routing and parsing of data. Further details for the actual software components can be found in the software section.

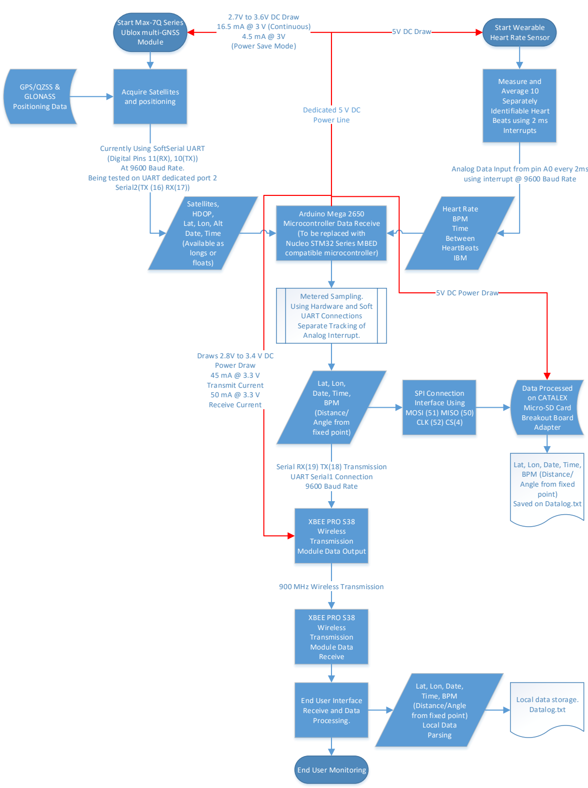


Fig. 32: Hardware and Dataflow Diagram [7]

2) Schematics: As discussed previously this diagram represents the wiring details for the wearable component aspect of the project, which is the part worn by the firefighter. It consists of the GPS module, heart rate sensor, microcontroller, a small breadboard, and the Xbee communication module.

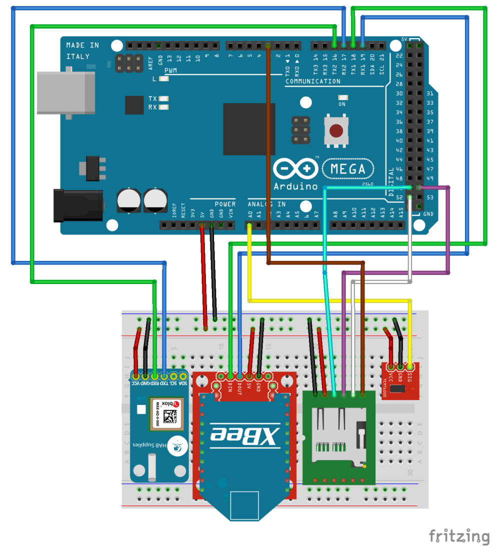


Fig. 33: Simplified Wiring Diagram of Laboratory Prototype [7]

The wiring pinout is once again listed here for ease of reference:

3) Deployable Prototype: The final deployable solution comes in the form of two hardware considerations, an enclosed integrated solution with external ports for the antenna and heart rate sensor that comprises the wearable aspect, as well as a simple receiver box with USB functionality and a transmission/power indicator light that resides on the recieving end. The full solution, observed below in the wearable, Figure 34, and receiver, Figure 35, has a simple on and off switch functionality for the wearable component, and a plug and play functionality on the receiver.

Fig. 34: Flashpoint V 0.50 Wearable Closed Solution [7]

Feature Punchlist Requirement: Max weight of 5 pounds. One of the bigger considerations for this particular deliverable is that it will not hinder the firefighters in their everyday mechanics. Weight plays a big role in light of all the other equipment that the firefighters already carry with them. The feature indicates the desired deliverable of making the wearable as light as possible, but certainly within less than a 5 pound mark.

Feature Testplan:

To test this particular feature the full set of hardware that the firefighter would be asked to wear was be weighed, including: casing, wiring, battery pack, and attachments, with a scale that can measure up to 100ths of a pound. Overall components were found to not exceed the 5 pound mark to consider this feature properly tested. Additionally, any replacement of parts or adjustments to the casing will be reevaluated at every step of the design process to ensure adherence to this feature.

Modifications:

This particular feature, along with the majority of the wearable related punchlist deliverables, did not require too much in the way of altering the process of testing itself, but rather on careful planning and back up options. An array of cases were ordered ahead of time to ensure multiple options in terms of not just weight, but also dimension. The result was an array of cases that varied noticeably in terms of weight. The options ranged from light plastic cases in the 40 gram range (0.088 lbs) to metal enclosures in the 230 g (0.51 lb) range. The variety was selected with regards to durability, practicality, ease of alteration, and functionality. The only alteration that was needed was the need to change the weight on the case based on some of its other features, detailed further in the sections below.

Feature Punchlist Desired add-on: Max size 6" x 6"

Another important aspect of making the wearable design more manageable in the field is limiting its size. Whereas this is not a specific deliverable in the feature punchlist, the team will strive to deliver a device that is as compact as possible, with the self-set limitation of 6" by 6".

Feature Testplan:

The wearable component(excluding the protruding antenna or attached heart rate sensor) will be measured using a measuring tool that can accurately measure to the 10th of an inch. Once again, any changes made to the casing or overall main wearable design will cause a reassessment of this measurement.

Modifications:

No real alterations were necessary for this particular aspect of the test plan. Whereas the cases were not kept in an ás isćondition, the alterations needed to the cases resulted in having material removed, or holes made in the cases under test. This resulted in dimensions that were virtually unchanged, if slightly smaller than the expected test measurements where the goal continues to be to make the resultant full case solution as small as possible. As was the case with weight, many cases were ordered ahead of time so as to have a wide selection of dimensions to work with, with the idea being that options were needed to figure out how best to set all the components inside a case, and maintain functionality, even while striving to make the case small and unobtrusive.

4) Wearable Testing Results: Two big considerations of the wearable component consisted of the weight and size restrictions. The deliverables have the end result wearable component at under 6 inches by 6 inches (excluding the antenna and heart-rate wiring), as well as weighing less than 5 pounds. An approach to this particular part of the testing consisted of ordering various case options so as to have flexibility in terms of fitting all the different components together. During the process of trying to organize the various components into one case, the weight and dimensions of the various options were tracked.

Table VIII below summarizes the weight of the various involved components, as well as the weight of some of the more promising cases. Flashpoint V 0.15 summarizes the overall weight of one of the first full contained solutions, with Flashpoint V 0.25 being the latest and slightly more refined current solution. With the original goal of having the full solution be less than 5 lbs, the current working solution being less than 1 lb is actually a huge success in the way of weight restrictions, and means that if the need arose we could consider heavier materials or even bigger cases if the space or functionality were needed. Additionally, all the attempted plastic solutions were well within less than a pound, with the heavier solutions, the metal cases, being the only ones that crossed the pound mark. Even with the use of

TABLE VIII: Flashpoint Wearable Weight Specifications [7]

	Weight	
Component	grams	lbs
Deep Short Case	52	0.115
Wide Flat Case	114	0.251
Red Metal Case	230	0.507
Wide Square Case	137	0.302
Wide Tall Case	162	0.357
Wide Narrow Case	115	0.254
Large Case	150	0.331
Flashpoint V 0.15	345	0.761
Flashpoint V 0.25	260	0.5732
Flashpoint V 0.50	410	0.904

TABLE IX: Flashpoint Wearable Dimension Specifications [7]

	Weight		Dimensions		
Component	grams	lbs	L (in)	W (in)	H (in)
Deep Short Case	52	0.115	4.558	2.402	1.339
Wide Flat Case	114	0.251	4.000	2.062	1.140
Red Metal Case	230	0.507	4.409	2.382	1.220
Wide Square Case	137	0.302	4.500	4.500	1.510
Wide Tall Case	162	0.357	5.594	4.344	1.840
Wide Narrow Case	115	0.254	5.308	2.942	1.959
Large Case	150	0.331	5.500	3.130	2.500

metal casing, however, the enclosure would certainly meet the design specification of being well under 5 pounds. Besides the weight, having a compact and unobtrusive solution was the other big wearable consideration. Similar to the weight, the various dimensions of the components were taken into account, with an emphasis on the dimensions of the case itself being made. Table IX below summarizes some of the better case options, in terms of size, that still allowed for the proper housing of all necessary components. It also illustrates the variety of size options that were assessed with regards to a solution. The current Flashpoint V 0.25 solution (highlighted in the indicated table) measures L: 4.558" by W: 2.402" by H: 1.339", and falls well within the 6" by 6" specifications established in the feature punchlist.

5) Battery Life Testing Results: The battery was tested on March 12th overnight. The user interface was running and the unit was receiving GNSS and pulse sensor data for the entire time. After 12 hours the battery was disconnected and the test was declared a success for 12 hours minimum battery life. Furthermore, the battery was sized to be able to supply 400mA but our system was pulling less than 300mA.

TABLE X: Pulse Sensor Testing Results [7]

Test	Flashpoint	Pulse-Ox
Test 1	85	86
Test 2	79	81
Test 3	77	78
Test 4	84	84
Test 5	76	78
Test 6	84	85

6) Analog Heart Rate Sensor: Comprised of a simple Analog output, the sensor simply makes uses of one analog pin on the microcontroller.

- Vcc - 5 V pinout
- Grnd - Common Ground
- Analog Signal Out - Pin A0 (Yellow)

Feature Punchlist Requirement: The heart rate that is being read into the user interface must be within 30 percent of the actual value. The heart rate is to be measured while at rest. Also the heart rate must be between 30 and 200 beats per minute.
Modifications:
The purchased pulse reader was used to compare the heart rate, which worked fine. No modifications had to be done to the testing plan.

7) Pulse Sensor Testing Results: Pulse sensor data was monitored over a 12 hour period checking the pulse received through the Flashpoint system against the pulse reading from a Pulse Oximeter with 2% accuracy every 2 hours. The pulse oximeter was a cheaper model and this caused some difficulty in gaining adequate testing results. The pulse oximeter takes about 10 seconds to register a reading and if the person being tested moves or bends fingers in a way that restricts blood flow the pulse sensor did not get an accurate reading. It also has difficulty updating the pulse when it changes. It appeared to be accurate every time it was reset based on comparison to manual readings and the data from the Flashpoint pulse sensor. The results showed that the pulse is within +/- 30 percent of the actual pulse so this meets the feature set requirements.

8) GPS Module: This module communicates with the microcontroller via a UART using Serial2 on the microcontroller board.

- RX on Module(TX on Board) Pin 16 (Green)

- TX on Module(RX on Board) Pin 17 (Blue)
- Vcc - 5 V
- Grnd - Common Ground

9) Adafruit MicroSD card breakout board: This module utilizes SPI communication, which relies on the microcontroller, acting as the master, to wake up and request information from the module, referred to as the slave, through a shared clock connection for synchronization.

- CS (Chip Select) - Pin 3 (Brown)
- SCK (Serial Clock) - Pin 52 (White)
- MOSI (Master Out Slave In) - Pin 51 (Purple)
- MISO (Master In Slave Out) - Pin 50 (Teal)
- Vcc - 5V
- Grnd - Common Ground

10)Xbee Communication Module: This module communicates with the microcontroller via a UART using Serial1 on the microcontroller board.

- RX on Module(TX on Board) Pin 18 (Green)
- TX on Module(RX on Board) Pin 19 (Blue)
- Vcc - 5 V
- Grnd - Common Ground

C. User Interface

The User Interface component relies on a simple black-box style module with an attached antenna that is connected to the Windows platform of choice (tablet, laptop, PC, etc) via a USB to miniUSB cable/connection. The module provides the incoming serial data via the USB connection and the XBee module wireless serial communication. It is shown below in Figure 35.

Fig. 35: Flashpoint V 0.50 Receiver Hardware [7]

D. Test Plan for Hardware

1) Data Storage:

This section deals with the ability to store the heart rate and location data for review. It is important for incident commanders and investigators to be able to access past data in order to figure out what has happened, in case something goes wrong.

Feature Punchlist Requirement: Heart rate and location history

The storage of heart rate and location data of the firefighters onto an SD card for after incident review.

Feature Testplan:

The system will be set up and heart rate and location data will be collected. Once the data collection is done, the SD card will be unmounted and plugged into a computer in order to see if the data has been recorded. The accuracy can be determined by the date and time of the recorded data.

Modifications:

The data storage aspect of our device is straight-forward. We purchased a few SD card modules which kept crashing our system, which is obviously not what we wanted. After some more research, we found a SD card module that is not only smaller than the other ones, but is also very reliable and doesn't cause any issues in our system like the previous ones. As far as the testing goes, since we know the location and heart rate of the user for our testing process, we can verify the accuracy of our data by visual inspection of the contents of the SD card.

E. Data Storage

The SD card was unmounted and plugged into a computer after we tested the user interface. The collected data was written to the SD card as desired and the test was deemed successful.

Feature Punchlist Requirement: Overall Component Testing.

After having had white box testing for each of the individual components, this particular part of the testing plan will focus on two aspects of testing: overall component white-box testing, and overall component black-box testing. White box-testing would allow for redesign and inner rework of essential components as overall integration and functionality is tested. Black box testing would consist of testing from a more consumer or external engineering level, where adjustments can still be made, albeit more superficially, to ensure full functionality for the end user.

Feature Testplan:

The first part of testing will focus on ensuring that the individually tested features all work as expected when put together, essentially testing overall functionality and integration with corresponding troubleshooting steps to adjust any feature as necessary while ensuring that each feature still meets its individual testing criteria. White box testing will be considered completed when each of the features meets its corresponding criteria while being tested as part of the overall component. Weight, power, and measurement restrictions would have to be met, while simultaneously being able to track location and heart rate monitoring, all of this would have to be stored locally in memory, and properly communicated and displayed at the incident commander

interface. Troubleshooting in this white-box step would allow for rewiring, recoding, and or component replacement (only if strictly necessary), which would in turn require retesting of affected features (weight, size, etc).
Once white box testing is complete, the device will be left operating for a full run of operation with intervention from the testers if needed. However, black box testing would imply that while components can be plugged/unplugged, power-cycled and run through troubleshooting, this troubleshooting would be more on part with an external engineer testing the device. This would restrict the ability of the tester to rewire, recode, or replace inner components. The test would be considered complete when the device can be successfully tested while only troubleshooting in this fashion, if necessary.

Modifications:

As a whole, the overall testing of the wearable aspects of the device was the most involved of all the physical testing procedures, and still requires some further work to be done. Finding different cases that fit the dimension and weight restrictions was not as difficult as it was to figure out how best to implement all the components as seamlessly as possible into a self-contained solution that was reliable. Part of the difficulty arose from the various options that were available, as well as the lack of experience in what the most successful designs in terms of a wearable electronic device happened to be. An insight, that though mitigated with research, will still require further debugging and extended testing. Restrictions in terms of overheating, unintentional shorts, insulation, padding, spacing, lining up connections, and ensuring reliable ports to the outside of the device were all issues that arose from this testing. Other considerations included a functional way to add an on/off switch, a programming and a charging connection. One other interesting issue that arose from full integration white box testing was the realization that having the wireless communication module too close to the heart rate monitoring incurred noticeable Electromagnetic Interference and heart beat noise. To reduce this the team had to relocate the heart rate sensor connection, as well as establish better grounding and some shielding for both the cable and the module itself. Additionally, any alterations had to be tracked with relation to the overall weight and dimension of the component, as well as an effort to retain a sealed, water and fire resistant device that could still be mounted comfortably and in an unobstructive fashion.

1) Overall Component Testing: Overall component testing is the resultant and last thing to test in a fully working and functional project. With this in mind, it is also the longer lasting and more involved testing. The goal of this particular test is to ensure the original working prototype was able to be altered into a more polished state that is wearable, light weight, retains functionality, and is self-contained, all while lasting its designated more than 12 hour range. The greatest difficulties in testing arose from not just having all the separate components work together, but work together in a finalized state. As such, preliminary test of the overall functionality are running well, but still need to be further explored.
Some considerations of which the particulars were not as easy to predict were the lining up of all the different components inside an enclosure not just in a functional manner, but an efficient one. The various case options were tested individually, alterations were made in the way of holes being drilled, components being lined up and measured, and mountain options being revisited. Some of the mounting attempts involved anything from specialized double sided tape and velcro, to epoxy and Room Temperature Vulcanization silicone (RTV). Troubleshooting aspects that arose during testing included contact isolation (assisted by epoxy and RTV), spacing, padding, mounting, and case alterations. Various holes had to be measured, remeasured, drilled and sealed to allow for outer programming and charging mounts, as well as room for wireless antennas and heart rate sensor wiring.
The latest design, depicted in figures 36 and **??**, includes all necessary components in a pre-measured design, with corresponding ports. Further full solution testing still needs to be conducted after all the components can be more carefully realigned.
Moving forward, and after a preliminary round of tests, a few extra sets of casing and components were ordered so as to more efficiently and cleanly line them up inside the case for better functionality. Slightly bigger casing was also ordered to accommodate better alignment, and more padding/isolation. Additionally, a few extra buttons needed to be implemented into the design. Finally, the casing and straps that attaches to firefighter arms and belt need to be mounted permanently and further tested.
If time and resources were not an issue, all the wiring would be outsourced into a pre-designed PCB solution that would be more compact and light weight, additionally, instead of a pre-designed stock box, a specially designed case would be designed and printed on a high end 3D printer, or outsourced as well. Along with this, it was hard to find a full enclosure solution that also contained the wearable aspect, this would be streamlined and combined in the case design. Which in turn produced two variations of an enclosed solution, as noted in the dimension and weight tables. The working prototypes took the form of a compact working solution with tightly fit components in Figure 36 and one with slightly larger dimensions that allowed for a better layout that was better organized and easier to isolate components in, noted in Figure 37.

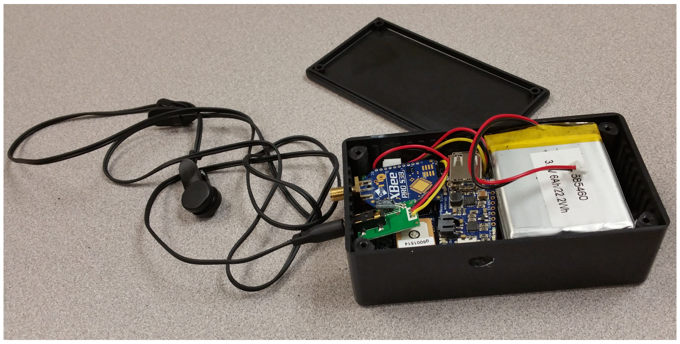


Fig. 36: Flashpoint V 0.25 Wearable Solutio [7]

Fig. 37: Flashpoint V 0.50 Wearable Closed Solution [7]

Appendix C
Software

The Software section of the project can by and large once again be broken down into two separate components. Processing needed to occur on the wearable side of the project, so as to properly obtain and handle signal information on the wearable carried by a firefighter, but the incident commander also needs a means of obtaining this information and being able to manage the information on an easy to use interface. Thus, the two sections are comprised of a script for data handling by the microcontroller in the wearable section, and a user interface application, that would obtain data from a wireless receiver, to be loaded onto a laptop for ease of data access to the incident commander. A C-based script, called a sketch by Arduino [42], was created and loaded onto the mega 2560 to handle and process the heart rate and location information, save a log onto the micro-SD card, combine the pertinent data onto a comma-delimited string, and then transmit the data to the Xbee wireless transmission module. The data is then obtained by the wireless receiving module, logged locally for the incident commander, and displayed on the map of user face, with a pin pointing to location and displaying heart rate information. Figure 38 below depicts the flowchart information of data processing as it occurs on the wearable sketch, and will be used as reference to detail information about the specific components below.

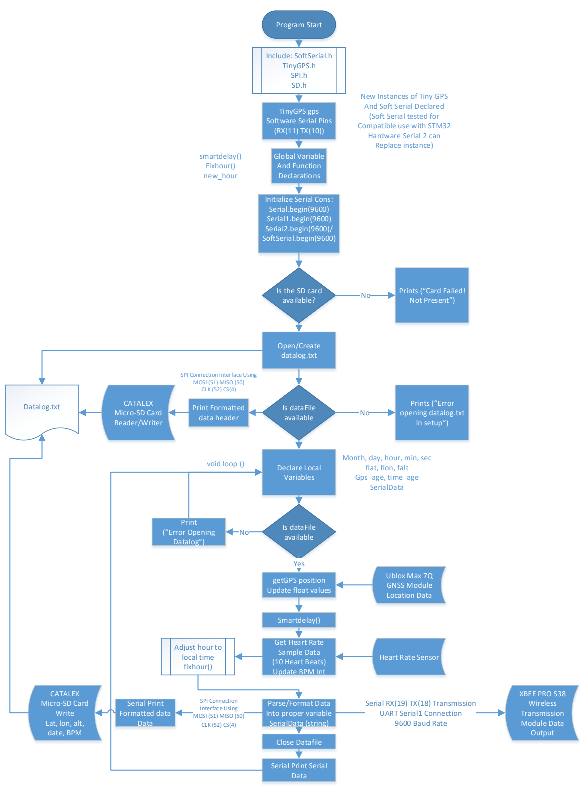


Fig. 38: Wearable Program Flowchart [7]

A. Navigation

The software components specifically related to the Navigation system revolved around the open source library called TinyGPS [43]. First an instance of TinyGPS needed to be declared, then, since the module is communicating via a UART connection, Serial2 was used, which is asigned to pins 16 and 17. A Serial2 begin command is given, and the baud rate is set to 9600. The library contains a series of commands that can return various sets of information, including an option for latitude and longitude expressed as either longs or floats to 1/1000000th of a degree. For the purposes of this project, the values were saved as floats and parsed into a comma delimited string through the use of typecasting. Inside the void loop of the sketch the location is tracked, along with the signal "age" which tracks, in milliseconds, the last time the device received viable satellite data.

1) Flow-Charts:

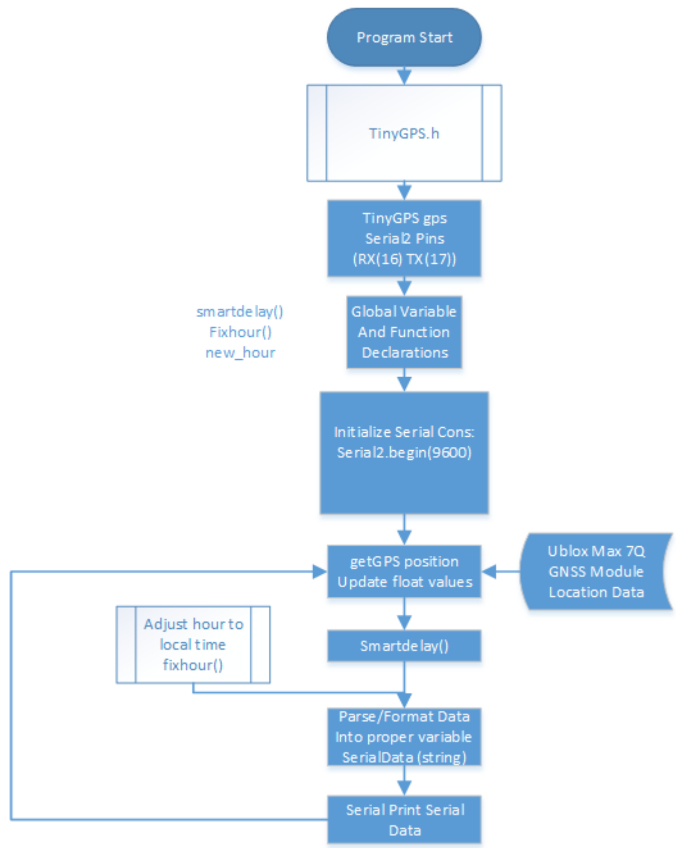


Fig. 39: Navigation Module Flowchart [7]

B. Communication

The communication section of the software simply consists of initializing the Serial1 UART connection at a baud rate of 9600, obtaining the relevant data, and using that serial port to send information to the wireless transmission module (using Pins 18 and 19).

1) Flow-Charts:

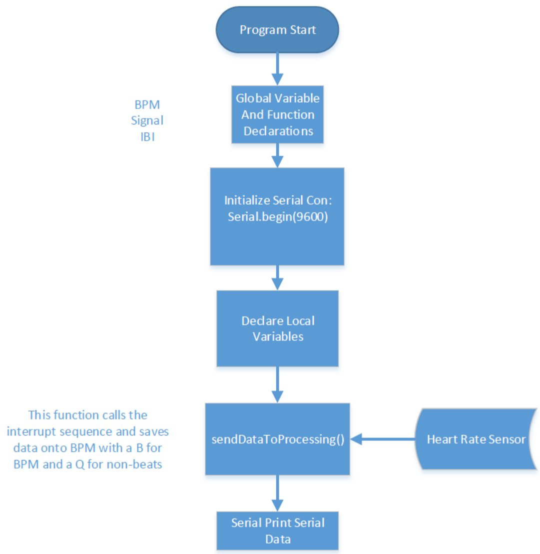


Fig. 40: Heart Rate Flowchart [7]

C. Wearable Technology

The wearable section comprises the navigation module, the heart rate sensor, the micro-sd card on body storage, and the communication module interface. Figure 32 depicts the wearable aspects and physical connections as well as the flow of data as it pertains to all the above-mentioned items. The flowchart for the code discussed is referenced in Figure 38. The way the code is set up on the sketch consists of initializing an instance of the TinyGPS library mentioned in the navigation software section, the SD and SPI libraries needed by the microSD card module, as well as Serial connections 1 and 2 at a baud rate of 9600 (which is required by the TinyGPS library [43]). Global variables and functions are declared so as to store BPM heart rate values, and allow for synchronization assistance with the smartdelay() function. The code then enters its loop, where it checks to make sure it has access to the micro-SD card, creates a datalog file if it can, and provides an error if it can't. It then checks for a GPS location signal that consists of updating float values for latitude, longitude, and then ints for data age, and date as well as time. Once the data has been obtained, type casting allows for the data to be converted into a long comma-delimited string with a] symbol as a line end. The data is saved onto the memory card's log file and then , if the Serial1 port is available, the code sends its string of information out through, only to loop back again.

Feature Punchlist Requirement: Overall Component Testing.
After having had white box testing for each of the individual components, this particular part of the testing plan focused on two aspects of testing: overall component white-box testing, and overall component black-box testing. White box-testing would allow for redesign and inner rework of essential components as overall integration and functionality is tested. Black box testing would consist of testing from a more consumer or external engineering level, where adjustments can still be made, albeit more superficially, to ensure full functionality for the end user.
Feature Testplan:
The first part of testing focused on ensuring that the individually tested features all work as expected when put together, essentially testing overall functionality and integration with corresponding troubleshooting steps to adjust any feature as necessary while ensuring that each feature still meets its individual testing criteria. White box testing was considered completed when each of the features meets its corresponding criteria while being tested as part of the overall component. Weight, power, and measurement restrictions would have to be met, while simultaneously being able to track location and heart rate monitoring, all of this would have to be stored locally in memory, and properly communicated and displayed at the incident commander interface. Troubleshooting in this white-box step would allow for rewiring, recoding, and or component replacement (only if strictly necessary), which would in turn require retesting of affected features (weight, size, etc).
Once white box testing was complete, the device was left operating for a full run of operation with intervention from the testers if needed. However, black box testing would imply that while components can be plugged/unplugged, power-cycled and run through troubleshooting, this troubleshooting would be more on part with an external engineer testing the device. This would restrict the ability of the tester to rewire, recode, or replace inner components. The test would be considered complete when the device can be successfully tested while only troubleshooting in this fashion, if necessary.

1) Wearable and Full Sensor Integration Software Testing Results: The testable software component of the wearable aspect of the device consisted of a C-based sketch, as noted in Figure 38 above , that had a role of properly transmitting data wirelessly while integrating all the corresponding sensors. The resultant test was then to transmit a series of strings of data and be able to wirelessly receive it at the user interface hardware component. The data was accurately, and consistently tracked at the output of the wearable module, and then verified to be the same at the receiving end, without any corruption or data loss. An example of the sample data, excluding the user interface, and monitored through serial ports connections is demonstrated below in Figure 41. The data string being transmitted consists of the latitude and longitude in the form of long values, along with an int value for the heart rate, and a string for a date time stamp in Coordinated Universal Time (UTC). All the values are comma delimited and have a] symbol to end the string.

```
Latit    Long    Alt    Fix   Date    Time      Date
(deg)    (deg)   (m)    Age                     Age
-------------------------------------------------

38564040,-121407662,0,4/25/2016 1:1:36 UTC]
38564020,-121407670,0,4/25/2016 1:1:39 UTC]
38564012,-121407673,0,4/25/2016 1:1:42 UTC]
38564007,-121407668,0,4/25/2016 1:1:45 UTC]
38564005,-121407680,0,4/25/2016 1:1:48 UTC]
38564007,-121407682,0,4/25/2016 1:1:51 UTC]
38564008,-121407677,0,4/25/2016 1:1:54 UTC]
38564012,-121407683,0,4/25/2016 1:1:57 UTC]
38564017,-121407688,0,4/25/2016 1:2:0 UTC]
38564018,-121407683,0,4/25/2016 1:2:3 UTC]
38564022,-121407682,0,4/25/2016 1:2:6 UTC]
38564027,-121407680,0,4/25/2016 1:2:9 UTC]
38564023,-121407682,0,4/25/2016 1:2:12 UTC]
38564020,-121407692,0,4/25/2016 1:2:15 UTC]
38564018,-121407708,0,4/25/2016 1:2:18 UTC]
38564018,-121407717,0,4/25/2016 1:2:21 UTC]
38564025,-121407732,0,4/25/2016 1:2:24 UTC]
38564033,-121407743,0,4/25/2016 1:2:28 UTC]
38564043,-121407753,0,4/25/2016 1:2:31 UTC]
38564047,-121407773,0,4/25/2016 1:2:34 UTC]
38564068,-121407787,0,4/25/2016 1:2:37 UTC]
38564082,-121407788,0,4/25/2016 1:2:40 UTC]
38564100,-121407802,0,4/25/2016 1:2:43 UTC]
38564110,-121407823,0,4/25/2016 1:2:46 UTC]
38564123,-121407835,0,4/25/2016 1:2:49 UTC]
38564135,-121407863,0,4/25/2016 1:2:52 UTC]
38564140,-121407882,0,4/25/2016 1:2:55 UTC]
38564133,-121407892,0,4/25/2016 1:2:58 UTC]
38564132,-121407912,0,4/25/2016 1:3:1 UTC]
38564133,-121407950,0,4/25/2016 1:3:4 UTC]
38564150,-121407982,0,4/25/2016 1:3:7 UTC]
38564165,-121408005,0,4/25/2016 1:3:10 UTC]
```

Fig. 41: Sample Wearable Transmission Data [7]

D. Heart Rate Monitor

The heart rate monitoring section proved to be somewhat difficult to test and implement. The code consisted of two sketches, the main sketch simply initializes Serial data output and then calls a function called sendDataToProcessing() that calls an Interrupt sketch and obtains the heartrate in beats per minute (bpm). The interrupt sketch itself consists of sampling heart rate signals using an optical sensor and determining when a beat happens by gauging an abrupt change in the analog signal. The sketch alternates between turning interrupts on and off, uses Timer 2 on the Mega 2560 and disables the PWM functionality of pins 11 and 3. It then saves the heart beat in a 10 value array called rate[9] where it averages the values and divides 60000 by the value to obtain an average heart rate. A smartdelay() function that comes built into the TinyGPS series of sample sketches had to be used to make sure the interrupt sequence from the heart rate monitor did not affect the GPS tracking.

1) Pulse Sensor Testing Results: Pulse sensor data was monitored over a 12 hour period checking the pulse received through the Flashpoint system against the pulse reading from a Pulse Oximeter with 2% accuracy every 2 hours. The pulse oximeter was a cheaper model and this caused some difficulty in gaining adequate testing results. The pulse oximeter takes about 10 seconds to register a reading and if the person being tested moves or bends fingers in a way that restricts blood flow the pulse sensor did not get an accurate reading. It also has difficulty updating the pulse when it changes. It appeared to be accurate every time it was reset based on comparison to manual readings and the data from the Flashpoint pulse sensor. The results showed that the pulse is within +/- 30 percent of the actual pulse so this meets the feature set requirements.

TABLE XI: Pulse Sensor Testing Results [7]

Test	Flashpoint	Pulse-Ox
Test 1	85	86
Test 2	79	81
Test 3	77	78
Test 4	84	84
Test 5	76	78
Test 6	84	85

2) Flow-Charts:

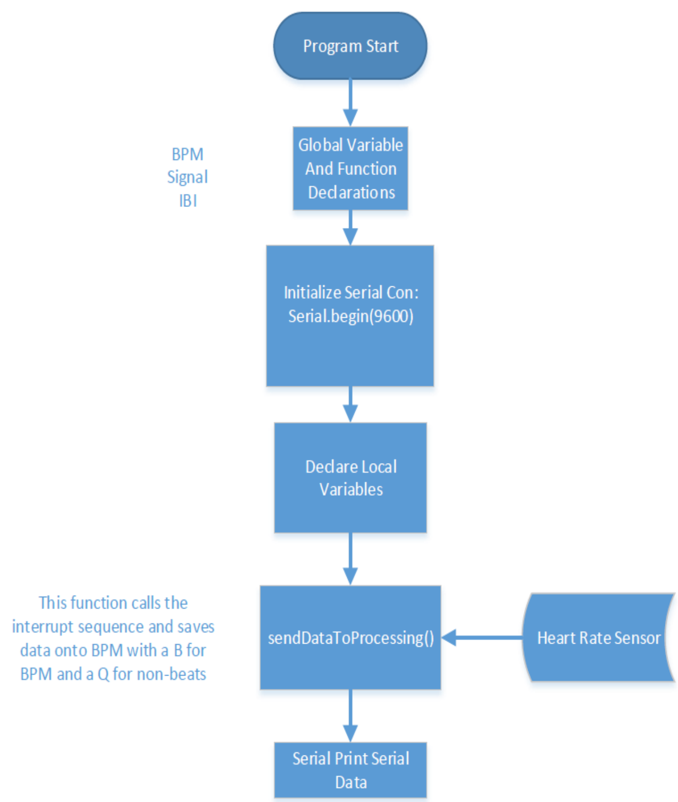


Fig. 42: Heart Rate Flowchart [7]

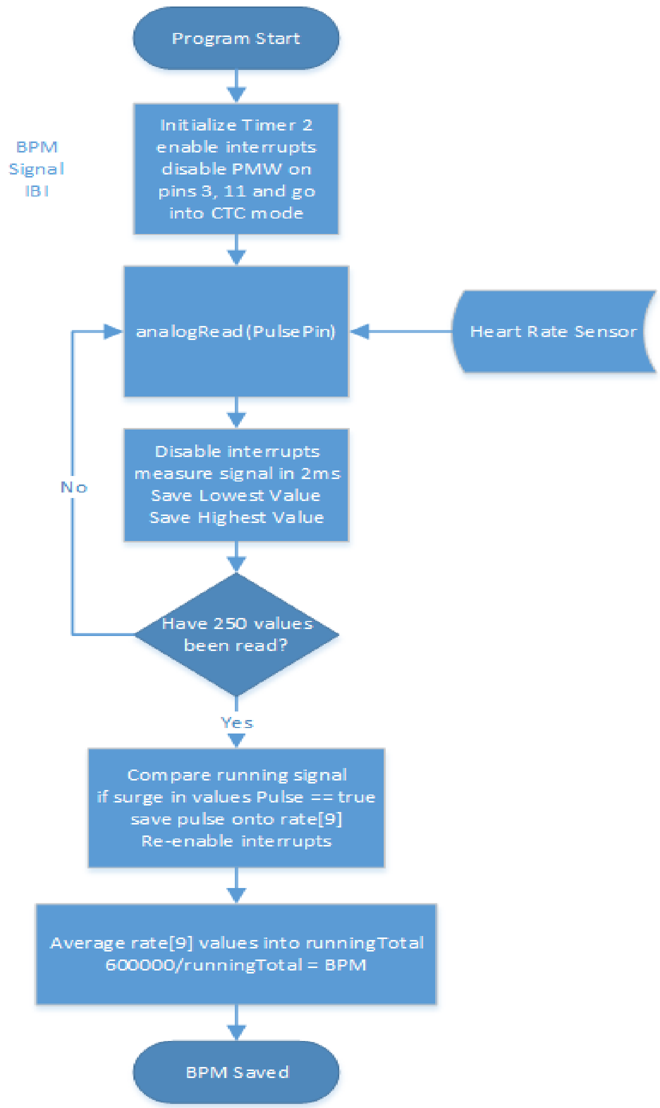


Fig. 43: Heart Rate Interrupt Sequence Flowchart [7]

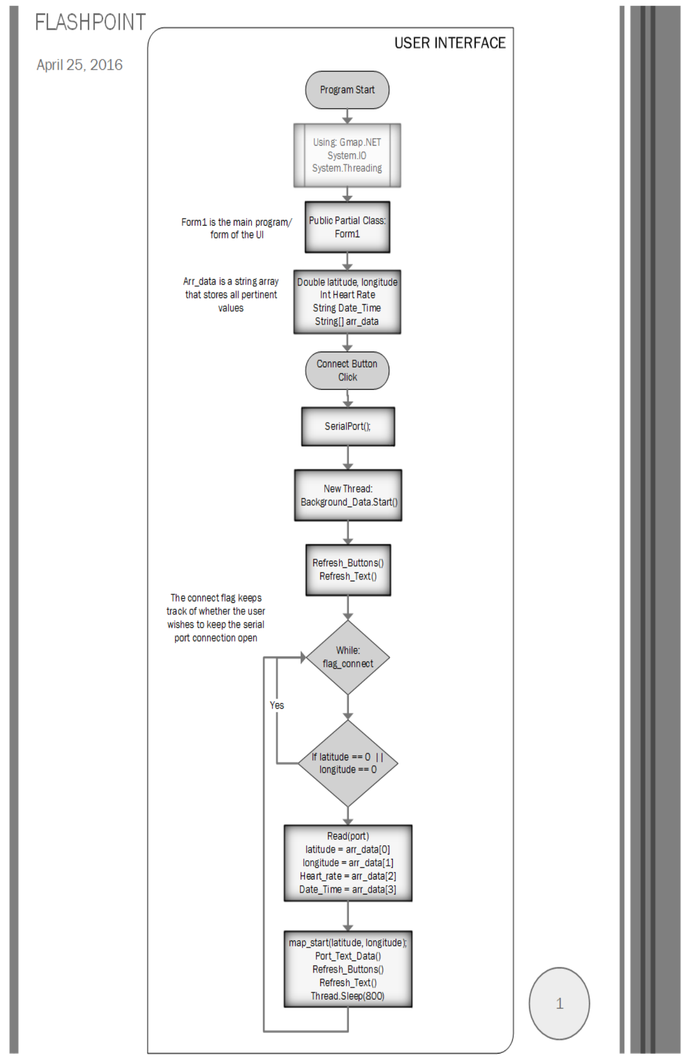


Fig. 44: User Interface Flowchart 1 [7]

E. User Interface

The user interface is installed on a Windows laptop or tablet and was developed as a Windows Form in C#. The user interface receives the location and heart rate data by serial transmission through the wireless stand-alone network. A XBee communication module has to be attached to the laptop or tablet so that the data can be received and processed by the user interface. The user interface can be seen in figure 47.

1) Flow-Charts: The flow charts for the basic program of the user interface can be seen in figure 44.

The flowcharts for the functions behind the basic user interface program can be seen in 45. These functions include GMAP, which provides the cached google map to visually display the location data on a map. The check for digits function checks whether or not the incoming data is valid and the background data function assesses whether or not a command in a separate thread has been issued. The functions corresponding to the buttons and textboxes continuously check for new data and then refresh the textboxes with the newly acquired location and heart rate data.

Figure 46 shows the most important function of the user interface, the read function. This function reads the incoming data from the serial port connection, checks for the validity of the data and then passes it along for further processing.

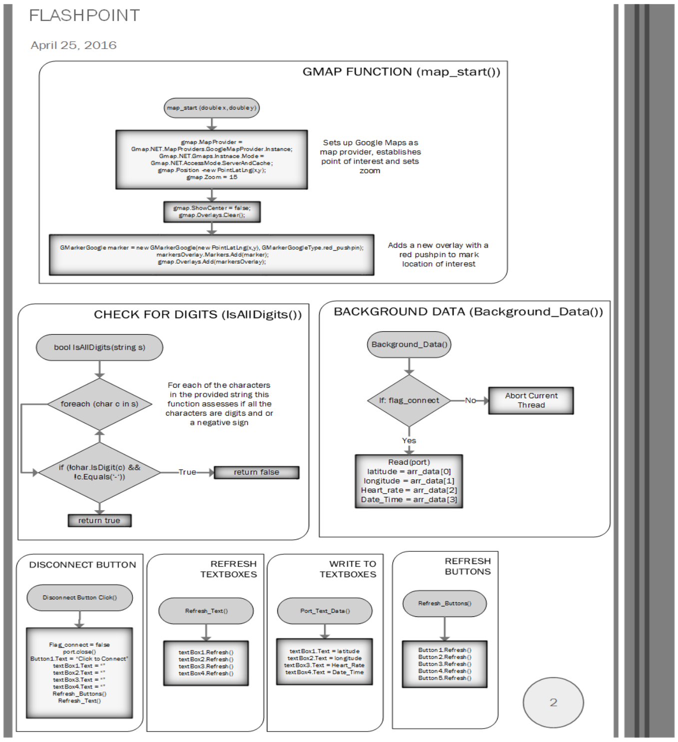


Fig. 45: User Interface Flowchart 2 [7]

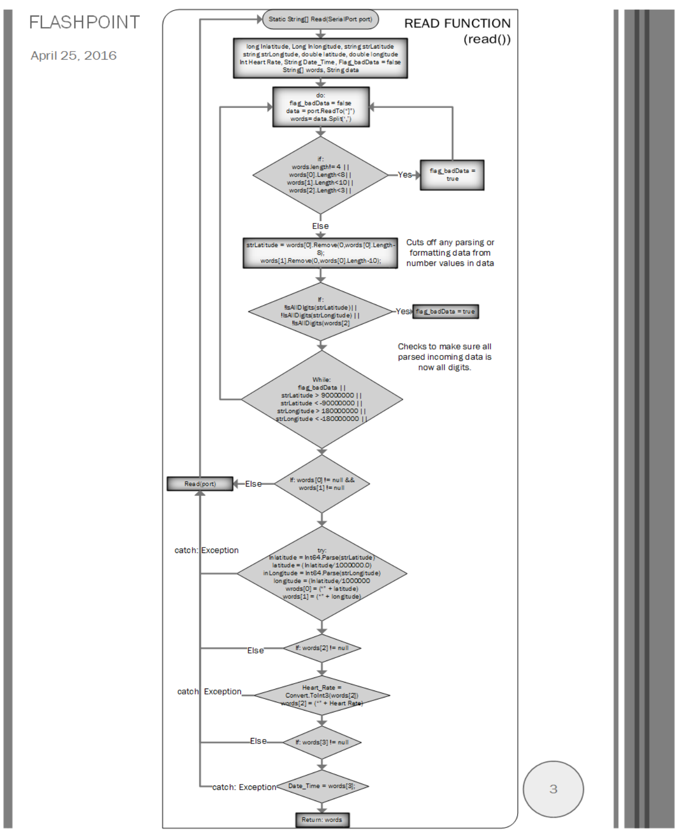


Fig. 46: User Interface Flowchart 3 [7]

F. Test Plan for Software

1) User Interface:
This part of the feature set is the connection between the firefighter and the incident commander. The user interface will be utilized to display the heart rate and location data of the firefighters that are out in the field. The user interface is being developed in C# and will run on Windows platforms.
Feature Punchlist Requirement: Location and Heart Rate displayed on laptop/ tablet
One of the main parts of our project is the ability for an incident commander to track the firefighters out in the field. In order to do so, a reliable display of the heart rate and location data needs to be developed.
Feature Testplan
In order to test this feature set, the user interface will be installed on a tablet. We will then connect the XBee module to the tablet to see if we can receive data from the corresponding XBee module that is connected to the wearable device to be worn by the firefighter. If the heart rate and location data will be displayed on the user interface, the feature set will be met.
Modifications
Developing the user interface as a windows form in Visual Studio (written in C#) is proving to be a challenge. The lack of flexibility makes it difficult to achieve the goals we have set out to do in order to develop a user interface that is robust, as well as aesthetically pleasing. We will probably continue to develop it as a Windows Form application because of the time constraint, but in hindsight, we should have used a different platform.
As far as the testing goes, instead of installing the user interface on a tablet, it was run from a laptop. This made the testing process and troubleshooting easier and more time efficient. The user interface was later installed on a tablet as well and functioned as intended.

Fig. 47: User Interface [7]

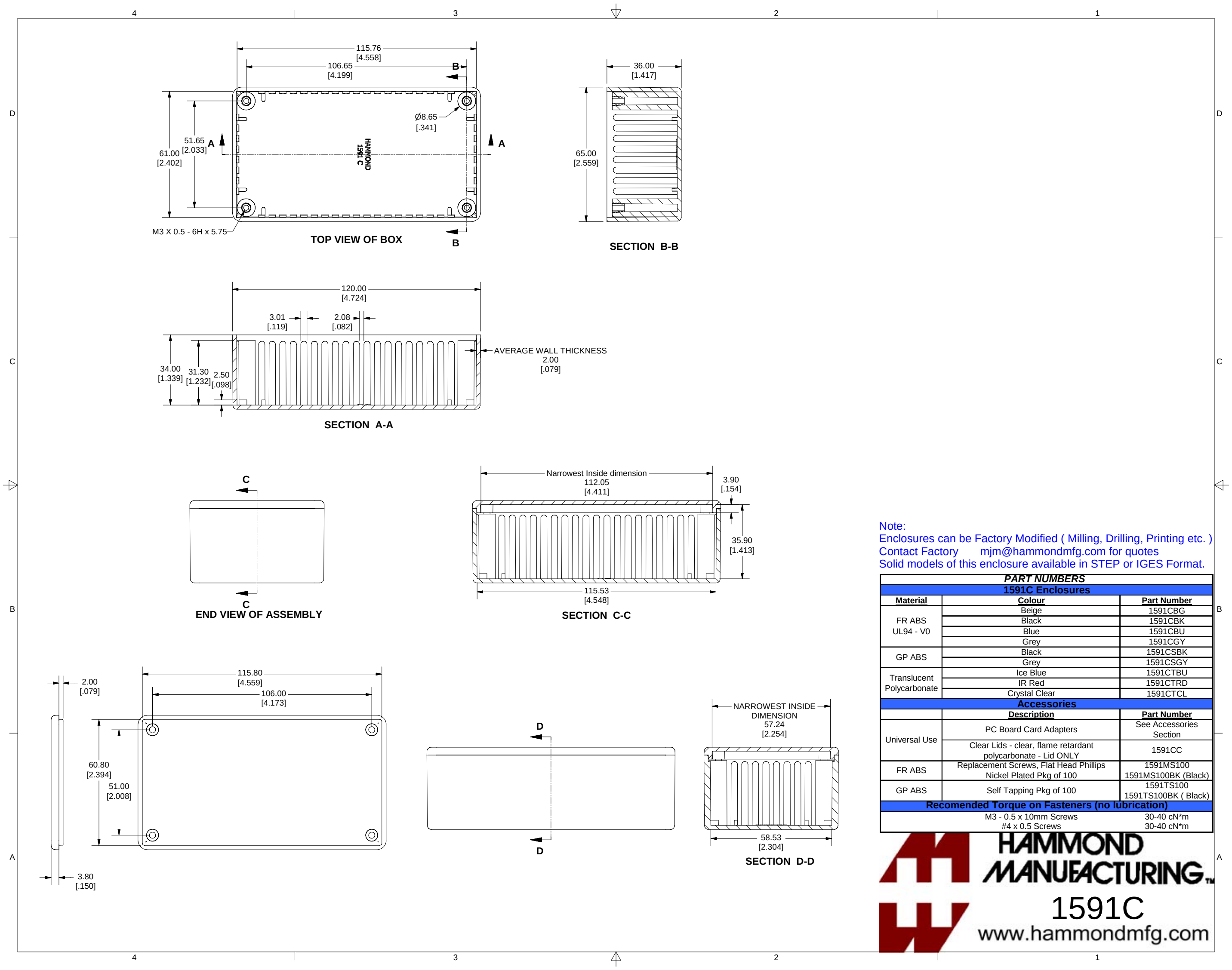
2) Testing Results:: The user interface was tested on a laptop as laid out in the modified test plan. The first test we performed was inside Riverside Hall. The data was read into the user interface. In order to verify whether or not we are

getting the correct data, we also placed a different pulse sensor onto the team member who had the components. We knew his location, which was inside Riverside Hall. We didn't have any transmission issues and the data that was read in was accurate.
The second test that was performed took place outside. We took a laptop and placed in on a fixed spot. A team member then clipped the heart rate sensor onto his ear, took the prototype and walked around campus. A snapshot of the results that were read in can be seen in figure 47.
The test was successful. The main goal was to display the location and heart rate data, which was accomplished. The full working solution can be observed on a windows tablet, and with the corresponding receiver hardware in Figure 48 below.

Fig. 48: Flashpoint V 0.50 Receiver Hardware and User Interface [7]

Appendix D
Mechanical Documentation

Attached are the physical specifications for the case used in one of two working prototypes, with the second having no specific data sheets, but available at [45].



PART NUMBERS		
1591C Enclosures		
Material	**Colour**	**Part Number**
FR ABS UL94 - V0	Beige	1591CBG
	Black	1591CBK
	Blue	1591CBU
	Grey	1591CGY
GP ABS	Black	1591CSBK
	Grey	1591CSGY
Translucent Polycarbonate	Ice Blue	1591CTBU
	IR Red	1591CTRD
	Crystal Clear	1591CTCL
Accessories		
	Description	**Part Number**
Universal Use	PC Board Card Adapters	See Accessories Section
	Clear Lids - clear, flame retardant polycarbonate - Lid ONLY	1591CC
FR ABS	Replacement Screws, Flat Head Phillips Nickel Plated Pkg of 100	1591MS100 1591MS100BK (Black)
GP ABS	Self Tapping Pkg of 100	1591TS100 1591TS100BK (Black)
Recomended Torque on Fasteners (no lubrication)		
	M3 - 0.5 x 10mm Screws	30-40 cN*m
	#4 x 0.5 Screws	30-40 cN*m

Appendix E
Vendor Contacts

Flashpoint did not receive any specific or direct assistance from outside vendors/contacts.

Stephen Fleming

Resume

Self-starter with excellent communication, presentation, analytical, and organizational skills. Reliable, responsible and proven ability to define goals and take projects from conception to completion. Excellent interpersonal and leadership skills. Great adaptability to changing environments. Works well with hands. Fast learner.

EDUCATION

Senior in Electrical Engineering;
Sacramento State University; Sacramento, CA
Graduate May 2016

PROFESSIONAL EXPERIENCE

Engineer Technician
Sirus Technology **May 2011-Present**

- Managed manufacturing department on the evening shift.
- Operate and Calibrate Vacuum Coating Chambers.
- Analyze data and determine proper calibration settings.
- Operate Glass cutting Core Mill.
- Troubleshoot equipment malfunctions.

Medic (Healthcare Specialist)
United States Army (Honorable Discharge) **October 2003-September 2007**

- Provided medical support in an Emergency Room setting to soldiers during 15 month tour in Iraq.
- Stopped bleeding, started IV's, participated in surgery, prescribed medication, monitored vital signs, etc.
- Head medic to a team of 4 E.R. response medics for 9 months.
- Gave presentations to soldiers about basic medical skills.

SKILLS

- CPR / EMT skills – Can assist in emergency lifesaving situations.
- Proficiency with Microsoft Word, Excel, and Power Point.
- Management/Leadership skills
- Quality Control / Organization / Efficient
- Research / Problem Solving

Birgit Fleming

Engineering Technician

Recognized as a skilled engineering technician who can translate conceptual designs to functional manufacturing systems. Key contributor in all phases of project activity including electrical design, design review, component specification and sourcing, construction, testing and commissioning of automated high vacuum production equipment.

Hands-on team member who is comfortable using a wide variety of electrical and mechanical tools and shop equipment to accomplish objectives.

Chosen by CEO to lead design team for company's first automated robotic testing project.

SKILLS

- Proficient in design software including AutoCAD and Solidworks
- Efficient at building equipment from electrical and mechanical drawings
- Extensively practiced in use of shop tools and equipment
- Experienced in company network server configuration/administration and IT end user support
- Skilled in oral and written communication, as well as team coordination, time management and project organization
- Proficient in Microsoft applications
- Bilingual English/German

PROFESSIONAL EXPERIENCE

Engineering Technician
Alluxa, Inc. (formerly Sirrus Technology), Roseville, CA 2014-present

Engineering Technician
Sirrus Technology, Inc., Santa Rosa, CA 2011-2013

Clerical Assistant / IT Backup
DVA, Bad Homburg, Germany 2006 – 2007

EDUCATION

In Progress: Bachelor of Science (Major: Electrical and Electronics Engineering)
Sacramento State University, Sacramento, CA

Certification, Administrative/Foreign Language Assistant *(2-year vocational school)*
Kaufmaennische Schule, Bad Nauheim, Germany

Completion (High school diploma)
Henry-Benrath Schule, Friedberg, Germany

ACTIVITIES AND ACCOMPLISHMENTS

- Dean's Honor List
- IEEE (Member)

Tony Rodriguez

OBJECTIVE: An entry position in electronic engineering.

EDUCATION:

In progress: **B.S. Electrical/Electronic Engineering** • CSU Sacramento • GPA: 3.97 • May 2016

Related Courses:

Electronics I	Network Analysis	Applied Electromagnetics
Electronics II	Power System Analysis	Electromagnetic Conversion
Intro to Microprocessors	Signals & Systems	Introduction to Feedback Systems
Logic Design	Probability and Random Signals	Digital Signal Processing
Circuit Analysis	Robotics	Digital Control Systems*
Modern Communications	Physical Electronics*	*Spring 2016

PROJECT EXPERIENCE:

Power Meter Calibration Test Verification
Worked with metrology documentation to verify, make changes and implement two new calibration software test procedures on electronic power measurement devices. Researched metrology, coordinated with overseas team, helped test new adapter design, and worked to organize and present large volume of data. Tested, adjusted, and verified functionality using VEE and C#.

DataBase Merging Tool Project
Tasked with providing an .exe tool to merge and properly adjust large data filled .mdb Microsoft Access results databases. Worked in .NET framework using C# and Windows Forms. Tool had to account for a series of unique keys, merging of multiple databases per run, indirect SQL commands through a wrapper, and varying factors in database setup.

E.&J. Gallo Winery Equipment Integration Project
With a large cross-functional team of engineers worked on a multi-million dollar 9 month integration and commissioning project for mass wine bottling. This project ran from construction, through qualification, to full production. Personally tasked with qualification plans and creating efficiency through repeatability testing.

E.&J. Gallo Material Handling System
Adjusted and qualified a 3 floor material delivery system. Oversaw installation of new parts, sensors, and implemented changes. Qualified 10 different package families on new system, coordinated weekly status report to engineers, management and operations, while ensuring to meet deadlines in month long project.

E.&J. Gallo Renovation of 20 Year Old Wine Labeler
Co-led the renovation of a 20 year old wine labeler. Implemented and tested a new add-on mechanical part. Tested and qualified 2 main families of products affected by the change and reported to management and operations.

KNOWLEDGE AND SKILLS:

Communication and Project Management:

• Installation, qualification, and commissioning experience in a large scale manufacturing environment.
• Process development, qualification and integration.
• Troubleshooting and root cause analysis experience.
• Exceptional self-starter with problem solving experience.
• Excellent written and verbal communication skills in a large, cross-functional engineering team environment.
• Team coordination, goal setting, accountability, time management and project report out experience under stringent deadlines.

Programming: C, C++, C#, Java, Verilog, VHDL, Python, VEE

Software: MultiSIM, MATLAB, Advanced Design System, Visual Basic, ModelSim, MS Office, Visual Studio, .NET

Tools: On hand experience with oscilloscopes, FPGAs (Altera's DE0 Nano), power meters, function generators, Arduino Uno, Parallax Propeller, Microchip PIC, Raspberry Pi, and AC/DC power supplies.

Trilingual: English, Spanish and comprehensive French.

WORK EXPERIENCE:

Electronics Engineering Intern	**Defense Microelectronic Activity**	09/15-Present
Software Engineering Intern	**Keysight Technologies**	6/15-8/15
Production Engineering Intern	***E. & J. Gallo Winery***	7/12- 8/13
Supervisor	***Micro Branch / Self Help Federal Credit Union***	7/11- 7/12
Team Leader	***Radioshack Corporation***	5/05- 7/11

ACTIVITIES AND ACCOMPLISHMENTS:

- Dean's Honor's List
- IEEE (Member)
- Class Outstanding Graduate EEE Department/Spring16
- Tau Beta Pi Engineering Honor Society (Member)
- Power & Energy Society (Member)

Cole Preszler

QUALIFICATION SUMMARY

- 15 years of professional communications electronics maintenance and management experience
- Fixed Site and Mobile HF, VHF, UHF, Satcom, Fiber Optic installation and maintenance
- Climb Certified, RF/CPR/ESD/Workplace Hazard Training
- Active TOP SECRET(TS)/Sensitive Compartmented Information(SCI)/TALENTKEYHOLE(TK) Security Clearance

EDUCATION

BS in Electrical and Electronics Engineering, CSU Sacramento, 3.6 GPA (In Progress)
AAS in Electronic Systems Technology, Community College of the Air Force, 2009
Air Force Senior NCO Academy
ETVS/Rivet Switch/SCAMP ATC systems school
USAF Project Management Course

KNOWLEDGE & SKILLS

Problem Solving:
Vast experience troubleshooting and installing communications systems worldwide. RF, fiber-optic, ethernet, antenna infrastructure and equipment.

Systems:
HF, VHF, UHF, Satcom Fixed Site and Mobile Communication Systems. Public Address, Emergency Warning, Sound Reinforcement Systems. Air Traffic Control Communication Systems.

Communication and Project Management:
Satellite Access Management, C4ISR Systems Management, Budget planning.

EMPLOYMENT

Project Management Superintendent 12/11- 11/13
Beale Air Force Base, CA - USAF
Military and commercial UHF and Ku satellite access/circuit management. Led team of 8 supporting Plans, Programs, and Project Management for worldwide communications operations of RQ-4 Global Hawk Remotely Piloted Aircraft. Government purchase Approving Official.

Flight Chief, Tactical Systems 9/10- 10/11
Osan Air Base, Korea - USAF
Led establishment of on-demand tactical satellite and network infrastructures and integration nation-wide.

Non-Commissioned Officer in Charge 7/7- 8/10
Misawa Air Base, Japan - USAF
Led airbase fiber optic single-mode and multi-mode network installation, antenna, and RF Transmission Systems maintenance on HF, VHF, UHF, and satellite fixed communications systems.

ACTIVITIES & ACCOMPLISHMENTS

- Dean's List, CSU Sacramento, Summer 2014-present
- USAF Ground Radio Technical Training Honor Graduate
- USAF 7th Air Force Information Dominance Senior Non-Commissioned Officer of the Year 2011
- USAF NCO Academy Distinguished Graduate

Appendix G
Data Sheets

No significant or unique documents were deemed necessary to include here. For data specifications consult the appendices, and the References section.